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LINKING TRADE AND THE ENVIRONMENT IN CHINA

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Abstract: This study uses a computer simulation approach to examine the empirical interactions between trade and the environment in the Chinese case based upon a trade and environment model (TEM). The simulation results show that increased trade can lead to increased GDP, wastewater discharges, levy rates, and FDI inflows. An increase in levy rates, a measure of the strictness of environmental policies, may have negative impacts on GDP, industrial wastewater discharges, trade values, and FDI inflows. If levy rates increase as trade expands at the same rate, wastewater pollution can be reduced and positive GDP growth can also be achieved. However, an increase in levy rates and FDI together alone can result in a reduction not only in wastewater pollution but also in GDP levels. Our simulation results suggest that trade is essential to achieve coordinated development between the economy and the environment. The results also indicate that the non-linear simultaneous equations model and its 2SLS estimation results are reasonably robust. Specifically, the deterministic simulation results are consistent with and very close to those derived from comparative statics. In addition, the stochastic simulation results indicate that the TEM model is reasonably stable to error structure shocks and the impacts of uncertainty on model performance are generally insignificant. Moreover, the stochastic error and coefficient simulation demonstrates that the TEM model is also rather robust to the changes in the estimated values of the coefficients.

LINKING TRADE AND THE ENVIRONMENT IN CHINA

1. INTRODUCTION

Econometric attempts to model trade and environment relationships have been limited and their results show little evidence that freer trade would bring about significant changes in environmental quality. Also, there is little evidence that differences in the strictness of environmental policy represent a significant determinant of trade patterns and flows. The ambiguousness of these results can be ascribed 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 with each other.

The purpose of this study is to develop, estimate, and simulate a simultaneous model of these interactions based on the work of Dean related to China (Dean 1999). Though some interesting attempts have been made to analyze Chinese environmental problem (Dean 1999, and Wu 2000), the environmental implications of the surge in foreign trade and investment in China are complex, very largely contested, and to the best of our knowledge, have not received empirical investigation.

This paper consists of the following parts: trade and the environment in China, model specification and estimation, model simulation, results and discussion, and conclusions.

2. TRADE AND THE ENVIRONMENT IN CHINA

China’s environmental problems have been aggravated by its rapidly developing economy (Wu 2000, and World Bank 1997). Rapid economic growth has instigated enormous volumes of wastewater, air pollutants, industrial solid wastes, and toxic hazards. These factors, together with widespread depletion of natural resources, have adversely affected human health, increased natural disasters, dampened gains from trade, and caused social instability and conflicts.

As a result, the Chinese government has begun to treat environmental protection as an important national policy. It has been widely accepted in China that the pace of environmental protection must be commensurate with economic growth in order for China to achieve sustainable development. China has promulgated and enforced its Environmental Protection Law, first implemented in 1979 and later amended in 1989. Many other laws also exist and it is worth noting that China has an extensive pollution charge system. From its inception in the early 1980s to 1996, about 30 billion RMB yuan (3.66 billion US dollars) have been collected from more than 500,000 major polluters. In 1996 alone, the system collected about 4 billion RMB yuan (0.49 billion US dollars). Charges are levied for effluents of wastewater, air pollutants, and solid waste discharge. According to the *China Environmental Yearbook* 1997 (NEPA 1998), about 63 percent of total environmental levies in 1996 were derived from water pollution sources.

Historically, China’s trade policy regime has aimed to stimulate export growth to generate foreign exchange without regarding its costs, while its import policy has been hampered with controls to reduce import growth. Such an approach has neglected any relationships between trade and the environment. According to Jha et al. (1999), unchecked production from export-oriented rural small and medium-sized enterprises has led to the deterioration of China’s environment. Though not the intention of the central government, exporters have so far encountered few domestic environmental controls due to provincial regional protectionism (Wu 2000 and Jha et al. 1999).

The impact of FDI on the environment has been mixed and controversial. In China’s case, Jha et al. (1999) note that FDI enterprises have a higher investment share in pollution abatement (2.27 percent) than that of their local counterparts (0.94 percent). Moreover, the former tend to use more efficient technology and equipment that also reduce pollution. However, under pressures of the rising costs of pollution abatement in their parent country or in other developed countries, some foreign firms have diverted their pollution intensive industries to China. In 1991, for example, over 36 percent of all FDI was invested in highly polluting industries, including printing, dyeing and electroplating (Xia 1995). More recent reports (Xia 1995) confirm that some parts of China may indeed be “pollution havens” for some foreign investors.

3. MODEL SPECIFICATION AND ESTIMATION

Our analysis begins with Dean's (1999) simultaneous equations model that links the environment and economic growth and continues with the inclusion of trade and FDI. The proposed model consists of six equations. In Equation (1), similar to Dean’s model, total output (Y) is a function of labor input (L), capital input (K), and emissions released to the environment in the course of production. Trade values (T) is modeled as an efficiency component leading to a shift in the production function.

$$Y=A(T)\,h(L, K, E) \qquad (1)$$

One expects that $h_L > o$, $h_K > 0$, and $h_E > 0$ (where the subscript refers 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 the total factor productivity.

In Equation (2), according to Dean (1999), the derived demand for emissions can be expressed as a function of the levy rate (r), output (Y), and the share of pollution-intensive goods in output (S), 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).

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

Assuming an inverted-U relationship exists between per capita emissions and per capita outputs as reported in studies by Seldon and Song (1994) and Shafik and Bandyopadhyay (1992), the relationship between emissions and output would also have an inverted-U shape. We may then expect that $f_Y > 0$, given a position on the left side of the inverted U, and $f_Y < 0$ on the right side of the inverted U.

Equation (3) is the inverse supply curve for emissions (E), where we expect $g_E > 0$ and $g_Y > 0$, assuming that clean environment is normal good and the community will allow higher levels of emissions only if polluters pay a higher charge.

$$r = g(E, Y) \qquad (3)$$

Following Dean (1999), Equation (4) represents the share of pollution intensive goods in total output. Again, assume that an increase in output raises income and clean goods are relatively income elastic, then S will decrease as Y increases and $Z_Y < 0$.

$$S=Z\,(T, Y) \qquad (4)$$

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 relative clean goods, one expects $Z_T < 0$.

In Equation (5), trade flows (T) reflect output (Y), FDI, geographic remoteness (R), and a trade policy indicator (t), where $W_Y > 0$, $W_{FDI} >0$, $W_R < 0$, and $W_t > 0$ if a trade policy is designed to promote trade; Otherwise, $W_t < 0$.

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

The FDI determinants considered in Equation (6) include output (Y), cumulative FDI inflows in the previous year (FDI_{-1}), wage rates (w), infrastructure quality indicators (I), policy indicators (P), and levy rates (r). As shown in Equation (10), the purpose of separating levy rates from other economic and policy variables is to test whether stricter environmental policies affect FDI inflows.

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

Typically, one expects $V_Y > 0$, $V_{FDI-1} > 0$, $V_I > 0$, $V_P > 0$, $V_r < 0$, and $V_w < > 0$. Figure 1 traces these various interactions, based on a comparative static approach to incremental impacts.

The empirical framework employed reflects the lack of long environmental and economic time series for China as a whole. As a consequence, more attention is given to model disaggregation with concentration on the Chinese provinces. Model estimation employs a provincial-level panel data set that not only expands the sample size for econometric estimation and improves the efficiency of estimates, but it also permits one to better deal with the effects of missing or unobserved variables (Hsiao 1986). The estimation method employed depends on 2SLS estimation with the linearized reduced form and employs the White heteroskedasticity consistent covariance matrix estimator to assure a normal error structure. An exercise of this method and its results including model validation appear in Huang and Labys (2004). A table describing the definitions of the variables and the values of the variable parameters appears in Appendix A.

4. MODEL SIMULATION

Our simulation of the above theoretical model is based on specification adjustments to deal with our panel data set and consists of the following equations (see Huang and Labys, 2004, for more detailed information of model estimation):

$$\log Y_{it} = -1.238 + 0.157 \log T_{it} + 0.345 \log L_{it} + 0.357 \log K_{it} + 0.137 \log E_{it} + u_{1it}$$

$$\log E_{it} = -5.327 - 0.509 \log r_{it} + 2.406 \log Y_{it} - 0.103 (\log Y_{it})^2 - 0.108 \log S_{it} + 0.430 \log SOE_{it} + u_{2it}$$

$$\log r_{it} = 4.443 - 0.055 \log E_{it} + 0.264 \log IN_{it} - 0.163 \log C_{it} - 0.362 \log ed_{it} + 0.119 \log PD_{it} + u_{3it}$$

$$\log S_{it} = 0.223 + 0.006 \log T_{it} - 0.011 \log Y_{it} + 0.915 \log S_{i(t-1)} + 0.023 \log V_{it} - 0.010 D_i + u_{4it}$$

$$\log T_{it} = 10.619 + 0.715 \log Y_{it} + 0.127 \log FDI_{it} - 0.478 \log R_{it} - 0.198 \log ER_{1t} - 0.035 (\log TN_t)*(\log TP_i) + 0.542 D_i + 0.033 DT_t + u_{5it}$$

$$\log FDI_{it} = -2.212 + 1.010 \log Y_{it} + 0.252 \log r_{it} + 0.358 \log CFDI_{i(t-1)}$$

$$+ 0.648 \log TI_{it} - 0.197 \log TAX_{it} + 0.389 \log PGDP_{i(t-1)} + 0.395 D_i$$

$$- 0.827 DT_t + u_{6it}$$

To analyze the linkages between trade, environment, and FDI, we examine ten possible scenarios as shown in Table 1. Both deterministic and stochastic simulations are considered based on scenarios that involve initial changes in the included endogenous variables. In order to investigate the effect of these changes on other endogenous variables, the model is solved by excluding the endogenous variables that initiate a change for the entire solution sample. To evaluate the net effect of each scenario, the results of a scenario obtained from a deterministic or a stochastic simulation are compared with its corresponding deterministic or stochastic baseline solutions. This comparison is measured by percentage changes of the mean average of an endogenous variable relative to that of its baseline solution. In a deterministic simulation, this represents an average of 252 simulated values. In a stochastic simulation, however, this average becomes the mean of 252,000 simulated values for each of the scenarios analyzed is simulated with one thousand repetitions.

The computational algorithm is based on an iterative Gauss-Seidel method embedded in EViews 4, employing a dynamic solution with a convergence criterion of 0.00001. Values for endogenous variables of the model are computed for each observation in the solution sample. Since the solution sample is set to cover all 28 provinces and 9 time periods, each endogenous variable thus has 252 simulated values.

For deterministic simulations, all equations in the model are solved so that they hold without error during the simulation period, and all coefficients are fixed at their point estimates. That is, the equations of the model are solved so that each of the equations is exactly satisfied. This results in a single path for the endogenous variables that can be evaluated by solving the model once. Although the application of deterministic simulation procedures to econometric models that contain nonlinearities in the endogenous variables can generate solution values different from the corresponding historical values even if the econometric model is properly specified, the differences between the simulated and the actual values are systematic and consistent in nature (Howrey and Kelejian 1971).

The purpose of the stochastic error solutions is to assess the interactions between the trade and environmental variables subject to uncertainty. For stochastic simulations, the model is solved for a set of randomly drawn residuals and/or coefficients. That is, the model is solved so that the fitted residuals match randomly drawn errors, and/or the coefficients of the model are varied randomly. For each variable and observation of a stochastic simulation, a set of independent random numbers are drawn from the standard normal distribution, then these numbers are scaled to match the estimated variance-covariance matrix of the system calculated from the model equation residuals. Simulation of the model generates a distribution of outcomes for the endogenous variables in every period. This distribution is approximated by repeatedly solving the model using different draws for the random components in the model and then calculating statistics, such as means and standard deviations, over different outcomes. In each repetition, as for the deterministic simulation, each endogenous variable has 252 simulated values. Therefore, though a stochastic simulation follows a similar procedure to that of a deterministic one, several variations are obtained. First, when binding the variables, a temporary series is created for every endogenous variable in the model. Additional series in the workfile are used to hold the statistics for the tracked endogenous variables. Second, the model is solved repeatedly for different draws of the stochastic components of the model. If coefficient uncertainty is included in a simulation, then a new set of coefficients is drawn before each repetition. During the repetition, errors are generated for each observation in accordance with the residual uncertainty. At the end of each repetition, the statistics for the tracked endogenous variables are updated to reflect the additional results.

5. Results and Discussions

The means and deviations of the baseline solutions are summarized in Table 2 while the impacts of the introduction of error shocks and coefficient shocks on the deterministic baseline solutions are presented in Table 3. As Howrey and Kelejian (1971) suggest, the deterministic simulation of a model with nonlinear endogenous variables may provide results that systematically diverge from actual observations. The stochastic baseline results also show such a systematic deviation from actuals (see Table 2) and from those of the deterministic baselines (see Table 3). All of the stochastic solutions have greater average means and smaller average deviations (though why there exists such a systematic difference between the stochastic and the deterministic solutions requires further examination). That is, given the nature of error shocks as a combined effect of all missing variables in our system, this combined effect on each of the endogenous variables in the model is positive. Similar to the deterministic simulation case, such systematic differences should not affect the comparisons between the stochastic simulated results of different scenarios and those of the corresponding stochastic baseline solutions.

Results of the deterministic, the stochastic error, and the stochastic error and coefficient solutions are reported in Tables 4, 5, and 6, respectively. These tables report changes in average means of the endogenous variables compared with their corresponding baseline solutions. In contrast to the deterministic solutions in Table 4, the stochastic simulation results (Tables 5 and 6) are very close to deterministic ones except for the results of the FDI variables. A significant difference between the stochastic and the deterministic solution for the FDI variable is not surprising given that FDI is the most unpredictable and uncertain endogenous variable in our system as indicated by the summary statistics of the variables (Huang 2002). In addition, a comparison between Tables 5 and 6 shows that random draws of the values of coefficients do not generate obvious deviations in outcomes for most endogenous variables, suggesting that the TEM model is reasonably not sensitive to coefficient perturbations. That is, the model is rather robust to changes in the estimated values of the coefficients. Therefore, the averaged outcomes of the three types of simulations (Table 7) are used in the following discussion.

5.1 Impacts of an Increase in Trade Values

The averaged simulation results reported in Table 7 show that a 10% (20%) increase in trade values can lead to a 1.73% (3.36%) increase in GDP levels, 1.56% (2.98%) in wastewater discharges, 0.45% (0.75%) in levy rates, 0.03% (0.07%) in industrial shares in GDP, and 1.95% (4.46%) in FDI. The results regarding the impact on GDP are close to the findings of an econometric study by Liang (2000), which indicates that an increase of 10% in China's exports would increase China's GDP by 1.43% on average.

Since our results suggest that trade would lead to more discharges of wastewater, can it be inferred that China has a comparative advantage in pollution intensive goods? More careful examination of the results shows that the increase in wastewater discharges is smaller than the increase in GDP, that is, while trade generates a considerable increase in GDP, it produces a relatively smaller increase in industrial wastewater. In addition, the industrial share in GDP, a measure of output composition, remains almost unchanged, suggesting that trade does not significantly change the composition of output and hence generate little additional emissions through a composition effect. Therefore, the results provide no evident support for the hypothesis that China has a comparative advantage in pollution intensive goods.

5.2 Impacts of an Increase in FDI Inflows

Our simulation results show that an increase in FDI inflows by 10% (20%) expands GDP and trade by 0.23% (0.41%) and 1.39% (2.41%), respectively, suggesting that FDI inflows in China are more likely to be export-oriented and trade promoting. Our results also indicate that the increases in FDI can lead to a 0.19% (0.24%) increase in industrial wastewater discharges, 0.05% (0.03%) in levy rates, and 0.02% (0.02%) in the industrial share in GDP. Since the increase in wastewater discharge arising from FDI inflows is smaller than that in GDP and the impact of FDI on the industrial share is almost negligible, no conclusion can be made regarding whether or not FDI inflows are pollution intensive in the Chinese case.

5.3 Impacts of an Increase in Levy Rates

Increasing levy rates by 10% (20%) would decrease industrial wastewater discharges by 5.52% (10.18%), suggesting China's emissions charge system is an effective mean of industrial wastewater control. However, higher levy rates also have a negative impact on the economy. As shown in Table 7, GDP and trade would decrease accordingly by 0.79% (1.57%) and 0.23% (0.68%), respectively. Our finding concerning the impact of levy rates on FDI inflows is inconsistent. When levy rates increase by 10%, FDI inflows would decrease by 0.13% but an increase in FDI by 20% may lead to a 0.68 % increase in FDI. This inconsistent result is probably due to the unpredictability and volatility of the FDI variable. Our results cannot confirm that an increase in levy rates may have negative impact on FDI inflows. In addition, our results show that increases in levy rates have virtually no impact on the industrial share in GDP composition.

5.4 Impacts of a Simultaneous Increase in Trade and Levy Rates

While increasing GDP and FDI inflows by 0.89% (1.75%) and 3.86% (6.75%), respectively, a simultaneous increase in levy rates and trade by 10% (20%) may decrease industrial wastewater discharges by 3.99% (7.55%) though the industrial share in GDP may also increase by 0.05% (0.08%). That is, if levy rates increase as trade expands at the same rate, wastewater pollution can be reduced and positive GDP growth can also be achieved, suggesting that in order to achieve sustainable development, accompanying trade expansion with appropriate environmental policies is the key.

5.5 Impacts of a Simultaneous Increase in FDI and Levy Rates

The impacts of a simultaneous increase in levy rates and FDI inflows by 10% (20%) are that GDP decreases by 0.60% (1.18%), industrial wastewater discharges decrease by 5.43% (9.92%), trade values increase by 1.05% (1.74%), and the industrial share in GDP increases by 0.01% (0.02%). The increase in levy rates and FDI together alone can result in a reduction not only in wastewater pollution but also in GDP levels because the positive effect of FDI is overcompensated by the negative effect of levy rates on GDP. Since increasing trade and levy rates together can reduce wastewater discharges and increase GDP simultaneously, trade is essential to achieve coordinated development between the economy and the environment.

5. CONCLUSIONS

The examination of the empirical interactions between trade and the environment requires going beyond any econometric interpretation to employ model simulation methods capable of assessing the impact and simultaneous relationships between the major variables. The simulation results show that increased trade can lead to increased GDP, wastewater discharges, levy rates, and FDI inflows. An increase in levy rates, a measure of the strictness of environmental policies, may have negative impacts on GDP, industrial wastewater discharges, trade values, and FDI inflows. If levy rates increase as trade expands at the same rate, wastewater pollution can be reduced and positive GDP growth can also be achieved. However, an increase in levy rates and FDI together alone can result in a reduction not only in wastewater pollution but also in GDP levels. Our simulation results suggest that trade is essential to achieve coordinated development between the economy and the environment.

The results also indicate that the non-linear simultaneous equations model and its 2SLS estimation results are reasonably robust. Specifically, the deterministic simulation results are consistent with and very close to those derived from comparative statics. In addition, the stochastic simulation results indicate that the TEM model is reasonably stable to error structure shocks and the impacts of uncertainty on model performance are generally insignificant. Moreover, the stochastic error and coefficient simulation demonstrates that the TEM model is also rather robust to the changes in the estimated values of the coefficients.

Concerning future research with this form of model, we suggest the following. First, there is a need for more case-specific empirical studies on trade and environmental issues. Second, both more theoretical and more empirical studies are required to investigate the impact of environmental degradation on trade and economic growth, i.e. sustainable development. There are many publications that explain how trade can affect the environment, and also many studies on how environmental policies would affect international trade. However, our knowledge of the trade and economic consequences of environmental degradation is still relatively limited. Third, greater efforts should be made to investigate trade and environment issues using disaggregate industrial-level data such as those employed in input-output models and CGE models. And lastly, more theoretical and empirical research is also needed to incorporate a spatial element into the investigation of trade and environment issues. These issues often include reference space or location. Yet, in most of the trade and environment literature, location is not part of the analysis, mostly because appropriate data do not exist. Further application of the present modeling approach in China as well as in other countries thus depends on the quality of data that would improve policy analysis and impact forecasts.

Table 1 List of Simulation Scenarios

Scenario	Increase in Endogenous Variables		
	Trade	FDI	Levy Rate
Scenario 1	10%		
Scenario 2	20%		
Scenario 3		10%	
Scenario 4		20%	
Scenario 5			10%
Scenario 6			20%
Scenario 7	10%		10%
Scenario 8	20%		20%
Scenario 9		10%	10%
Scenario 10		20%	20%

Table 2 Means and Deviations of Baseline Solutions In Industrial Wastewater Pollution (IWW) Case

Baseline	Means and Deviations (in parentheses)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
Actual Sample Mean (Deviation)	809.23 (624.44)	853.99 (596.28)	4.12 (1.73)	43.35 (8.81)	436587.4 (1119777)	61879.1 (297739.7)
Trade Det. Solution	809.09	796.69	3.91	43.33	436587.4	44934.5
Excluding trade with error shocks only	815.62 (108.31)	896.71 (469.22)	4.16 (1.50)	43.36 (1.57)	436587.4 (0.0)	89028.4 (149588.7)
Excluding trade with error & coef. shocks	816.65 (111.02)	899.99 (478.57)	4.16 (1.54)	43.37 (1.58)	436587.4 (0.0)	90458.3 (158860.0)
FDI Det Solution	807.31	800.49	3.90	43.32	316719.0	61879.1
Excluding FDI with error shocks only	818.20 (139.46)	902.99 (475.44)	4.15 (1.51)	43.35 (1.55)	362892.1 (202833.8)	61879.1 (0.0)
Excluding FDI with error & coef. shocks	819.48 (143.29)	908.79 (492.60)	4.16 (1.54)	43.35 (1.58)	366493.5 (212256.0)	61879.1 (0.0)
Levy Rate Det Solution	806.49	809.75	4.11	43.32	312118.3	43031.7
Excluding levy rates with error shocks only	818.46 (146.09)	902.00 (451.86)	4.11 (0.00)	43.35 (1.55)	358904.5 (204440.2)	87797.9 (167416.6)
Excluding levy rates with error & coef. shocks	818.83 (149.72)	907.37 (464.63)	4.11 (0.00)	43.35 (1.58)	361261.3 (213816.1)	88650.6 (148457.5)
Levy rate & Trade Det. Solution	807.56	803.35	4.11	43.33	436587.4	45463.3
Excluding levy rates & trade with error shocks only	815.24 (113.24)	892.94 (433.73)	4.11 (0.00)	43.36 (1.56)	436587.4 (0.0)	86805.7 (137525.1)
Excluding levy rates & trade with error & coef. shocks	816.02 (115.74)	897.03 (443.39)	4.11 (0.00)	43.37 (1.58)	436587.4 (0.0)	90267.8 (156330.0)
Levy rate & FDI Det. Solution	805.79	809.69	4.11	43.32	315500.3	61879.1
Excluding levy rates & FDI with error shocks only	817.81 (146.39)	905.39 (457.67)	4.11 (0.00)	43.35 (1.55)	361563.0 (205943.2)	61879.1 (0.0)
Excluding levy rates & FDI with error & coef. shocks	818.99 (149.63)	906.36 (463.63)	4.11 (0.00)	43.36 (1.58)	365519.4 (213555.2)	61879.1 (0.0)

Table 3 Deterministic Baseline Solution (DBS) vs. Stochastic Baseline Solution (SBS) In Industrial Wastewater Pollution (IWW) Case

Stochastic Baseline	Changes in Endogenous Variables Compared with DBS (%)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
1. Excluding trade with error shocks only	0.81	12.55	6.34	0.07	0.00	98.13
2. Excluding trade with error & coef. shocks	0.82	12.86	6.40	0.07	0.00	99.82
3. Excluding FDI with error shocks only	1.35	12.80	6.32	0.06	14.58	0.00
4. Excluding FDI with error & coef. shocks	1.51	13.53	6.62	0.05	15.72	0.00
5. Excluding levy rates with error shocks only	1.48	11.39	0.00	0.07	14.99	104.03
6. Excluding levy rates with error & coef. shocks	1.53	12.06	0.00	0.07	15.74	106.01
7. Excluding levy rates & trade with error shocks only	0.95	11.15	0.00	0.06	0.00	90.94
8. Excluding levy rates & trade with error & coef. shocks	1.05	11.66	0.00	0.08	0.00	98.55
9. Excluding levy rates & FDI with error shocks only	1.49	11.82	0.00	0.07	14.60	0.00
10. Excluding levy rates & FDI with error & coef. shocks	1.64	11.94	0.00	0.08	15.85	0.00

Table 4 Deterministic Simulation Results in Industrial Wastewater (IWW) Pollution Case

Scenario	Changes in Endogenous Variables (%)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
1. A 10% increase in trade values	1.71	1.53	0.36	0.04	10.00	1.79
2. A 20% increase in trade values	3.30	2.93	0.69	0.07	20.00	3.46
3. A 10% increase in FDI inflows	0.25	0.22	0.05	0.01	1.40	10.00
4. A 20% increase in FDI inflows	0.47	0.42	0.10	0.01	2.69	20.00
5. A 10% increase in levy rates	-0.84	-5.54	10.00	0.01	-0.40	1.58
6. A 20% increase in levy rates	-1.60	-10.32	20.00	0.01	-0.76	3.04
7. A 10% increase in levy rates and in trade values	0.96	-3.81	10.00	0.04	10.00	3.41
8. A 20% increase in levy rates and in trade values	1.85	-7.17	20.00	0.08	20.00	6.62
9. A 10% increase in levy rates and in FDI inflows	-0.63	-5.34	10.00	0.01	0.77	10.00
10. A 20% increase in levy rates and in FDI inflows	-1.20	-9.96	20.00	0.02	1.47	20.00

Table 5 Stochastic Error Simulation Results in Industrial Wastewater (IWW) Pollution Case

Scenario	Changes in Endogenous Variables (%)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
1. A 10% increase in trade values	1.74	1.54	0.41	0.02	10.00	1.42
2. A 20% increase in trade values	3.40	3.28	0.80	0.05	20.00	4.36
3. A 10% increase in FDI inflows	0.28	0.27	0.11	0.01	1.26	10.00
4. A 20% increase in FDI inflows	0.39	0.08	0.08	0.01	2.13	20.00
5. A 10% increase in levy rates	-0.82	-5.42	10.00	-0.01	-0.50	-3.73
6. A 20% increase in levy rates	-1.55	-9.77	20.00	0.02	-1.21	-3.99
7. A 10% increase in levy rates and in trade values	0.91	-3.94	10.00	0.06	10.00	5.32
8. A 20% increase in levy rates and in trade values	1.77	-7.54	20.00	0.08	20.00	8.13
9. A 10% increase in levy rates and in FDI inflows	-0.58	-5.67	10.00	0.00	1.36	10.00
10. A 20% increase in levy rates and in FDI inflows	-1.11	-9.80	20.00	0.02	2.01	20.00

Table 6 Stochastic Error Coefficient Simulation Results in Industrial Wastewater (IWW) Pollution Case

Scenario	Changes in Endogenous Variables (%)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
1. A 10% increase in trade values	1.75	1.60	0.58	0.04	10.00	2.64
2. A 20% increase in trade values	3.38	2.72	0.77	0.08	20.00	5.56
3. A 10% increase in FDI inflows	0.16	0.09	0.00	0.03	1.51	10.00
4. A 20% increase in FDI inflows	0.37	0.23	-0.09	0.03	2.40	20.00
5. A 10% increase in levy rates	-0.71	-5.60	10.00	0.00	0.22	1.76
6. A 20% increase in levy rates	-1.57	-10.46	20.00	0.01	-0.08	2.99
7. A 10% increase in levy rates and in trade values	0.80	-4.22	10.00	0.04	10.00	2.84
8. A 20% increase in levy rates and in trade values	1.64	-7.94	20.00	0.07	20.00	5.50
9. A 10% increase in levy rates and in FDI inflows	-0.60	-5.29	10.00	0.01	1.02	10.00
10. A 20% increase in levy rates and in FDI inflows	-1.24	-10.01	20.00	0.02	1.75	20.00

Table 7 Averaged Simulation Results in Industrial Wastewater (IWW) Pollution Case

Scenario	Changes in Endogenous Variables (%)					
	GDP (eq1)	IWW (eq2)	Levy Rate (eq3)	Industrial Share (eq4)	Trade (eq5)	FDI (eq6)
1. A 10% increase in trade values	1.73	1.56	0.45	0.03	10.00	1.95
2. A 20% increase in trade values	3.36	2.98	0.75	0.07	20.00	4.46
3. A 10% increase in FDI inflows	0.23	0.19	0.05	0.02	1.39	10.00
4. A 20% increase in FDI inflows	0.41	0.24	0.03	0.02	2.41	20.00
5. A 10% increase in levy rates	-0.79	-5.52	10.00	0.00	-0.23	-0.13
6. A 20% increase in levy rates	-1.57	-10.18	20.00	0.01	-0.68	0.68
7. A 10% increase in levy rates and in trade values	0.89	-3.99	10.00	0.05	10.00	3.86
8. A 20% increase in levy rates and in trade values	1.75	-7.55	20.00	0.08	20.00	6.75
9. A 10% increase in levy rates and in FDI inflows	-0.60	-5.43	10.00	0.01	1.05	10.00
10. A 20% increase in levy rates and in FDI inflows	-1.18	-9.92	20.00	0.02	1.74	20.00

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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, investments, 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 regardless of the levels of their development. Tibet and Hainan are excluded due to data insufficiency. 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.

Industrial GDPs include all the values created by the industrial and construction sectors that consist of enterprises of different types of ownerships such as private, collective-owned, and state-owned and various industries such as textile, machinery, mining, chemical, electricity, construction material, and fertilizer. The capital variable K_{it} is measured by proxy as cumulative total investment in fixed assets since 1986 with no depreciations. The labor variable L_{it} is simply measured as the number of total employed persons and their working skills are not accounted for due to the lack of data.

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 as a price indicator for environmental demand and supply, it does reflect the differentials in strictness of environmental enforcement across provinces. Another variable, 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, 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.	$e_3<0$.	Author's 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.	$e_7<0$, $f_8<0$.	