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MODELING TRADE AND ENVIRONMENTAL LINKAGES IN CHINA

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Abstract: Interactions between trade and the environment have been studied extensively as a reaction to the pressure that the accelerated pace of globalization has placed on environment and trade. Distinguishing itself from previous work, this study focuses on a modeling analysis of the interactions between trade and the environment in China. A nonlinear simultaneous equation trade and environment model (TEM) is presented that expands Dean's basic model by endogenizing the trade and foreign direct investment variables. This model can be used not only to analyze the trade impacts of environmental policies and the environmental impact of trade, but also to identify the sources of those influences. In addition, the nonlinear specification of the relationship between emissions and economic scale allows for an explicit test of the environmental Kuznets curve. Using the White heteroscedasticity consistent covariance matrix estimates and employing a Chinese regional panel data set, the empirical results suggest that there may indeed have existed a tradeoff between economic growth and environmental protection in China's development. That is, increased trade and rapid economic growth may have led to greater pollution emissions on the one hand, while environmental policies may have led to reduced economic growth and trade on the other. Policy alternatives to mitigate these negative impacts also are explored.

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1. INTRODUCTION

Empirical attempts to model relationships between trade and the environment have been well documented but their results have been limited (Huang and Labys 2002). Whether we examine the impact of environmental regulation and pollution abatement costs on international trade flows or the impact of international trade, including a country's openness, on economic growth and the environment, little evidence exists that freer trade would bring about significant changes in environmental quality. Also, there is little evidence that differences in the strictness of environmental policies can significantly determine trade patterns and flows.

The ambiguousness of these results can be attributed to at least two methodological pitfalls. First, most studies have tended to analyze cross-country or panel data, typically for a sample of both developing and developed countries. In a cross-country setting, positive and negative effects would probably cancel each other. Secondly, most studies, both cross- and single-country, are based on single equation models. Such models reveal only a one-directional relationship among trade, income and the environment. In reality, trade, income and the environment are interrelated and interact with each other.

An econometric investigation of these various interactions might better be based not only on a simultaneous equation system but also on one that would decompose any changes in emissions in three ways: a scale effect, a composition effect, and a technique effect. The purpose of this study is to develop and estimate an appropriate modeling framework such that its analytical solution can lead to a deciphering of these effects. In particular we advance the work of Dean related to

China (Dean 1999 and Huang 2002). Though other interesting attempts have been made to analyze Chinese environmental problems (e.g., Wu 2000), the environmental implications of the surge in foreign trade and investment in China are complex, very largely contested, and not fully illuminated by existing empirical data and analysis. At the same time, China's environmental protection agencies, aware of their pollution problems, have responded by enforcing regulatory standards for waste water and air pollutant discharges. It is worth noting that an extensive water and air pollution levy system has been in place in China since 1983 (Wang and Wheeler 1996). How the enforcement of environmental policy in China affects its trade and foreign direct investment is also important and, to the best of our knowledge, has not received empirical investigation.

This paper consists of the following parts: econometric modeling approach, empirical model, interpreting the coefficients, model validation, the analytical solution, and conclusions.

2. ECONOMETRIC MODELING APPROACH

The recent emergence of econometric studies on trade and environmental interactions began with Tobey (1990) and Grossman and Krueger (1993, 1995). Tobey employs a cross-sectional Heckscher-Ohlin-Vanek (HOV) model to test the hypothesis that the stringency of environmental policies is directly related to the exports of pollution-intensive commodities. Tobey's econometric results showed that environmental policy has no significant impact on patterns of world trade. Grossman and Krueger link environmental quality to higher economic growth and freer trade. In their regression equations, environmental quality indicators such as SO_2 concentrations are expressed as a function of per capita income and trade (measured as an export to GDP ratio). Their results suggest that after controlling for other noneconomic determinants of pollution, indicators of some pollution concentrations at first rise and then fall with increasing per capita income, but little evidence exists that freer trade would deteriorate environmental quality. While such models enable economists to evaluate trade and environmental interactions, they reveal only a one-directional relationship among these variables, i.e., either how trade or income affects environmental quality or how environmental policies influence trade flows and income. In reality, trade, income and the environment are interrelated and interact with each other. For instance, environmental degradation results frequently in developing countries that rely heavily on natural resource production. Such degradation could well reduce their capacity to produce and hence to export and to grow.

In order to analyze the issues involved and to formulate useful policies, an empirical investigation of these various interactions should also be able to decompose any changes in emissions in three ways: a scale effect, a composition effect, and a technique effect (Grossman and Kruger 1993, Dean 1999, and Antweiler, et al. 2001). A scale effect occurs when the scale of economic activity expands. If the nature of that activity is unchanged but the scale is growing, then more pollution will be generated along with output. A composition effect occurs when national output composition is altered. If the share of pollution-intensive goods in output increases, then this change in output composition will exacerbate existing environmental problems. A technique effect arises from increases in income that call for cleaner production methods. In addition, a technique effect may also exist as a result of increases in income, if newly affluent individuals would demand a cleaner environment.

We attempt to decipher these trade and environmental interactions by first performing an analytical model solution and then by decomposing any changes in pollutant emissions into the above effects. The analytical solution for these effects and their definitions appear in Appendix B. The model we employ stems from Dean's (1999) basic system:

$$Y = A(t)h(L, K, E)$$

(i)

$$E = f(r, Y, S)$$

(ii)

$$r = g(E, Y)$$

(iii)

$$S = z(t, Y)$$

(iv)

The first equation shows total output (real income) Y to be a function of the level of trade restrictions t, the stock of conventional factors of production K and L, and the level of emissions E. Increased openness is assumed to lead to higher total factor productivity ($A' < 0$). Since emissions are treated as an input, the total output Y is positively related to the equilibrium level of emissions E at any point of time. The second equation shows that demand for E is a function of the emissions charge r, Y, and the share of pollution-intensive goods in total output S. The third equation is the inverse supply curve for E, which is derived from individual utility functions. The second and third equations simultaneously determine the equilibrium level of emissions and the equilibrium emissions charge. The fourth equation stipulates that the composition of output, S, is a function of real income and the restrictiveness of the trade regime t.

For a country with a comparative advantage in pollution intensive goods, an increase in trade restrictiveness moves production towards relatively cleaner goods and hence leads to a lowered share of pollution-intensive goods in total output. Clearly, this system provides a useful framework to investigate how trade liberalization can affect the environment. However, since the trade variable is exogenous, the relationship between trade and the environment modeled in the system is one-directional[1]. We correct this directionality by endogenizing trade and foreign direct investment. The endogenous treatment of trade highlights the trade effects of domestic environmental policy, while foreign direct investment (FDI) determines whether differences in environmental regulations affect location. Rather than testing the “pollution haven” and “industrial flight” hypotheses, we instead evaluate whether more stringent environmental regulations have an economic impact on a region’s ability to absorb FDI.

This new model consists of six equations. Equation (1)resembles (i) above, except that trade value[2] T is modeled as an efficiency component leading to a shift in the production function. Physically, pollution is an unwanted by-product. From another perspective, however, the environment can be regarded as a factor of production because it is “used up” in the productive process. Also, pollution abatement requires the input of valuable production factors such as labor and capital; thus higher permissible emissions can also be considered a conventional production factor (McGuire 1982, Merrifield 1988, and Dean 1999).

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[1] Dean (1999) further reduced the four equation system into a two equation model, in which industrial wastewater emissions growth and income growth were dependent variables, while the black market premium of the US dollar was an exogenous variable used to capture the overall trade restrictiveness. Clearly, such an empirical setup is useful only for investigating the influence of trade on the environment.

[2] In this study, trade value rather than trade policies is preferred because of the use of the provincial data. In China, trade policies such as foreign exchange rates and tariff rates, in general, are uniformly set nationally and as a result, trade value can better reflect the impact of trade on GDP and the production of pollution intensive goods at the provincial level.

Including trade in a production function may seem illogical, because it may be inappropriate to simply treat exports, imports or total trade values as an output or as a productive factor. For example, in a trade balance situation, while part of production output is exported, the same amount of goods is usually imported, leaving the total output level unchanged. According to Heckscher and Ohlin (1991), however, differences in the relative scarcity of production factors between regions implies an uneconomic pattern of production, and the tendency of trade to equalize factor prices reflects production efficiency. Trade tends to lessen, if not completely eliminate, factor scarcity among regions by encouraging them to specialize in the production of goods that intensively use resources in relative abundance. Trade can thus lead to a shift in the production function, as trade flows increase with the input bundle held constant:

$$Y=A\ (T)\ h\ (L, K, E)$$

(1)

Here h_L>o, h_K>0, and h_E>0 (where the subscripts refer to the derivative of the function with respect to L, K, and E, respectively). In addition, assume A'> 0, that is, the more an economy is engaged in trade, the higher is its total factor productivity.

Factor theory suggests that emissions are released until their marginal product equals their price, which in the presence of a pollution levy system is the effective levy rate. However, it is difficult to directly measure this marginal product since emissions are a joint output rather than a direct input of production. The opportunity costs of a reduced level of emissions through abatement thus consist of resources forgone in production. This implies that pollution abatement could result in a loss of output. Hence, from the polluter’s perspective, the optimal level of emissions discharged define the point at which the marginal cost of abatement and the levy rate are equal.

$$E= f\,(r, Y, S) \qquad (2)$$

Equation (2) resembles (ii) above where $f_r < 0$ and $f_S > 0$ (f_r , f_Y and f_S are derivatives of function f with respect to r, Y, and S respectively). Assuming that an inverted-U relationship exists between per capita emissions and per capita outputs as reported by Selden and Song (1994) and Shafik and Bandyopadhyay (1994), the relationship between emissions and output would also have an inverted-U shape. In this case $f_Y > 0$, when placed on the left side of the inverted- U, and $f_Y < 0$, when on the right side of the inverted-U.

While emissions demand reflects the economics of cost-minimizing abatement by industry, emissions supply, which specifies the pollution price imposed by the community as damage increases, reflects marginal social damage (MSD). In practice, emissions supply can be an interplay of limited information, perceived self-interest and a different ability or willingness to enforce community standards (Wang and Wheeler 1996). In Dean (1999) the supply of emissions is interpreted as the community's willingness to tolerate environmental damage. Let utility be a positive function of goods and clean environment E_o, then $E = \bar{E} - E_o$, where $\bar{E}$ is the total stock of environment as a good. Analogous to modeling the labor/leisure tradeoff, Dean notes that utility maximization yields the community's demand for E_o, and their willingness, therefore, to supply (tolerate) E. The inverse supply curve for E resembles (iii) above:

$$r = g\,(E, Y)$$

(3)

where we expect $g_E > 0$ and $g_Y > 0$. This assumes that clean environment is a normal good and that a society will allow higher levels of emissions only if polluters pay higher charges.

Equation (4) following (iv) above represents the share of pollution intensive goods in total output. Again, assume that an increase in output raises income and that clean goods are relatively income elastic; then S will decrease as Y increases and $Z_Y < 0$.

$$S = Z(T, Y) \tag{4}$$

For economies that possess a comparative advantage in pollution intensive goods, an increase in trade will lead to a rise in S and hence $Z_T > 0$; while for economies with a comparative advantage in relatively clean goods, one expects $Z_T < 0$.

Trade may arise from a variety of causes. For example, trade can be caused by differences in technology and/or by differences in endowment between trading partners. Though the former may not be ranked with factor endowments as a cause of trade, they still can have a profound impact on trade (Markusen et al. 1995). In addition, FDI can be trade promoting rather than trade destroying (Kojima 1976 and Reuber 1973). Both Kojima and Reuber argue that FDI is likely to occur when a country's comparative advantage in some product in eroded or when comparative disadvantage exists. FDI moves factors (technology, management skills, and movable capital) to foreign locations, where total production costs are lowest for any given product. Hence, FDI can generate exports and imports for the host country. In general, the size of an economy, the economy's proximity to its trading partners, and the economy's trade regime are important determinants of its production and trade patterns (Leamer and Stern 1970, Markusen et al. 1995, and Frankel and Romer

1999). Trade flows (exports plus imports)[3] T, thus reflect output Y (the size of the economy), FDI, geographic remoteness R, and a trade policy indicator, t:

$$T = W\,(Y, FDI, R, t) \qquad (5)$$

Here we expect $W_Y > 0$, $W_{FDI} > 0$, $W_R < 0$. $W_t > 0$ if a trade policy is designed to promote trade; otherwise, $W_t < 0$.

There are many explanations of FDI motives and patterns, i.e. see Leamer and Stern (1970) and Ni (1998) for an overview of the theory of international capital movements. The attractiveness of an area can be enhanced by factors such as the quality of infrastructure, the availability of specialized service supplies and of skilled labor, location related reputation effects, and the development of so-called industrial clusters (Porter 1990). From the Heckscher-Ohlin-Samuelson theory, decisions on the location of FDI's are predominantly made on the basis of traditional sources of comparative advantage such as relative wages, market sizes, and transportation costs (Vernon 1996, Aliber 1970, Hirsch 1976, and Wheeler and Mody 1992). In addition, impediments to international trade such as tariffs and non-tariff barriers may also influence location (Clegg 1992).

Equation (6) explains FDI on the basis of conventional comparative advantage factors, market size and market growth (Kravis and Lipsey 1982 and Veugelers 1991), and agglomeration factors such as infrastructure quality and the level of previous FDI (Wheeler and Mody 1992, Head and Ries 1996, and Ni 1998). Moreover, though a higher wage rate means higher production costs, some empirical studies also reveal a

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[3] Exports plus imports are used as the trade variable because exports or imports alone describe only part of the relationship between trade and the environment. For instance, if exports have a negative while imports have a positive impact on the environment, the overall impact of trade on the environment can be either positive, negative, or zero depending on the relative magnitudes of the two

positive relationship between FDI and wage rates because higher wage rates are usually related to higher productivity (Kravis and Lipsey 1982 and Erickson and Kuruvilla 1994). These various interactions can be represented as follows:

$$FDI = V(Y, CFDI_{-1}, w, I, P, r) \tag{6}$$

where Y is output, $CFDI_{-1}$ is cumulative FDI inflows in the previous year, w is wage rates, I is infrastructure quality indicators, P reflects policy, and r is levy rates. The purpose of separating levy rates from other economic and policy variables is to test whether stricter environmental policies affect FDI inflows. Typically, one expects $V_Y > 0$, $V_{FDI\text{-}1} > 0$, $V_I > 0$, $V_P > 0$, $V_r < 0$, and $V_w <> 0$. Figure 1 summarizes the different interactions between the variables specified in Equations (1-6).

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effects. Hence, ignoring either of these impacts will lead to an incomplete perception of the overall impact of trade on the environment.

Figure 1 Interactions between Trade and the Environment

3. EMPIRICAL MODEL

Model Specification

Had adequate environmental and economic time series data existed for China as a whole, it would have been possible to estimate the theoretical model directly. Because of the lack of such data, it became necessary to work with a panel data set that includes mainly 28 of 34 provinces and is limited to the years 1987-1995. Such panel data not only expand the sample size for econometric estimation and improve the efficiency of estimates, but they also allow one to better deal with the effects of missing or unobserved variables (Hsiao 1986). This data set also permitted us to include industrial wastewater discharges and their levy rate as key environmental variables. Required modifications of the model to accommodate these data are shown in Table 1. It should be noted that in specifying Equation (4), the industrial share in GDP is used to approximate the share of pollution-intensive goods in output, because the emissions date reported in China are limited to the pollution sources from the industrial sector[4]. In addition to the three determinants of emissions demand included in Equation (2), it is hypothesized that state ownership may also be important[5]. Similarly, the specifications of other equations also include some additional explanatory variables,

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[4] In China, the industrial sector includes most of the pollution-intensive production activities such as mining, manufacturing, construction, and the production of chemicals, fertilizers, pesticides, tap water, power, steam, gas, and processed food such as sugar and vegetable oil. Agricultural goods are not included as pollution-intensive output due to lack of their emissions data.

[5] According to Wang and Wheeler (1996), state-owned firms may be more pollution intensive than those of other ownership types for several reasons. First, state-owned firms may generate more emissions per unit of output because they are less efficient. Second, state-owned firms may be less sensitive to emissions charges due to soft budget constraints. Third, evidence from other Asian countries suggests that state-owned firms resist environmental regulations more successfully than privately-owned ones (Pargal and Wheeler 1996 and Hartman, Hug, and Wheeler 1996). Therefore, the industrial output share of state-owned firms has been included to control for this ownership factor.

Table 1 Empirical Model Specification

(1) Gross Domestic Product

$$\log Y_{it} = a_0 + a_1 \log T_{it} + a_2 \log L_{it} + a_3 \log K_{it} + a_4 \log E_{it} + u_{1it}$$

(2) Emissions Demand

$$\log E_{it} = b_0 + b_1 \log r_{it} + b_2 \log Y_{it} + b_3 (\log Y_{it})^2 + b_4 \log S_{it} + b_5 \log SOE_{it} + u_{2it}$$

(3) Emissions Supply (Inverted)

$$\log r_{it} = c_0 + c_1 \log E_{it} + c_2 \log IN_{it} + c_3 \log C_{it} + c_4 \log ed_{it} + c_5 \log PD_{it} + u_{3it}$$

(4) Industrial Output Share in GDP

$$\log S_{it} = d_0 + d_1 \log T_{it} + d_2 \log Y_{it} + d_3 \log S_{i(t-1)} + d_4 \log V_{it} + d_5 D_i + u_{4it}$$

(5) Trade Values (Exports plus Imports)

$$\log T_{it} = e_0 + e_1 \log Y_{it} + e_2 \log FDI_{it} + e_3 \log R_{it} + e_4 \log ER_{1t}$$

$$+ e_5 (\log TN_t)*(\log TP_i) + e_6 D_i + e_7 DT_t + u_{5it}$$

(6) Foreign Direct Investment Inflows

$$\log FDI_{it} = f_0 + f_1 \log Y_{it} + f_2 \log r_{it} + f_3 \log CFDI_{i(t-1)} + f_4 \log TI_{it} + f_5 \log TAX_{it}$$

$$+ f_6 \log PGDP_{i(t-1)} + f_7 D_i + f_8 DT_t + u_{6it}$$

as suggested in the trade and environmental literature. Refer to Appendix Table A for variable definitions, coefficient assumptions, and data sources.

Model Estimation

To properly estimate the model, two problems had to be dealt with. First, difficulties of computation and statistical inference arise when estimating nonlinear simultaneous equations systems (Amemiya 1985, and Goldfeld and Quandt 1972). Because it may not be possible to solve for the reduced-form equations in these systems, the application of two stage least squares (2SLS) becomes difficult (Greene 1997). In our case, because of the presence of the squared-output term in the emissions demand equation, the reduced-form equations of the system consist of functions of the squared root of linear relations among the exogenous variables. Kelejian (1971), Parke (1982), and Amemiya (1985) demonstrate that equivalent systems linear in parameters but nonlinear in endogenous variables can still be consistently estimated with 2SLS based on a Taylor expansion approximation of the reduced-form equations, using a polynomial function of the exogenous variables.

Second, though more precise parameter estimates may be obtained by exploiting the variation in data both across provinces and within provinces over time, the exploitation in a nonlinear simultaneous equation setting is obviously a challenge, particularly when error components are considered. Hsiao (1986) and Baltagi (1995) provide a general treatment of panel data in a linear simultaneous equations framework, and unobservable error components are dealt with by Baltagi (1981 and 1984), Magnus (1982), Prucha (1985), and Kinal and Lahiri (1990 and 1993). Despite the success of this work, few empirical applications have followed (Maddala 1987, and Kinal and Lahiri 1993).

This study employs these various results, including nonlinear 2SLS and approximating the reduced-form equations with second-degree polynomials. Fitted values for 2SLS are obtained by regressing all of the endogenous variables, including *log*^{2} *Y* and *log (Y/p)* on a constant, the exogenous variables and their squares, and all distinct cross products. We also assume for the exogenous variables X_{it}, that $E [u_{jit} | X_{it}] = 0$, $E [u_{jit}^2 | X_{it}] = \sigma_j^2$, and $E [u_{jit} u_{jks}] = 0$, for all $i \neq k$ and $t \neq s$, i.e., no fixed or random effects are controlled for in this estimator[6]. Since both the economic and the environmental data differ significantly in magnitude over provinces, heteroscedasticity problems may arise. While 2SLS provides consistent parameter estimates in the presence of heteroscedasticity, the resulting standard errors may be incorrect and should not be used for inference. The White (1980) heteroscedasticity consistent covariance matrix estimator has thus been applied to derive the correct estimates of coefficient covariances in the presence of heteroscedasticity of unknown form. Model estimation and simulation are based on Eviews 4.0.

4. INTERPRETING THE COEFFICIENTS

Results of estimating the restricted equation system are reported in Table 2. Most of the coefficients of the variables bear the expected signs and are significantly different from zero. Equation (1) shows, as expected, that increases in industrial wastewater

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[6] Approaches suggested in Hsiao (1986) and Baltagi (1995) were also tried to control for provincial-specific and time-specific fixed and random effects but the results did not make economic sense. See Huang (2002) for more details and discussion.

Table 2 Model Estimation Results (*t* statistics are in parentheses)

Variables	**Equation Identification and Dependent Variables**					
	(1) GDP (log Y)	(2) IWW (log E)	(3) Levy rate (log r)	(4) Industrial share (log S)	(5) Trade (log T)	(6) FDI (log FDI)
Constant	-1.238 (-10.903)	-5.327 (-4.003)	4.443 (7.721)	0.223 (3.295)	10.619 (4.382)	-2.212 (-1.694)
GDP (log Y)		2.406 (6.426)		-0.011 (-1.021)	0.715 (11.689)	1.010 (6.332)
GDP Square (log^2 Y)		-0.103 (-3.413)				
Income (log (Y/P))			0.264 (3.609)			
Emissions (IWW) (log E)	0.137 (6.466)		-0.055 (-1.833)			
Levy Rate on IWW (log r)		-0.509 (-6.741)				0.252 (0.962)
Industrial output share (log S)		-0.108 (-0.671)				
Trade (log T)	0.157 (10.072)			0.006 (1.273)		
FDI (log FDI)					0.127 (4.032)	
Labor (log L)	0.345 (16.746)					
Capital (log K)	0.357 (17.890)					
State-owned Enterprises (log SOE)		0.430 (4.946)				
Citizen Complaints (log C)			-0.163 (-2.800)			
Education (log ed)			-0.362 (-4.138)			
Population Density (log PD)			0.119 (3.877)			
Industrial Share$_{-1}$ (log S$_{-1}$)				0.915 (61.326)		
Investments (log V)				0.023 (1.877)		
Remoteness (log R)					-0.478 (-5.312)	
Exchange rate (log E R)					-0.198 (-0.648)	
Tariffs (LogTN*logTP)					-0.035 (-0.560)	
Cumulative FDI (log CFDI$_{-1}$)						0.358 (3.910)
Road intensity (log TI)						0.648 (3.270)
Tax rate (log Tax)						-0.197 (-1.146)
GDP per capita$_{-1}$ (log PGDP$_{-1}$)						0.389 (1.628)
Regional Dummy D				-0.010 (-1.400)	0.542 (5.095)	0.395 (2.016)
Time Dummy DT					0.033 (0.450)	-0.827 (-4.651)
Adjusted R^2 Observations	0.982 252	0.810 252	0.369 252	0.968 252	0.895 252	0.802 252

discharges, trade, labor input, and capital input will lead to GDP growth. The output elasticities of these factors are explicitly given in the estimated coefficients.

The coefficients of Equation (2) confirm statistically that an inverted-U relationship exists between industrial wastewater discharges and GDP. All other things equal, industrial wastewater discharges are likely to rise as GDP increases, but will reach their peak when the provincial GDP level reaches 11813.8 billion RMB yuan (about 1440.7 billion US$), which is about 146 times the mean over the 1987-1995 period. This result implies that industrial wastewater discharges will begin to decrease when GDP per capita reaches 293,854 RMB yuan (about 35,836 US$), which is well above a realistic level. This inverted-U relationship is further tested by an auxiliary regression of industrial wastewater discharges on a constant and GDP, featuring only provincial cross-sectional data. The coefficient estimate of GDP is 1.639 for 1987 and monotonically decreases to 0.448 for 1995. That is, though wastewater discharges increase as GDP grows, the rate of the pollution increase declines from year to year, suggesting that industrial wastewater pollution is concave in GDP levels over time.

The coefficient values in Equation (2) also clearly suggest that China’s pollution levy system is an effective instrument for industrial wastewater pollution control since, as the direct impact suggests, a one percent increase in the levy rate could lead to about a 0.5 percent decrease in industrial wastewater discharges. Some studies assert that China’s pollution levy rates are too low to have significant impacts on industrial emissions (Qu 1991, NEPA 1992 and 1994, and Markandya and Shibli 1995). However, our findings agree with those of Wang and Wheeler (1996) that the levy system has proven reasonably effective. The value of the estimated coefficient of the state ownership variable confirms that the state-owned enterprises pollute more than firms of other types of ownership. It is surprising that the coefficient of the industrial output share fails to carry the expected sign and is not statistically different from zero, suggesting that provinces with a higher industrial output share might be more environmentally efficient in wastewater pollution control.

Equation (3) indicates a positive relationship between the levy rate and per capita GDP. That is, as per capita GDP increases, society should pay a higher price for a cleaner environment. Since this equation explains environmental supply, we expect that there also exists a positive relationship between the levy rate and wastewater discharges; theoretically, a society is more likely to tolerate pollution when the polluter pays a higher price. However, in Equation (3), the coefficient on wastewater discharges is negative and not significant. This might suggest a zero or a negative price elasticity for environmental supply. That is, even if a higher levy rate is in place, individuals still do not have the willingness to tolerate more pollution.

As noted earlier, China's pollution levy rates have been argued to be too low to have significant impacts on pollution control. We can confirm that these levy rates are indeed too low for individuals to tolerate pollution discharges at the existing level. Observe the significant negative coefficient on social environmental complaints: the negative sign indicates dissatisfaction with pollution generation and environmental enforcement. Moreover, as expected, population density has a significant positive effect, and the illiteracy and semi-illiteracy rate has a significant negative impact on the levy rate.

In Equation (4), trade might have a positive impact on industrial output share but the impact is not significantly different from zero. Different results have been obtained in studies on whether China has a comparative advantage in pollution-intensive goods (Dasgupta et al. 1997 and Dean 1999). Our results suggest that trade does not have a significant impact on industrial output share, and, therefore, China may not have a comparative advantage in relatively pollution-intensive industrial goods. The result is consistent with the fact that the shares of manufactured goods in China's total exports and imports are very close for most of the 1987-1995 period. The coefficients on GDP and the regional policy dummy variable both have the expected negative signs but are not significant. As is the case of many developing countries, industrialization still provides a key to China's economic development, i.e. see Syrquin (1989). Therefore, it is not surprising that the GDP effect is insignificant. In addition, the coefficient of the investment variable shows that China's investments in fixed assets tend to increase the industrial output share only slightly.

In Equation (5), variables derived from the gravity model, GDP, and remoteness, both bear the expected signs and are statistically significant. Also as expected, both FDI and the regional geographical and policy dummy variable have significant positive effects on trade. The coefficient of the exchange rate suggests that a one percent increase in the exchange rate might lead to more trade, though the coefficient is negative. Since trade is measured in US dollars, any change in the exchange rate should influence trade by the same magnitude but in the opposite direction given the real trade flow constant. Unfortunately, this coefficient is not statistically significant. Similarly, the coefficient on tariffs might suggest that lower tariffs would stimulate trade, but it too is not statistically significant.

One could expect that the 1989 Tiananmen Square Incident (TSI) may have had a negative effect on trade, because of the economic sanctions that Western countries imposed on China afterwards. The results, however, show that such an impact is not significant and, if it were, the impact would probably be positive. This is not difficult to understand. While China's trade with its major Western trading partners such as the United States and Japan was negatively affected, this impact might have been overcompensated by China's efforts to expand its trade with its other trading partners.

Finally, in equation (6), except for the levy rate coefficient, all results have the expected effects. Provinces with higher GDP, cumulative FDIs, GDP per capita, and better infrstructure receive more foreign direct investment. Also, coastal provinces are more attractive to multinational firms. Higher taxes may have a negative effect on FDI inflows, but this effect is not significant. Though no negative trade effect has been associated with TSI, the coefficient of the time dummy in Equation (5) clearly indicates that TSI had a significant negative impact on FDI inflows, i.e., the same result obtained by Ni (1998). It is interesting to note that the levy rate variable does not have a negative effect on FDI, a result confirmed by other studies.

5. MODEL VALIDATION

Since no straightforward validation method is available for a system of this type, we instead evaluate four of the salient aspects of the system's structure. First, the 2SLS specification has been linearized by removing the squared endogenous variable from Equation (2). The purpose of doing this is to see how great a variation in the coefficient estimates might result if the system were specified differently. We thus remove the squared *logGDP* term from the second equation to make the system linear, since the GDP turning point is well above the current GDP levels. When the conventional 2SLS approach was applied to the linear system, most results are theoretically consistent with those reported in Table 2. (These and the following results can be obtained on request from the authors.)

Secondly, we also examine whether the estimated system is robust over the given time period by re-estimating it for the shorter period 1987-1995 to

1987-1993. Observe that, since 1993, a volume-based industrial wastewater discharge fee has been introduced into China's pollution levy system. This suggests that the levy rate data as well as the environmental response after 1993 may not be consistent with those in the previous years. Most of the new estimates show only a marginal deviation from those in Table 2. Neither changes in time period nor changes in the levy system affect the results.

Thirdly, the sensitivity of the estimates is analyzed by deleting all observations from the three municipalities or provinces (Beijing, Shanghai and Tianjin) that are obviously different from the other provinces in terms of their levels of economic and social development. Here the changes in coefficient values were more dramatic than those observed from the above adjustments, but only a few changes in signigicance occur.

And lastly, the stability of the estimated system and the existence of equilibrium values for the endogenous variables were evaluated by by consecutively solving the estimated model using a dynamic simulation with the lagged values of three endogenous variables (GDP, industrial output share S, and FDI). The model behaved fairly consistently subject to these changes in all of the deterministic and the stochastic runs we performed and it converged quickly, confirming the existence, stability and convergence conditions of the system.

6. THE ANALYTICAL SOLUTION

To better interpret the interactions between the trade and environmental variables, we perform an analytical solution of the model based on comparative static methods. We have chosen the latter approach because of the importance of interpreting the mentioned decomposition effects. (Results of also conducting a variety of dynamic simulations with the model appear in Huang (2002). The kinds of causal effects we trace among the variables for policy purposes are as follows: (1) how would a change in trade policy or in trade values affect levels of emissions and emissions charges; and (2) how would a change in emissions charges or in emissions levels influence FDI inflows and trade flows. These relationships not only involve effects between exogenous and endogenous variables, but also effects between endogenous variables that are simultaneously related. The latter have not been regularly dealt with in previous studies.

To perform the analytical solution, we first differentiate the equations of the model described in Table 1 and then rearrange them in matrix form; coefficient estimates from Table 2 are entered and then the determinant solved to trace the impacts of trade on the environment and vice versa (see Appendix Equations B-1 to B-7). The following considerations also are necessary. (1) Given that logarithms of variables are used in empirical estimation, the causal relations among variables identified in Appendix Equations (B-8)-(B-13) can be interpreted as elasticities. (2) In cases where the value of a variable is needed for computation, the sample mean of the variable is used and, therefore, any effects can be regarded as those applying to an "average province" in the sample. (3) In order to measure the trade and environmental linkages, the determinant of the system ($|\Delta|$) must be positive (0.613).

Environmental impacts of Trade

When the exchange rate and the tariff rate variables are considered, their coefficient estimates were not statistically significant and thus we consider environmental impacts only in terms of trade flows (total values of trade or exports plus imports). Following from Appendix Equation (B-8a), the impact of trade flows on emissions are computed and reported in Table 3. The results suggest that trade should lead to higher discharges of wastewater because trade induces an increase in economic scale (captured by the term $|\Delta|^{-1}hA'f_Y$). However, trade can also lead to reduced wastewater discharges through its income effect (captured by term $|\Delta|^{-1}hA'f_r g_Y$). We find that the total impact of trade on wastewater discharges is positive, a one percent increase in trade should increase wastewater discharges by about 0.3 percent.

Since trade may positively lead to increased pollution discharges, can it be inferred that China has had a comparative advantage in pollution-intensive goods? Indeed, the results provide no support for this hypothesis because no indication has been found that trade may change the composition of output and hence generate more emissions (the term $f_s Z_T$ captures this effect, displaying all zeros in Table 3).

Table 3 Variable Interactions

Impacts	Composition	Income	Scale	Total
Trade on wastewater emissions	0[a]	-0.034[b]	0.263[c]	0.297
Emissions charges on trade			-0.096[d]	-0.096
Trade on emissions charges	0[e]	0.068[f]	0[g]	0.068
Emissions charges on FDI			-0.115[h]	-0.115

a: Composition effects: $|\Delta|^{-1}f_S Z_T + |\Delta|^{-1}hA'f_S Z_Y.$

b: Income (technology) effect: $|\Delta|^{-1}hA'f_r g_{Y.}$

c: Scale effect: $|\Delta|^{-1}hA'f_Y$.

d: Scale effects: $|\Delta|^{-1}Ah_E f_r W_Y + |\Delta|^{-1}Ah_E f_r V_Y W_F$.

e: Composition effect: $|\Delta|^{-1}hA'f_S g_E Z_{Y.}$

f: Income (technology) effect: $|\Delta|^{-1}hA'g_Y$.

g: Scale effect: $|\Delta|^{-1}hA'f_Y g_{E.}$

h: Scale effect: $|\Delta|^{-1}Ah_E f_r V_Y$.

Source: see Appendix B for further explanation.

Trade impacts of an emissions charge

As already discussed, though the impact of an emissions charge on trade is not explicitly measured in the model, an emissions charge may affect trade indirectly (see Figure 1 and Appendix Equation (B-13)). Since the direct impact (Vr) of an emissions charge on FDI is not significantly identified in any of the empirical cases, Equation (B-13) has been reduced to two terms: (1) $Ah_E f_r W_{Y,}$ a direct impact on trade from a reduced economic scale due to the presence of emissions charges; and (2) $Ah_E f_r V_Y W_F$, an indirect impact also from the reduced economic scale but via its impact on FDIs. As shown in Table 3, a negative impact of an emissions charge on trade is identified in the wastewater pollution case, but the impact, as one might expect, is very small.

Impacts of trade flows on emissions charges

Since our results suggest that the effect of trade on industrial GDP share is not statistically different from zero (i.e., $Z_T = 0$ from Appendix Equation (B-11a)), trade may have three possible impacts on the emissions charge: the composition effect of income ($hA'f_S g_E Z_Y$), the scale effect of income ($hA'f_Y g_E$), and the technique effect of income ($hA'g_Y$) (i.e., see p.40 for further explanation). According to Table 3, trade has a positive impact on wastewater levy rate but this impact is only through an income or technique effect.

Impacts of an emissions charge on FDI

We have not found any statistically significant impacts that an emissions charge might have on FDI, even though this effect is explicitly defined in the sixth equation of the system. Most likely differentials in emissions levy rates across provinces are not a significant factor in the decisions of foreign firms in production location. However, one cannot conclude that emissions charges have no effect on

FDI. In Appendix Equation (B-12), though the first term in braces disappears since V_r is virtually equal to zero, the second term $|\Delta|^{-1}Ah_Ef_rV_Y$, still exists, suggesting that emissions charges may affect FDI via the path of reduced emissions and lowered GDP levels. As shown in Table 3, our results suggest that China's relatively tight controls on wastewater pollution may have had a negative impact on FDI.

7. CONCLUSIONS

This study describes a simultaneous econometric model capable of analyzing interactions between trade and the environment. This model has proven useful in a number of respects. As an example, our results show that increased trade can lead to increased wastewater discharges through a scale effect, but that trade can also lead to reduced wastewater discharges through an income effect (this result was confirmed by our finding that increased trade had led to higher emissions charges through an income effect). Moreover, the results show that the composition effect of trade on wastewater emissions was zero, suggesting that China may not have a comparative advantage in pollution intensive goods. Similarly, an emissions charge may have both a direct negative impact on trade from a reduced economic scale and an indirect negative impact also from the reduced economic scale but via its impact on FDIs. These results suggest that a tradeoff between economic growth and environmental protection might have taken place in China during the period examined.

This study also has confirmed the existence of an environmental Kuznets curve in the form of an inverted-U relationship between the amount of industrial wastewater discharges and GDP levels. Since wastewater pollution is quasi-controlled in China, the total amount of pollution could be decreased as the scale of economic activity increases, when an effective environmental policy is in place.

Concerning future research, there is a need for more case-specific empirical studies on trade and environmental issues among countries. In particular greater efforts should be made to investigate trade and environmental issues using disaggregate industrial-levels, such as those employed in input-output and CGE models. Since the environmental impacts of production differ from industry to industry and environmental policies have different impacts on different industries, CGE models enable one to examine the trade and environment relationship at the industry level and hence to produce more detailed and more accurate analyses of this relationship. Further application of the present and other modeling approaches in China or in other countries, of course, depends on the availability of better data.

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Appendix A: DATA AND VARIABLES

Most provincial emissions data were obtained from a province-level panel database constructed by the World Bank. This data set is limited to the industrial sector for the 1987-1995 period. Other provincial social and economic data are from various China Statistical Yearbooks (1987-1999) and the provincial Statistical Yearbooks (1987-1999). Detailed data sources and variable definitions are reported in Table A.

All nominal variables such as GDP, investment, trade flows, and FDIs are measured either in 1990 constant RMB yuan or in 1990 constant US dollars. Nominal variables measured in RMB yuan were converted either by Chinese GDP price indexes, by price indexes for investment in fixed assets, or by general consumer price indexes (obtained from various China Statistical Yearbooks), while variables in US dollars were transformed using implicit price deflators for US GDP published in the Survey of Current Business (BEA 2000).

The geographic structure of the data consists of 28 out of 34 provinces. Tibet and Hainan are excluded due to insufficiency of data. Chongqing was part of Sichuan before 1997. Taiwan is also excluded as well as Hong Kong and Macao. These three regions, however, constitute China's major trading partners and FDI sources.

Several environmental variables require some explanation. Since 1993, the levy data available are total levies collected on excess industrial wastewater discharges; the levy rate is approximated as the total levy on wastewater divided by the total discharge of the pollutant. Though this is a rough measure of prices relating environmental demand and supply, it does reflect the differentials in strictness of environmental enforcement across provinces. Another variable, the national level tariff, is simply calculated as the national total tariff revenues divided by national total imports. It is noticeable that our calculated tariffs are much lower than those reported by other sources such as the World Bank (1999). Nevertheless, they are used in this analysis because they capture the decreasing trend of the variable during the study period, and there is no available single source that releases China's tariff data.

Table A Variable Definition, Coefficient Assumption and Data Source

Variable Name	**Definition**	**Coefficient Assumption**	**Source**
Endogenous Variable			
Y_{it}	Gross Domestic Product (GDP), in 100 million RMB yuan at 1990 constant prices.	$b_2>0$, $c_2>0$, $d_2<0$, $e_1>0$, $f_1>0$.	Various issues of China Statistical Yearbook.
E_{it}	Industrial wastewater discharges, in million tons .	$a_4>0$, $c_1>0$.	China's provincial environmental data set compiled by the World Bank and various issues of China Environmental Year Book.
r_{it}	The levy rate, at 1990 constant prices, computed as total levy collected on industrial wastewater discharge divided by total amount of wastewater discharge, in cents per ton.	$b_1<0$, $f_2<0$.	China's provincial environmental data set compiled by the World Bank, various issues of China Environmental Yearbook.
S_{it}	Share of industrial GDP in total GDP, %.	$b_4>0$.	China Statistical Yearbooks.
T_{it}	Total trade flows (exports plus imports), in 10,000 US$ at 1990 constant prices.	$a_1>0$, $d_1<>0$.	China Statistical Yearbooks.
FDI_{it}	Foreign direct investment inflows, in 10,000 US$ at 1990 constant prices.	$e_2>0$.	China Statistical Yearbooks.
Exogenous Variables			
L_{it}	Number of total employed persons, in 10,000.	$a_2>0$.	China Statistical Yearbooks.
K_{it}	Cumulative total investment in fixed assets, in 100 million RMB yuan at 1990 constant prices.	$a_3>0$.	China Statistical Yearbooks.
SOE_{it}	Share of state-owned firms in industrial GDP, %.	$b_5>0$.	China Statistical Yearbooks.
N_{it}	Population, in 10,000.	$c_2'>0$.	China Statistical Yearbooks.

(Table A continued)

Variable Name	Definition	Coefficient Assumptions	Source
C_{it}	Number of pollution complaints per million population.	$c_3 <> 0$.	China's provincial environmental data set compiled by the World Bank, various issues of China Environmental Yearbook.
ed_{it}	Illiteracy and semi-illiteracy rate, %.	$c_4 < 0$.	China Statistical Yearbooks.
PD_{it}	Population density, in number of inhabitants per km^2.	$c_5 <> 0$.	China Statistical Yearbooks.
V_{it}	Investment in fixed assets, in 100 million RMB yuan at 1990 constant prices.	$d_4 <> 0$.	China Statistical Yearbooks.
R_{it}	Remoteness, computed as the nearest distance between a province's capital and the capitals of China's 15 biggest trading partners, in kilometers.	$e_3 < 0$.	Authors' calculation.
ER_t	Exchange rate, in RMB yuan per 100 US$.	$e_4 <> 0$.	China Statistical Yearbooks.
TN_t	National total tariff revenues divided by national total imports, %.	$e_5 < 0$.	China Statistical Yearbooks.
TP_i	1996 provincial ad valorem tariff rates, %.	$e_5 < 0$.	World Bank (1997).
$CFDI_{I(t-1)}$	Lagged cumulative FDI inflows, in 10,000 US$ at 1990 constant prices.	$f_3 > 0$.	China Statistical Yearbooks.
TI_{it}	Highway intensity, kilometers per 100 square kilometers.	$f_4 > 0$.	China Statistical Yearbooks.
TAX_{it}	Overall tax rate, tax revenue divided by GDP, %.	$f_5 < 0$.	China Statistical Yearbooks.
$PGDP_{i(t-1)}$	Lagged per capita GDP, in RMB yuan per capita.	$f_6 > 0$.	China Statistical Yearbooks.
D_i	Regional geographic and policy dummy variable, 1 for coastal provinces and Beijing, and 0 for other provinces.	$d_5 <> 0$, $e_6 > 0$, $f_7 > 0$.	
DT_t	Time dummy variable, 1 for 1989, 1990 and 1991, and 0 for other years.	$e_7 < 0$, $f_8 < 0$.	

Appendix B: ANALYTICAL SOLUTION

Equations (1) to (6) reveal how trade and environmental variables are interrelated. Their interpretation depends on differentiating (total) these equations:

$dY = hA' dT + Ah_l\, dL + Ah_K\, dK + Ah_E\, dE$ (B-1)

$dE = f_r\, dr + f_Y\, dY + f_S\, dS$ (B-2)

$dr = g_E\, dE + g_Y\, dY$ (B-3)

$dS = Z_T dT + Z_Y dY$ (B-4)

$dT = W_Y\, dY + W_F\, dF + W_R\, dR + W_T\, dT$ (B-5)

$dFDI = V_Y\, dY + V_r\, dr + V_{F-1}\, dCF_{-1} + V_I\, dI + V_P\, dP + V_w\, dw$ (B-6)

Diagrammatically, the implied mechanism of this system has been shown in Figure 1.

Rearranging equations (B-1) – (B-6), the proposed trade and environmental model (TEM) can be written in matrices notation form as follows:

$$\begin{bmatrix} 1 & -Ah_E & 0 & 0 & -hA' & 0 \\ -f_Y & 1 & -f_r & -f_S & 0 & 0 \\ -g_Y & -g_E & 1 & 0 & 0 & 0 \\ -Z_Y & 0 & 0 & 1 & -Z_T & 0 \\ -W_Y & 0 & 0 & 0 & 1 & -W_F \\ -V_Y & 0 & -V_r & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} dY \\ dE \\ dr \\ dS \\ dT \\ dFDI \end{bmatrix} = \begin{bmatrix} Ah_L dL + Ah_K dK \\ 0 \\ 0 \\ 0 \\ W_R dR + W_t dt \\ V_{CF-1} dCF_{-1} + V_I dI + V_P dP + V_w dw \end{bmatrix}$$

(B-7)

This matrix system can be solved for the determinant, which upon using the econometric parameter estimates can be used to solve for static causal effects among the variables relating trade and the environment as specified earlier.

The effects of a trade policy on emissions

Changes in emissions as suggested above would be given by

$$\frac{dE}{dt} = |\Delta|^{-1} W_t \left[f_S Z_T + hA'(f_r g_Y + f_Y + f_S Z_Y) \right] \qquad \text{(B-8)}$$

where $|\Delta|$ is the determinant of the system:

$$|\Delta| = \begin{bmatrix} 1 & -Ah_E & 0 & 0 & -hA' & 0 \\ -f_Y & 1 & -f_r - f_S & 0 & 0 & 0 \\ -g_Y & -g_E & 1 & 0 & 0 & 0 \\ -Z_Y & 0 & 0 & 1 & -Z_T & 0 \\ -W_Y & 0 & 0 & 0 & 1 & -W_F \\ -V_Y & 0 & -V_r & 0 & 0 & 1 \end{bmatrix}$$

(B-9)

Assuming at present that a theoretically correct system should not change the sign of the direct impact of an exogenous variable on an endogenous variable, then $|\Delta| > 0$.

The first term $f_s Z_T$ in the square brackets of (B-8) demonstrates the effect of a trade policy on the demand for emissions as an input due to a change in the composition of output. If an economy has a comparative advantage in pollution-intensive goods and its trade policy is designed to promote trade, then $Z_T > 0$ and $f_S Z_T > 0$. That is, increased trade could induce increased emissions. The second term in the square brackets captures the income effect of trade. The terms in parentheses reflect, respectively, the technique ($f_r g_Y$), scale (f_Y) and composition effects ($f_s Z_Y$) of an increase in income caused by the trade promoting policy. If an economy is in a state of development where increased income growth reduces emissions, i.e., on the right side of an inverted U, the sum of the term in parentheses would be negative. In addition, even if an economy is on the left side of an inverted U, the sum in parentheses could still be negative, where the technique and composition effects outweigh the scale effect. Though an economy may have a comparative advantage in pollution-intensive goods, a trade-promoting policy can lead to lower emissions, if the income effect of trade prevails.

Similarly, the effects of trade flows on emissions would be given by

$$\frac{dE}{dT} = \left|\Delta\right|^{-1}\left[f_S Z_T + hA'(f_r g_Y + f_Y + f_S Z_Y)\right] \qquad \text{(B-8a)}$$

The effects of a trade policy on FDI

Changes in foreign direct investment derive from

$$\frac{dF}{dt} = \left|\Delta\right|^{-1} W_t [hA'(f_S\, g_E\, V_r\, Z_Y + f_S\, g_E\, V_r + V_Y + g_Y\, V_r - f_r\, g_E\, V_Y)$$

$$+ Z_T(Ah_E\, (f_S\, V_Y + Ah_E\, f_S\, g_Y\, V_r + f_S\, g_E\, V_r)] \qquad \text{(B-10)}$$

The first term in the square brackets summarizes the effects of an increase in income on FDI due to the imposition of a given trade policy. The second term in brackets captures the trade-induced composition effects on FDI. Both the income and the composition effects are mixed in signs. If the impact of an environmental policy on FDI is very small (the strictness of environmental policies is not significant factor for foreign firms to choose places to invest) (V_r'' 0), then the first term would be positive but the second term would only be positive as long as the economy has a comparative advantage in pollution-intensive goods. In this case, trade liberalization stimulates foreign investment. For an economy with a comparative advantage in environmentally safe goods ESG, the second term could be negative due to the negative impact of a relatively reduced share of pollution-intensive goods on emissions and hence on economic scale. In the case that the trade-induced income effects dominate, trade promotion would lead to more FDI inflows.

The effects of a trade policy on emissions charges

The emissions charge impact is defined by

$$\frac{dr}{dt} = \left| \Delta \right|^{-1} W_t \,[Z_T\,(f_S\,g_E + Ah_E\,f_S\,g_Y) + hA'(f_S\,g_E\,Z_Y + f_Y\,g_E + g_Y)] \qquad \text{(B-11)}$$

The first term in square brackets shows the effect of trade on the price of the environment due to the trade-induced change in output composition. With a comparative advantage in pollution-intensive goods, the emissions charge can be raised in two ways. On the demand side, increased trade implies an increased demand for better environment and hence higher environmental prices (captured by f_Sg_E). On the supply side, this increased demand for environment as an input would also imply a higher lever of output and income, which would lead to a reduced supply of the environmental factor and hence to a higher emissions charge (captured by $Ah_Ef_Sg_Y$). On the other hand, with a comparative advantage in clean goods, increased trade would result in a decrease in demand for and an increase in supply of emissions; the first term would thus be negative and trade would lower emissions charges.

The second term in square brackets reveals the income effect of a trade policy on the emissions charge. Similar to the decomposition of effects that trade has on emissions, the components of the term can be interpreted as respectively the composition, scale, and technique effects of income, on emissions demand and supply. The composition effect of income, $f_Sg_EZ_{Y,}$ implies that higher income reduces the demand for emissions provided that clean goods are relatively income elastic, leading to a lower emissions charge. The scale effect of income, f_Yg_E, would increase (decrease) the demand for emissions if the growth stage of an economy is on the left (right) side of the inverted U and hence would cause the emissions charge to rise (decline). The technique effect of income, g_Y, implies that a rise in income would enhance an economy’s ability and willingness to pay a higher price for a cleaner environment and would thus reduce the supply of emissions and raise the emissions charge.

Generally, if an economy specializes in pollution-intensive goods and the technique affect of income dominates the overall effect of trade on the emissions charge, then trade could lead positively to stricter environmental policies and enforcement.

Similar to Equation (B-11), the emissions charge impact of trade flows can be defined by:

$$\frac{dr}{dT} = \left| \Delta \right|^{-1} [Z_T (f_S g_E + Ah_E f_S g_Y) + hA'(f_S g_E Z_Y + f_Y g_E + g_Y)] \qquad \text{(B-11a)}$$

The effects of the emissions charge on FDI

Another foreign direct investment effect can be measured by

$$\frac{dF}{dr} = \left| \Delta \right|^{-1} \{V_r [1- hA' W_Y - Ah_E (f_S W_Y Z_T + f_Y + f_S Z_Y)] + Ah_E f_r V_Y\} \qquad \text{(B-12)}$$

The first term in braces consists of both the positive and the negative effects of a change in the emissions charge on FDI. The negative effects include the direct impact Vr of the emissions charge, and the indirect impact $Ah_E f_S Z_Y$ of decreased economic scale caused by an income-induced change in output composition. The positive effect comes from the increased output scale due to positive interactions between trade and output $hA'W_Y$. The other two components of this term could be either positive or negative. If an economy has a comparative advantage in pollution-intensive goods, the trade-induced increasing demand for the environment as an input would raise the output and hence make the economy more attractive to FDIs (captured by $Ah_E f_S W_Y Z_T$). Otherwise this effect would be negative. When an economy is on the left (right) side of the inverted U, increased (decreased) output due to positive (negative) inter-influence between output and emissions (captured by Ah_Ef_Y) could lead to more (less) FDIs. Finally, the last term in braces $Ah_Ef_rV_Y$ suggests that the negative impact of a strict environmental policy such as a higher emissions charge on output would lead to lower FDIs, and this effect would dominate as long as the direct effect V_r approaches to zero.

The effects of the emissions charge on trade

Finally, trade impacts of an emissions charge can be measured by

$$\frac{dT}{dr} = \left| \Delta \right|^{-1} [V_r w_F (1-Ah_Ef_Y - Ah_Ef_SZ_Y) + Ah_E (f_rW_Y + f_rV_YW_F)] \qquad \text{(B-13)}$$

Though the proposed model does not explicitly measure the impact of environmental policies on trade, equation (B-13) can evaluate all the indirect effects from an increase in the emissions charge to trade, most likely negative. The only likely source of a positive effect, Ah_Ef_Y, is derived from the positive interaction between output and emissions when the economy is on the left side of the inverted U. In this case, the negative effect of an emissions charge on trade via FDI, V_rW_F, would be mitigated. Otherwise, just like the term $Ah_Ef_SZ_Y$ relating the composition effect of an increase in output, Ah_Ef_Y would aggravate the negative effect of the emissions charge on trade. A plausible explanation could be that, given emissions as an important input, any reductions in emissions would first lower the output scale and then the trade volume, given the direct impact of output on trade. For similar reasons, the second term in square brackets is negative because an increase in an emissions charge would reduce the demand for environment as an input, leading to a lower level of output and hence to reduced trade (captured by $Ah_Ef_rW_Y$). In addition, lowered output would make the economy less appealing to FDIs, and reduced FDIs would result in reduced exports and imports (captured by $Ah_Ef_rV_YW_F$).

Conventional trade and environment theory suggests that environment policies would raise production costs, lower the competitiveness of the economy, and hence lead to reduced trade (Siebert et al. 1980, McGuire 1982, and Baumol and Oates 1988). Though production costs and prices are excluded, the analytical results of the theoretical framework on the trade effects of environmental policies are consistent with the conventional view, but stem from a different perspective.