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Supply Chain Resilience under the Impact of Ecological Rule of Law: A Quasi-natural Experiment Based on the New Environmental Protection Law

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Abstract. Amid mounting global environmental concerns and advancing ecological rule of law, environmental regulations are increasingly influencing corporate operations and supply chain management, especially in major economies like China. The new Environmental Protection Law has garnered minimal scrutiny about its impact on supply chain resilience. To tackle this deficiency, this study utilizes the new Environmental Protection Law as a quasi-natural experiment and analyzes data from listed companies from the Shanghai and Shenzhen A-share markets, covering the period from 2010 to 2021 and employing a difference-in-differences approach to assess the law's effect on corporate supply chain resilience. Empirical findings demonstrate that the new Environmental Protection Law markedly improves supply chain resilience for non-heavily polluting firms. Enhancements in supply chain efficiency and the decentralization of supply chains are fundamental mechanisms. Subsequent analysis indicates that the extent of augmented supply chain resilience relies on the firm's customer concentration risk and degree of digitalization. This paper enhances the understanding of the relationship and mechanisms between the new Environmental Protection Law and supply chain resilience, offering policy recommendations for the enhancement of the environmental regulatory framework.

Keywords: Supply chain resilience, The new Environmental Protection Law, Environmental regulations, Difference-in-differences

1. Introduction

From 1978 to 2014 China’s growth outpaced its laws:the 1989 Environmental Protection Law carried weak sanctions and low compliance costs. The 2014 overhaul(EPL)—the“most stringent environmental legislation in history”—created the ecological protection red line, forcing firms to internalise externalities and embed Xi’s “lucid waters and lush mountains are invaluable assets” principle into their value chains.

The statute obliges companies to audit suppliers, adopt transparent ISO 14001 systems and pursue circular models; battery recyclers and EV makers now co-create low-carbon lifecycles, mitigating raw-material risk and easing EU entry. By mandating green standards, the law turns compliance into a resilient network effect that reallocates resources and fortifies supply chains.

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Previous studies have shown that the law cuts jobs, innovation, and investment [1-3]. Yet long-term effects on supply chain resilience (SCR) remain unexplored [4].

This article seeks to analyze the impact of EPL on SCR. Utilizing the Law as a quasi-natural experiment, we conduct a difference-in-differences (DID) analysis with data from Shanghai and Shenzhen A-share listed companies spanning 2010 to 2021 to empirically assess the policy's effect on SCR. Robustness test are performed to corroborate the results. The study analyzes heterogeneous effects stemming from customer concentration risk and degree of digitalization, emphasizing mechanism analysis that investigates the supply chain efficiency improvements and decentralization effects of EPL.

This publication presents the following contributions: The current literature has not investigated the correlation between EPL and SCR [5]. This research offers empirical information regarding the economic impacts of environmental legislation inside the supply chain. This study empirically evaluates the application of the "Porter Hypothesis" at the supply chain level, offering evidence for its adoption in China. This research employs the quasi-natural experiment established by EPL to successfully tackle endogeneity issues and provides insights for enhancing the design of environmental regulations.

2. Literature review

[6] frame regulation as a corrective and strategic lever for green governance, while [7] reveal short-term costs but long-term gains via green innovation, with regional differences [8]. show command-and-control and incentive rules spur R&D, though [9] find opposite effects [10]. add that public pressure amplifies compliance, [11] stress mandatory policies to avert cost externalization, and [12] note stronger penalties under EPL.

EPL pressures heavy polluters to shift funds from financial assets [13] toward green investments [5] and ESG initiatives that spur green innovation [14,15]. Conversely, tighter liquidity and higher risks curb overall investment [2], employment [1] and innovation inputs [3].

Resilience denotes a supply-chain’s capacity to recover and adapt after shocks [16]. Internally, ESG performance [17,18], digitalization [19,20] and crisis leadership [21,22] strengthen firms; externally, supplier diversification [23-26], collaboration [27,28] and green policy [29-31] further bolster resilience.

In summary, while current research has examined environmental legislation and SCR independently, certain constraints persist. Primarily, the majority of literature concentrates on the effects of EPL on significantly polluting firms, neglecting to broaden the research scope to encompass the supply chain level. Secondly, although existing research investigates numerous aspects and policy impacts on SCR, it has not established a connection between environmental restrictions and SCR.

3. Theoretical analysis and research hypotheses

EPL, though aimed at heavy polluters, also impacts other firms. Its “Information Disclosure and Public Participation” provisions (Arts. 53–58) require publishing violation data, increasing public scrutiny. Under institutional theory, non-heavy polluters adapt strategically to secure legitimacy. This social pressure accelerates green innovation—especially among firms without political ties—enhancing resistance to penalties and input volatility [32]. Simultaneously, scrutiny drives digital transformation [33], propagating digital supply networks that improve response speed and flexibility

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[19,34]. Together, green and digital upgrades build enduring supply-chain resilience.This study posits the subsequent hypotheses:

H1: EPL bolsters SCR for non-heavily polluting firms.

To meet stricter emission standards, firms upgrade production and logistics technologies [14], cutting waste while compelling upstream and downstream partners to adopt sustainable practices that standardize and streamline the entire supply chain. These simultaneous advances in technology, collaboration, and resource allocation equip companies to respond faster to shocks, enhancing SCR. This paper posits the following hypothesis:

H2:EPL bolsters company SCR through enhanced efficiency.

Stricter environmental rules raise supplier-entry barriers, pushing non-compliant SMEs out. Firms counter the risk of losing penalized primary suppliers by multiplying qualified sources and geographically diversifying procurement, while also shifting toward local, eco-friendly partners. Mandatory disclosure of carbon and environmental data [35] further decentralizes the network, easing single-point vulnerabilities and boosting resilience. This study posits the following hypotheses:

H3:EPL bolsters business SCR by diminishing supply chain concentration.

4. Research design

4.1. Sample selection and data sources

Companies are classified according to pollution levels as per Environmental Verification Catalogue issued by MEE in 2008 and the Guidelines for Industry Classification of Listed Companies updated by the China Securities Regulatory Commission in 2012. This study employs the initial sample of A-share listed businesses from 2010 to 2021. Companies identified as high pollutants constitute the control group, whereas non-heavily polluters—encompassing sectors such as wholesale, retail, education, and manufacturing—comprise the experimental group. A subsequent examination of the sample is executed: (1) Exclude firms designated as ST or *ST; (2) Exclude samples without sufficient data and those that could not be processed. The total dataset consists of 22,743 observations from 2,712 companies, which are obtained from the CSMAR database.

4.2. Model specification

Utilizing previous research that investigates the influence of EPL on businesses, we ascertain that the DID methodology is a robust technique for evaluating the law's impact on SCR. This study adopts a DID approach to identify the causal effect of EPL on SCR. The model is constructed as follows:

$$SCR_{i,t} = \beta_0 + \beta_1 EPL_{i,t} + \beta_2 Controls_{i,t} + Firm_i + Year_t + \varepsilon_{i,t} \quad (1)$$

4.3. Variable definitions

$SCRes_{i,t}$ represents the dependent variable that quantifies the condition of SCR. According to [18], we develop an evaluation index system for SCR of listed businesses, including five dimensions: predictive capability, resistance capability, recovery capability, human capital, and government influence. Entropy weighing is utilized to determine weights and evaluate SCR. $EPL_{i,t}$ is the independent variable, assigned a value of 1 if EPL is enacted and the company undergoes a shock, and 0 otherwise. The control variable $Controls_{i,t}$denotes business size (Size), return on asset (Roa),

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debt-to-asset ratio (Lev), government subsidies (Subsidy), and operating revenue (Sale). Individual fixed effects ($Firm_i$) and year fixed effects ($Year_t$) are accounted for.

Table 1 contains precise definitions for each variable.

Table 2 reports the descriptive statistics for each variable.

Table 1. Variable definitions

Variable type	Variable name	Variable symbol	Variable description
Dependent variable	SCR	$SCRes_{i,t}$	The higher the SCR value, the stronger the enterprise's SCR
Independent Variable	EPL	$EPL_{i,t}$	EPL has been implemented and the enterprise has been impacted: 1, otherwise 0
Control Variables	Enterprise Scale	Size	Company Total Assets
	Debt-to-Asset Ratio	Lev	Total liabilities / total assets
	Return on Asset	Roa	Net profit / shareholders' equity
	Government Subsidy	Subsidy	Amount of various types of government subsidies received by listed companies
	Sales Revenue	Sale	Enterprise Sales Revenue
	Year	$Year_t$	Year Fixed Effects
	Firm	$Firm_i$	Individual Fixed Effects

Table 2. Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
$SCRes_{i,t}$	22743	0.566	0.300	0.012	3.454
$EPL_{i,t}$	22743	0.456	0.498	0.000	1.000
Size	22743	22.205	1.329	17.971	28.636
Lev	22743	0.424	0.208	0.008	1.698
Roa	22743	0.040	0.074	-1.856	0.974
Subsidy	22743	15.891	2.901	0.000	22.876
Sale	22743	21.551	1.510	12.701	28.718

5. Empirical results analysis

5.1. Baseline regression

Table 3 displays the regression results on the influence of EPL on SCR. Column (1) presents the results, controlling solely for individual and year fixed effects. To prevent biased estimates, firm characteristics were additionally controlled, with the outcomes presented in columns (2) to (6). The findings demonstrate that the estimated coefficient for $EPL_{i,t}$ is significant ($p<0.01$), indicating that EPL substantially improves SCR of non-heavily polluting firms in comparison to heavily polluting enterprises. Consequently, H1 is valid.

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Table 3. Descriptive statistics

	(1)	(2)	(3)	(4)	(5)	(6)
	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$
$EPL_{i,t}$	0.045***	0.033***	0.035***	0.036***	0.036***	0.037***
	(5.276)	(4.131)	(4.319)	(4.454)	(4.603)	(4.653)
Size		0.081***	0.080***	0.084***	0.052***	0.054***
		(12.771)	(12.703)	(12.967)	(7.809)	(8.039)
Roa			0.055***	0.030	-0.014	-0.015
			(2.757)	(1.422)	(-0.735)	(-0.762)
Lev				-0.052***	-0.072***	-0.073***
				(-2.914)	(-4.020)	(-4.094)
Sale					0.037***	0.037***
					(6.136)	(6.253)
Subsidy						-0.002**
						(-2.356)
_cons	0.545***	-1.241***	-1.235***	-1.298***	-1.372***	-1.385***
	(141.287)	(-8.867)	(-8.824)	(-9.127)	(-9.533)	(-9.680)
$Firm_i$	Yes	Yes	Yes	Yes	Yes	Yes
$Year_t$	Yes	Yes	Yes	Yes	Yes	Yes
N	22749	22749	22749	22749	22749	22743
R^2	0.825	0.835	0.835	0.835	0.837	0.837

5.2. Robustness test

5.2.1. Parallel trend test

Before DID estimation, this paper verify the parallel-trend precondition: pre-policy supply-chain resilience trends of non-heavily (treatment) and heavily (control) polluting firms must coincide. Figure 1 plots β1 with a 95 % CI: coefficients from 2010–2013 are insignificant ($p > 0.05$), confirming parallel trends; 2015–2020 estimates are positive and significant ($p < 0.05$), indicating EPL strengthens SCR for non-heavily polluting firms.

5.2.2. Placebo test

We mitigated unobservables by random sampling: the original treatment and control samples were reshuffled 500 times and rerun in DiD regressions. The resulting probability-density of the $EPL_{i,t}$ coefficients is normal around zero (Figure 2), whereas our true estimate (0.036) lies far outside this placebo distribution. This falsification test confirms that the post-policy rise in SCR among non-heavily polluting firms is attributable to EPL, not chance.

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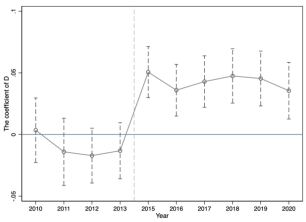


Figure 1. Parallel trend test

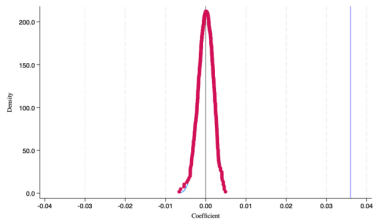


Figure 2. Placebo test

5.2.3. Propensity score matching and DID

To curb non-random policy selection bias, we pair non-heavily polluting firms (treated) with heavily polluting firms (control) via one-to-one nearest-neighbour propensity-score matching on size, leverage and other traits, then run PSMDID. The treated-coefficient is 0.047 ($p < 0.01$, Table 4, col. 1), confirming that EPL still raises SCR after rebalancing observables, so our baseline finding is robust.

5.2.4. Dual machine learning

This study utilizes dual machine learning (DDML) for re-estimation to address potential functional form specification mistakes and omitted variable biases in conventional econometric models. This approach employs cross-fitted machine learning algorithms to model the interaction between EPL and SCR, subsequently estimating causal effects through residual regression, thereby substantially diminishing reliance on model specification. Enterprise size, profitability, leverage ratio, and sales scale were designated as fundamental covariates, while adjusting for individual and year fixed effects. Column (2) of Table 4 indicates that the conclusions remain unaffected by machine learning.

Table 4. Robustness test

Variable	$SCRes_{i,t}$	
	PSMDID	DDML
	(1)	(2)
$EPL_{i,t}$	0.047*** (4.520)	0.046*** (6.174)
N	11704	23,131
Firm	Yes	Yes
Year	Yes	Yes
Controls	Yes	Yes

6. Heterogeneity analysis

6.1. Customer concentration risk

Substantial disparities in customer concentration risk among firms result in varying impacts of environmental regulations on SCR under EPL. Enterprises with an annual average surpassing the median are designated as high customer concentration risk (Customer Concentration Risk = 1);

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Conversely, those below are classified as low customer concentration risk (Customer Concentration Risk = 0). As shown in columns (1) and (2) of Table 5, the impact of EPLis notably positive ($p<0.01$) for firms facing high customer concentration risk, whereas it is not significant for those with low risk. This indicates that, relative to firms with minimal customer concentration risk, EPL significantly enhances SCR for those with elevated customer concentration risk.

6.2. Degree of digitalization

Digital transformation influences a company's resilience to supply chain risks and its system recovery capabilities. The extent of improvement in SCR influenced by environmental rules differs according to varying degrees of digitization. Companies were categorized according to their median level of digitalization: a digitalization level of 0 signifies the low group, while a digitalization level of 1 denotes the high group. The outcomes of the group-specific assessments are showed in columns (3) and (4) of Table 5. This indicates that, relative to low-digitalization firms, EPL has a more significant beneficial effect on improving SCR for highly digitalized companies.

Table 5. Analysis of heterogeneity

	(1)	(2)	(3)	(4)
	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$	$SCRes_{i,t}$
$EPL_{i,t}$	0.055***	0.018	0.049***	0.002
Controls	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
N	10543	10677	13348	7741
R2	0.846	0.876	0.887	0.851

7. Mechanism analysis

7.1. Supply chain efficiency

Elevated supply chain efficiency enhances emergency responsiveness and resource allocation, thereby strengthening resilience; conversely, diminished efficiency leads to sluggish response, resource waste, and greater vulnerability to disruptions. So this work utilizes OLS for validation. The outcomes are presented in Column (1) of Table 6. The estimated is markedly negative, signifying that SCR of non-heavily polluting enterprises can be augmented through enhanced supply chain efficiency, thereby corroborating H2.

7.2. Supply chain decentralization

Supply chain concentration denotes a company's reliance on a limited number of particular partners within its supply chain network. Excessive concentration puts the entire supply chain susceptible to significant disruptions when a primary supplier or client faces difficulties. Furthermore, slight variations in downstream consumer demand can be exacerbated upstream via the bullwhip effect, resulting in considerable disruption. This study utilizes OLS for testing purposes. As it shows in Table 6, the negative regression coefficient of $EPL_{i,t}$ suggests that decreasing supply chain

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concentration enables non-heavily polluting firms to improve SCR through EPL, hence confirming H3.

Table 6. Mechanism analysis

	(1)	(2)
	Supply Chain Efficiency	Supply Chain Decentralization
$EPL_{i,t}$	0.070** (2.500)	-0.004** (-2.289)
Controls	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
N	21645	21645
R^2	0.876	0.737

8. Conclusions and recommendations

Results show that EPL significantly improved SCR in these firms. Further analysis indicates that this effect occurs through enhanced supply chain efficiency and reduced concentration. Heterogeneity analysis also reveals stronger effects among firms with high customer concentration risk and digitalization levels.

The study's main contribution lies in systematically clarifying the synergistic interplay between environmental regulation and SCR, providing novel support for the Porter Hypothesis in China. It addresses the deficiency in extant literature by illustrating how environmental laws act not merely as financial burdens, but as external catalysts that spur internal transformation and bolster long-term resilience and competitiveness.

Based on these findings and China's current environmental policy context, we propose two policy recommendations: First, introduce pilot "SCR Insurance" programs where premiums are tied to environmental compliance. Supervised by the CBIRC, this market-based mechanism would incentivize improved environmental management and help distribute risks across supply chains. Second, develop a standardized "Green SCR Rating" system integrated into mandatory ESG disclosures. This index would enhance transparency and motivate firms to systematically identify and address environmental vulnerabilities across their supply networks.

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