中南财经政法大学

ZHONGNAN UNIVERSITY OF ECONOMICS AND LAW

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博文明理 · 厚德济世

Environment Regulation and the Innovation Performance of Chinese Export Firms:

The quasi-natural experiment based on the *Law of Promoting Clean Production*

Yingna WU (wuyingna@zuel.edu.cn), Zhongnan University of Economics and Law
Yuetong MA, Zhongnan University of Economics and Law
Liang DING (dingliang@jxufe.edu.cn), Jiangxi University of Finance and Economics

Research Question

1. Did more stringent environmental regulation encourage innovation in export firms in China?

2. Did exporting destinations make a difference to export firms' innovation performance?

3. Did the *Law of Promoting Clean Production* impact industries with different pollution intensities differently?

Data Analysis: Pollution intensity of Chinese industries

Table 1 The category, names and codes of the sample industries

Category	Description
Mining (B)	Extractive industry (06、07、08、09、10、11)
Manufacturing (C)	Food, tobacco and beverage manufacturing (13, 14, 15, 16), textile (17), leather, fur, feather (velvet) (19), paper and paper products industry (22), Printing and recording media reproduction (23), petroleum processing, coking and nuclear fuel processing industries (25), chemical raw material and chemical product manufacturing (26), medical manufacturing (27), chemical fiber manufacturing (28), rubber manufacturing (29), plastic manufacturing industry (30), non-metallic mineral product industry (31), ferrous metal smelting and rolling processing industry (32), non-ferrous metal smelting and rolling processing industry (33), metal products industry (34), mechanical electrical and electronic equipment manufacturing (35, 36, 37, 39, 40, 41)
Electricity, gas and water production and supply (D)	Electricity, gas and water production and supply industry (44、45、46)

Data Analysis: Pollution intensity of Chinese industries

- Pollution emission (Liu, 2012):

$$E_{ik} = P_{ik}/O_i$$

- Pollution scale (Liu, 2012):

$$S_{ik} = P_{ik}/\sum_{i=1}^{J} P_k$$

- Normalized E_{ik} and S_{ik}:

$$UE_{ik} = (E_{ik} - \min(E_{ik}))/\max(E_{ik}) - \min(E_{ik})$$

$$US_{ik} = (S_{ik} - \min(S_{ik}))/(\max(S_{ik}) - \min(S_{ik}))$$

- Industry pollution intensity index:

$$A_i = \frac{1}{K}\sum_{K=1}^{K}\sqrt{UE_{ik} \times US_{ik}}$$

Data Analysis: Pollution intensity of Chinese industries

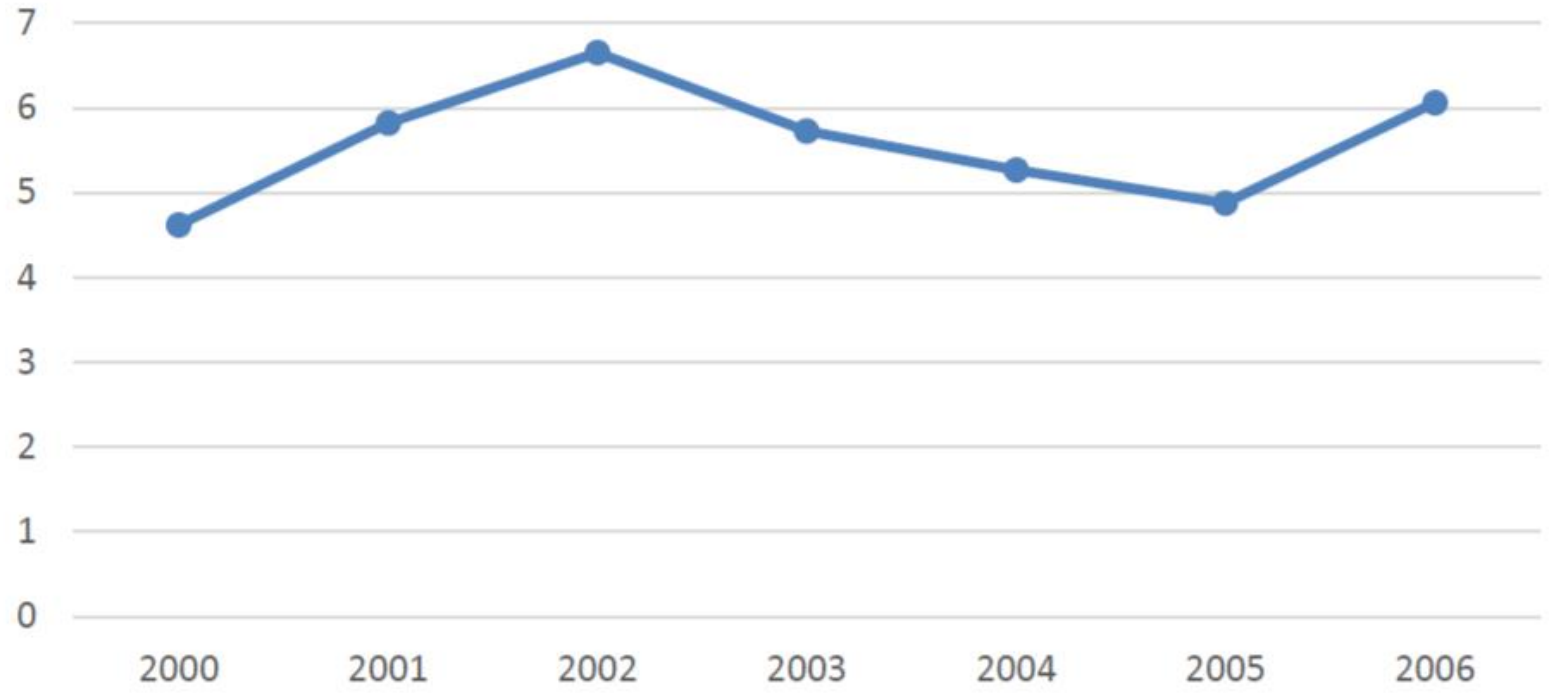
Table 2 Industry pollution-intensity levels

Pollution-intensive	Industry
High pollution-intensive industries	Extractive industry, textile, paper and paper products industry, petroleum processing, coking and nuclear fuel processing industry, chemical raw material and chemical product manufacturing, chemical fiber manufacturing, non-metallic mineral product industry, ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, electricity, gas and water production and supply industry
Moderate pollution-intensive industries	Leather, fur, feather (velvet), food, tobacco and beverage manufacturing, rubber products, pharmaceuticals, metal products
Low pollution-intensive industries	Printing and recording media reproduction, plastic products, mechanical electrical and electronic equipment manufacturing

Data Analysis:

Environmental regulatory stringency of Chinese industries

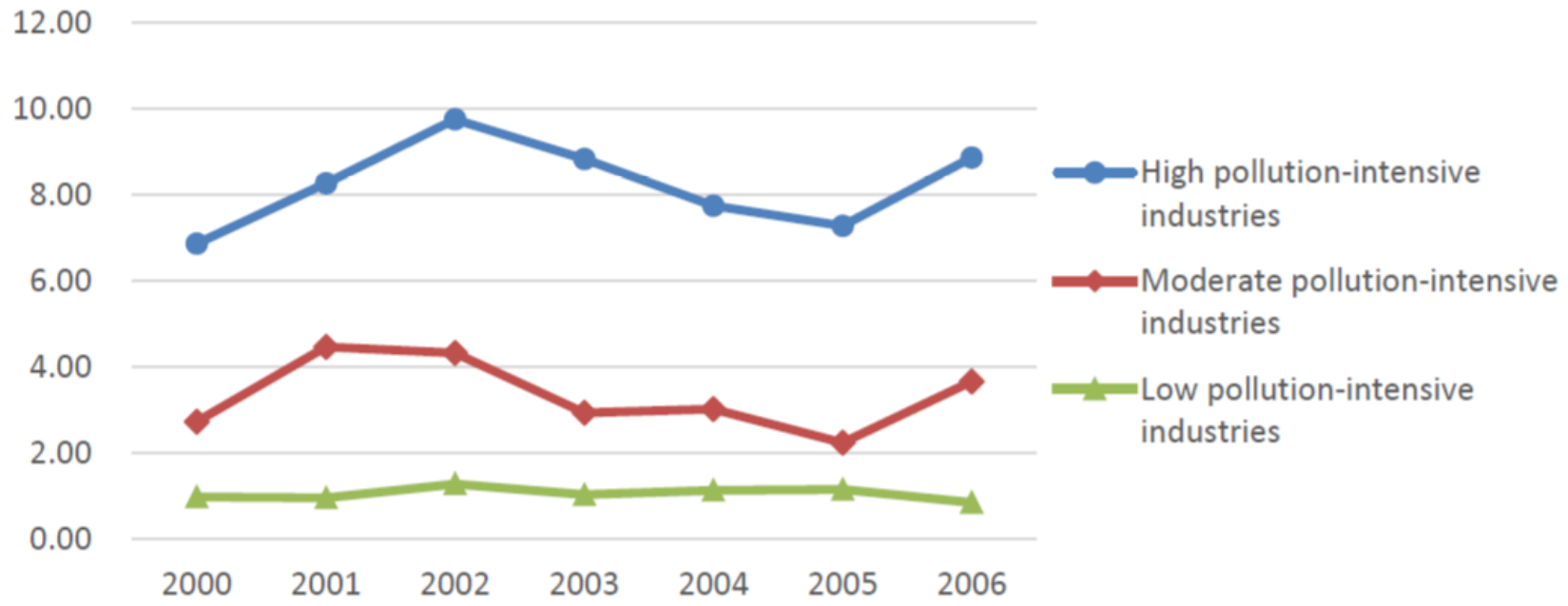
Figure 1 Average stringency of environmental regulation in Chinese industries from 2000 to 2006



Source: Authors' own calculation from China Environment Yearbooks 2000 to 2006.

Data Analysis:
Environmental regulatory stringency of Chinese industries

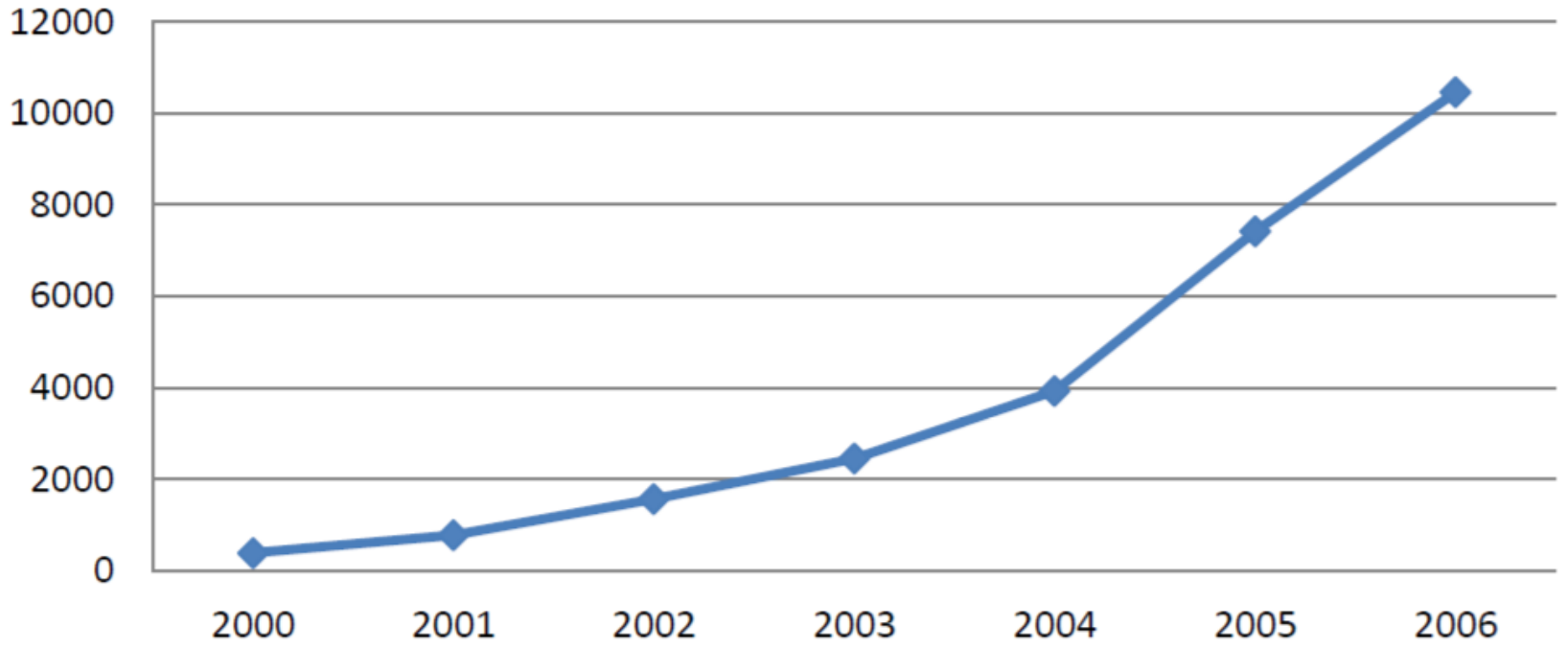
Figure 2 The stringency of environmental regulations of industries with different pollution-intensity levels from 2000 to 2006



Source: Authors' own calculation from China Environment Yearbooks and China Statistical Yearbooks 2000 to 2006.

Data Analysis: Patents filed by Chinese export firms

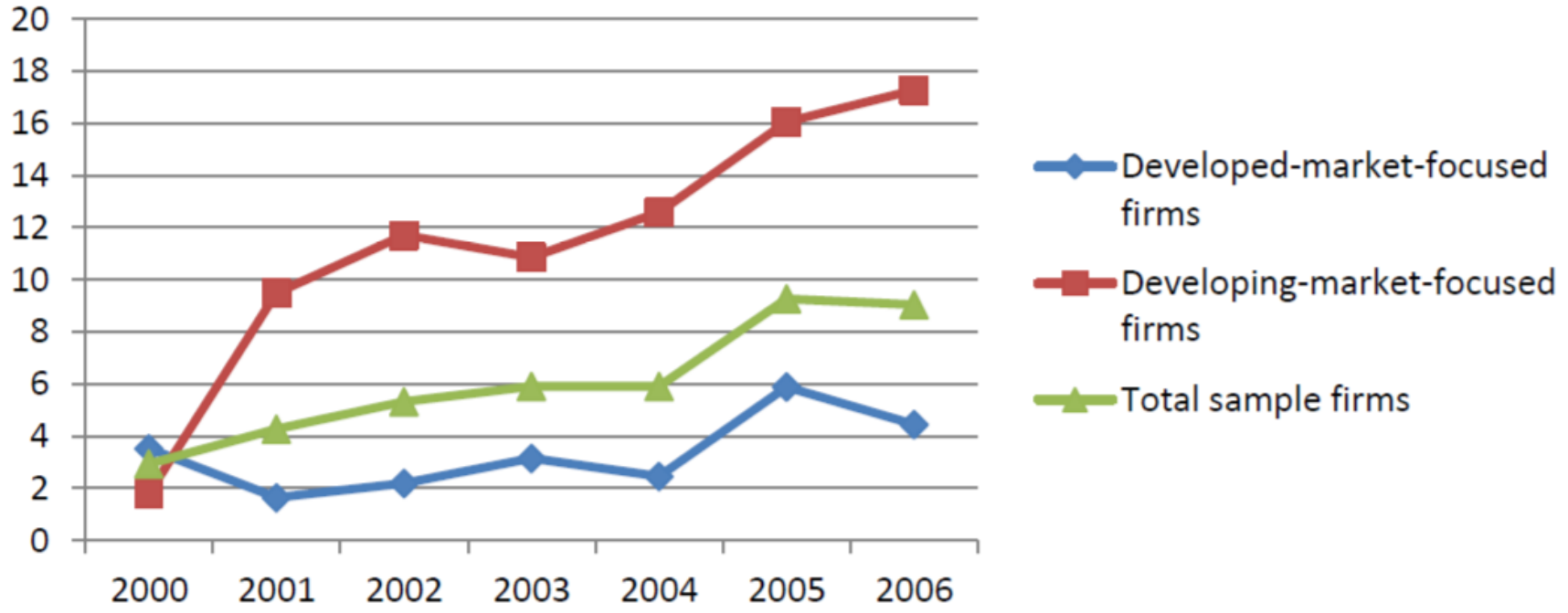
Figure 3 Total invention patents of export firms from Chinese industries (2000-2006)



Source: Authors' own calculation from Abstracts of China Patent Database, China Industrial Firm Database and China Customs Import and Export Data.

Data Analysis: Patents filed by Chinese export firms

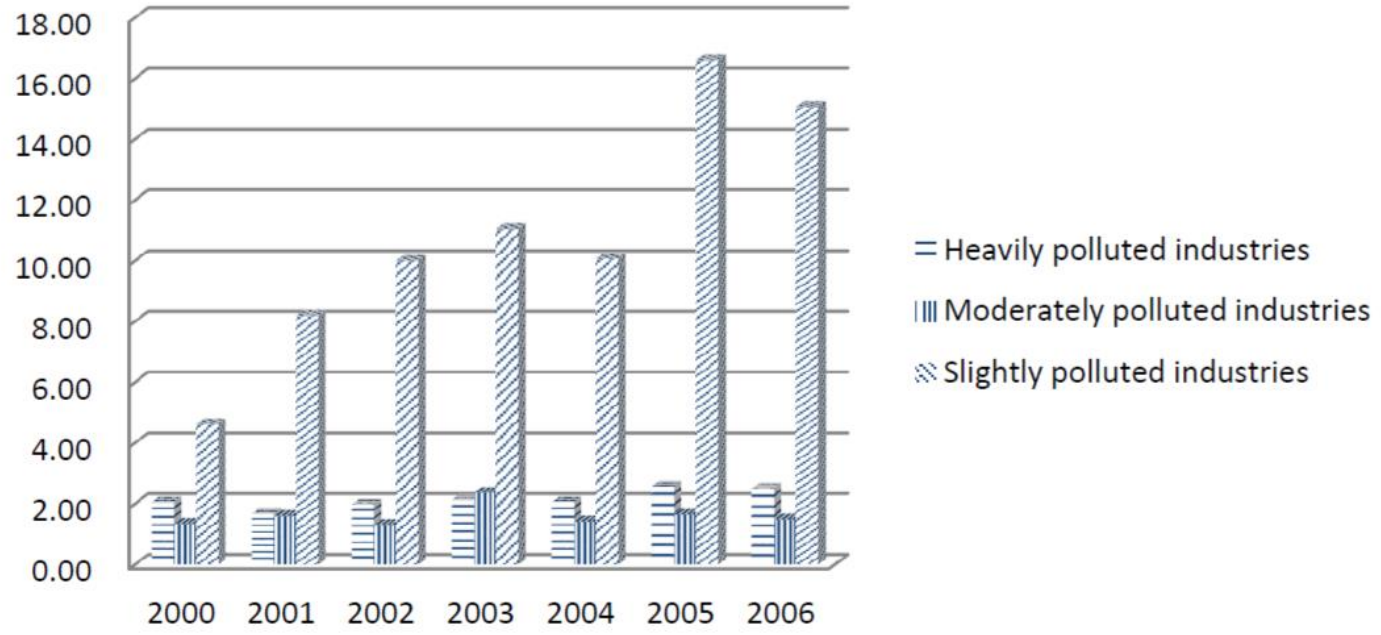
Figure 4 The average firm invention patents from 2000 to 2006



Source: Authors' own calculation from Abstracts of China Patent Database, China Industrial Firm Database and China Customs Import and Export Data.

Data Analysis: Patents filed by Chinese export firms

Figure 5 The average firm invention patents of industries at different pollution-intensity levels from 2000 to 2006



Source: Authors' own calculation from Abstracts of China Patent Database, China Industrial Firm Database and China Customs Import and Export Data.

Empirical Strategy

- Environmental regulatory stringency (*ERS*): Zhao (2008) and Brunnel and Levinson (2013)

$$ERS_i = (AC_i^W + AC_i^G) \times 1000/O_i$$

- Environmental regulatory stringency and export firms' innovation performance

$$Patent_{jt} = \alpha + \beta_1 ERS_{it} + \beta_2 C_{jt} + \beta_3 ERS_{it} \times C_{jt} + \beta_4 CV_{jt} + \varepsilon_{jt}$$

- The impacts of China's *Law of Promoting Clean Production* (2003): Liu et al. (2019)

$$Patent_{jit} = \alpha_j + \beta_1 Treat_i \times Post_t + \beta_2 X_{jit} + \sigma_t + \varepsilon_{jit}$$

Data Sources

- Patents data are from Abstracts of Chinese Patent Database years 2000 to 2006.
- Data used to estimate abatement costs of waste water and gas are from China Environmental Yearbooks 2000 to 2006.
- 28 OECD countries and 16 non-OECD economies are considered as developed export destinations.
- Each firm’s yearly export value to all destination countries is estimated by matching the China Customs Import and Export Data, Chinese Patent Database Digest and China Industrial Firm Database from 2000 to 2006.

Descriptive Statistics

Table 3 Descriptive statistical

Variable	Meaning	Number of samples	Mean	Std.Dev.	Min	Max
Patent	Number of invention patents	3648	7.3983	98.6700	0.0000	4094.0000
ERS	Environmental Regulation Intensity	3648	3.9239	3.6665	0.8264	25.1061
C	Export country	3648	0.6549	0.4755	0.0000	1.0000
ERS×C	The interactive terms	3648	2.5428	3.5135	0.0000	25.1061
Tassets	Company's total assets	3648	1426509.0000	5513631.0000	0.0000	1.36E+08
Sale	Company's sales revenue	3648	1383081.0000	6616183.0000	0.0000	1.88E+08
Netin	Company's net income	3648	138921.4000	2248203.0000	-3672382.0000	1.19E+08
Ssize	Company's size	3648	2133.9940	6299.7520	0.0000	131864.0000

Results:

Environmental regulatory stringency, export destination and patent

Table 4 Basic regression results of the sample

	1	2	3	4
ERS	-2.7847**		-2.6775***	-2.2768***
	(-2.58)		（-2.81）	（-2.96）
C	-20.0196**		-16.0216**	-17.5196**
	(-2.23)		（-2.37）	（-2.59）
ERS ×C	2.4556**		1.5771**	1.5109**
	(2.24)		（2.10）	（2.45）
Tassets		6.19e-06**	6.22e-06**	3.65e-06
		（2.35）	（2.36）	（1.19）
Sale				6.13e-06***
				（2.90）
Netin				-0.0000***
				（-2.72）
Ssize				-0.0008
				（-0.59）
Year Effect	Yes	Yes	Yes	Yes
Cons	20.8626***	-6.0061	11.1973**	12.6203***
	(2.79)	（-1.49）	（2.52）	（2.62）
R^2	0.0064	0.1200	0.1265	0.1861

Results:
DID regression

Table 5 Baseline regression results

	1	2	3	4	5
Treat×Post	-42.2625***		-42.1754***	-24.5370	-43.5851***
	(-2.83)		(-3.17)	(-1.35)	(-2.69)
C		-5.8804	-5.2234		-5.2150
		(-0.75)	(-0.67)		(-0.67)
Tassets		2.90e-06	2.62e-06		2.61e-06
		(1.35)	(1.23)		(1.22)
Sale		0.0000***	0.0000***		0.0000***
		(5.61)	(5.85)		(5.85)
Netin		-0.0000***	-0.0000***		-0.0000***
		(-7.74)	(-7.97)		(-7.94)
Ssize		0.0043**	0.0040**		0.0040**
		(2.34)	(2.13)		(2.13)
Value		1.41e-07*		1.96e-07*	-1.55e-08
		(1.68)		(1.72)	(-0.15)
Cons	-36.8572**	-40.0079**	-31.6678**	-48.8456***	-30.7066*
	(-2.48)	(-2.50)	(-2.10)	(-2.98)	(-1.88)
R^2	0.0029	0.1642	0.1663	0.0038	0.1665

Robustness Tests: replacing key variables

Table 6 Robust regression results

	1	2	3	4
ERS	-0.0989**		-0.1239**	-0.1028***
	(-2.31)		（-2.47）	（-2.64）
C	-11.3122**		-10.9445**	-12.5995**
	(-2.23)		（-2.41）	（-2.59）
ERS×C	0.0968**		0.1107**	0.0978**
	(2.22)		（2.31）	（2.56）
Tassets		6.19e-06**	6.19e-06**	3.61e-06
		（2.35）	（2.35）	（1.17）
Sale				6.23e-06***
				（2.92）
Netin				-0.0000***
				（-2.72）
Ssize				-0.0008
				（-0.63）
Year Effect	Yes	Yes	Yes	Yes
Cons	11.4299***	-6.0061	2.6929	5.5151*
	(2.90)	（-1.49）	（1.00）	（1.90）
R^2	0.0032	0.1200	0.1228	0.1837

Robustness Tests: parallel trend test

Table 7 Parallel trend test results

	1		1
Treat×Year00	23.4096	C	-4.5938
	-0.56		(-0.59)
Treat×Year01	-22.0627	**Tassets**	3.01e-06
	(-0.58)		-1.42
Treat×Year02	-55.8465	Sale	0.0000***
	(-1.40)		-6.2
Treat×Year03	-85.1932*	Netin	-0.0000***
	(-2.05)		(-8.11)
Treat×Year04	-124.6697***	**Ssize**	0.0029
	(-2.70)		-1.55
Treat×Year05	-150.3001***	Value	-6.68e-07***
	(-3.16)		(-3.29)
Treat×Year06	-203.7895***	Cons	-7.9871
	(-3.42)		(-0.23)
		R^2	0.1553

Robustness Tests: expectation effect test

Table 8 Expected effect test results

	1	2
Treat×Post03	-41.1008**	-35.5385*
	(-2.45)	(-1.90)
Treat×Post01	-13.8219	
	(-0.59)	
Treat×Post02		-18.4976
		(-0.86)
C	-5.3167	-5.2452
	(-0.68)	(-0.67)
Tassets	2.60e-06	2.60e-06
	(1.22)	(1.21)
Sale	0.0000***	0.0000***
	(5.85)	(5.86)
Netin	-0.0000***	-0.0000***
	(-7.95)	(-7.95)
Ssize	0.0040**	0.0039**
	(2.11)	(2.09)
Value	-3.27e-08	-3.80e-08
	(-0.31)	(-0.36)
Cons	-30.1918*	-29.7488*
	(-1.85)	(-1.82)
R^2	0.1658	0.1661

Robustness Tests: DID test of different policies

Table 9 Multi-policy DID test results

	1	2	3	4
Treat ×Post01	-28.2806			
	(-1.24)			
Treat ×Post02		-38.8261**		
		(-2.08)		
Treat ×Post04			-48.3709***	
			(-3.26)	
Treat ×Post05				-38.9035***
				(-3.04)
C	-6.0110	-5.6859	-4.5536	-5.7903
	(-0.77)	(-0.73)	(-0.58)	(-0.74)
Tassets	2.85e-06	2.76e-06	2.70e-06	3.02e-06
	(1.33)	(1.29)	(1.27)	(1.41)
Sale	0.0000***	0.0000***	0.0000***	0.0000***
	(5.66)	(5.74)	(5.88)	(5.77)
Netin	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	(-7.78)	(-7.85)	(-7.91)	(-7.82)
Ssize	0.0043**	0.0041**	0.0040**	0.0039**
	(2.27)	(2.17)	(2.14)	(2.07)
Value	8.77e-08	3.34e-08	-6.84e-08	-2.84e-08
	(0.93)	(0.34)	(-0.65)	(-0.28)
Cons	-37.8700**	-34.3931**	-28.7546*	-29.6660*
	(-2.35)	(-2.12)	(-1.76)	(-1.82)
R^2	0.1643	0.1654	0.1665	0.1675

Effects Identification

- The **cost effect** of the environmental regulatory stringency will inhibit the innovation of export firms;
- The **competition effect** will lead to innovation that could offset the compliance and abatement costs, and even create more profit.
- Intermediary effect models

$$Patent_{jt} = \beta_0 + \beta_1 ERS_{it} + \beta_2 C_{jt} + \beta_3 ERS_{it} \times C_{jt} + \beta_4 CV_{jt} + \varepsilon_{jt} \quad (10)$$

$$M_{jt} = a_0 + a_1 ERS_{it} + a_2 CV_{jt} + \varepsilon_{jt} \quad (11)$$

$$Patent_{jt} = \gamma_0 + \gamma_1 ERS_{it} + \gamma_2 M_{jt} + \gamma_3 C_{jt} + \gamma_4 ERS_{it} \times C_{jt} + \gamma_5 CV_{jt} + \varepsilon_{jt} \quad (12)$$

Table 10 Mechanism test regression results

	1	2	3
ERS	-2.2768***	9983.0100***	0.2447
	(-2.96)	(5.00)	(0.71)
C_o			-0.0002***
			(-5.87)
C	-17.5196**		-1.3876
	(-2.59)		(-0.53)
ERS ×C	1.5109**		0.0864
	(2.45)		(0.25)
T_{assets}	3.65e-06	-0.0521**	-4.42e-06**
	(1.19)	(-2.19)	(-2.25)
S_{ale}	6.13e-06***	0.9704***	0.0002***
	(2.90)	(56.66)	(5.98)
N_{etin}	-0.0000***	-1.0133***	-0.0002***
	(-2.72)	(-38.60)	(-6.05)
SS_{ize}	-0.0008	-9.9540	-0.0023**
	(-0.59)	(-1.00)	(-2.33)
C_{ons}	12.6203***	-45138.7500*	-5.3242
	(2.62)	(-1.87)	(-1.35)
R^2	0.1861	0.9911	0.7298

Conclusions

1. During the time period tested in our research, the impact of environmental regulation on the innovation performance of export firms is negative.
2. For firms that mainly exported to developed countries, environmental regulations showed a positive relationship with export firms' innovation.
3. The implementation of the Law of Promoting Clean Production has weakened the innovation performance of export firms in high and moderate pollution-intensive industries.

Policy Implications

1. As income increases in China, Chinese market will demand cleaner products and service. Therefore, more stringent environmental regulations will be appropriate.
2. Well-designed environmental and trade policies, such as tax rebates, are necessary to stimulate innovation activities in high and moderate pollution-intensive firms.
3. In order to encourage more productive innovation activities in firms, more effort is required to devoted to intellectual property protection in China.

Thank you for listening!