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The Impact of Carrot and Stick on Green Innovation in Enterprises: A Perspective of Policy Combination

Zhan Wang

Business School, Sichuan University, Chengdu, China
3958396026@qq.com

Abstract. This paper takes a policy combination angle, pairing the rollout of the new Environmental Protection Law with the accelerated depreciation policy for fixed assets. Using annual data on A-share listed firms from 2008 to 2021, we ask whether tax incentives and environmental regulation, when deployed together, reinforce or cancel each other out in driving corporate green innovation. The results show that each policy on its own has a positive and significant effect on green innovation. But when both are in place at the same time, the combined impact is noticeably weaker—what we call a policy offsetting effect. Digging deeper, we find that this offset is largely driven by a crowding-out mechanism: firms end up diverting funds away from green projects toward other investment opportunities. The heterogeneity analysis adds further nuance. The offsetting effect is strongest for labor-intensive firms, those operating in highly competitive markets, smaller-sized companies, high-tech industries, and the manufacturing sector.

Keywords: Tax incentives, Environmental regulation, Policy combination, Green innovation

1. Introduction

Climate change has become severe enough that every country now faces the hard task of balancing economic growth against environmental protection. China set out its own answer to this challenge in 2020, announcing plans to peak CO_2 emissions by 2030 and reach carbon neutrality by 2060 [1]. This makes a green transition not just desirable but essential—one that must carefully weigh socio-economic development against ecological constraints. That said, the road ahead is particularly steep for China. As the world's top carbon emitter still undergoing late-stage industrialization, the country confronts a uniquely demanding challenge [2]. Compressing the peak-to-neutrality timeline into just three decades demands a wholesale overhaul of conventional production models. This is especially true for the large share of traditional firms that still operate under the old high investment, high energy use, high pollution, low efficiency paradigm [3]. Against this backdrop, the 14th Five-Year Plan makes clear that building a green technology innovation system is a top priority. Such innovation is widely regarded as the backbone of sustainable development, since it allows firms to bring environmental costs into their decision-making and pushes the economy onto a greener trajectory [4].

Yet green innovation is far from easy to pull off. Unlike ordinary R&D, it comes with heightened risk, longer payback periods, and heavy capital demands—all of which leave firms struggling to

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secure adequate funding [5]. On top of that, green innovation carries a dual externality problem. On one hand, green technology spillovers generate positive externalities; on the other, the environmental pollution that firms produce creates negative ones [6]. This kind of market failure calls for government action—specifically, a mix of policies that ease firms' financing pressures while tightening environmental compliance.

In practice, governments tend to mix carrots with sticks. Fiscal tools like tax breaks are used to loosen financing constraints, while strict environmental rules push firms to account for pollution costs. Take the accelerated depreciation policy for fixed assets, for instance. By boosting corporate cash flow, it helps ease funding pressures and, in turn, supports greater R&D spending [7]. Empirical work backs this up. Li and Wu [8], for example, show that tax incentives effectively spur corporate innovation by raising net cash flow. As for environmental regulation, its logic is to correct pollution externalities. The traditional restraint view holds that such rules raise compliance costs and squeeze corporate finances [9]. The Porter hypothesis takes a different angle, arguing that well-crafted regulations can actually trigger innovation, with efficiency gains more than offsetting the added costs [10]. Studies using Chinese data tend to line up with Porter. Song et al. [11], for instance, find that tough laws like the 2015 New Environmental Protection Law can push firms toward green technology adoption.

Most of the existing work has looked at these policies one at a time, so how tax incentives and environmental regulation interact with each other is still relatively under-studied. That said, the policy combination literature does point out that instruments within the same domain can either reinforce each other or work against one another [12]. That said, very little work has examined how these two cross-domain tools-tax incentives on one side, environmental regulations on the other-jointly shape corporate green innovation. Pang has pointed out that although some work flags up coordination effects, the way mixed policy tools actually play out is anything but simple [13]. A key question then becomes: when tax incentives and environmental regulations are combined, do they push green innovation forward or hold it back? It is certainly reasonable to expect a synergy-tax breaks could fund the very innovations firms need to satisfy regulatory demands. But there is also a credible counterargument: the compliance burden imposed by regulations may cause firms to channel the extra cash flow away from green R&D and into other uses, producing an offsetting rather than reinforcing effect.

This paper sets out to fill that gap. We focus on two concrete policy instruments in the Chinese context: the fixed asset accelerated depreciation policy, which serves as the carrot, and the formal rollout of the 2015 New Environmental Protection Law, which acts as the stick. Three questions guide our analysis. First, do these policies independently encourage green innovation? Second, when put together, do they reinforce or cancel each other out? Third, how do these interaction effects differ depending on firm-level characteristics? Methodologically, we rely on a multi-period difference-in-differences framework, drawing on patent data from A-share listed firms over the 2008–2021 window. In doing so, we go beyond the single-policy focus that dominates the existing literature and try to pin down the causal impact of combining policy tools. The results should be of practical value to policymakers who are looking to fine-tune both standalone and bundled policy instruments in support of green innovation.

2. Institutional background and research hypotheses

China's dual-carbon targets call for strong policy levers to push firm-level green innovation. On the carrot side, the government relies heavily on tax incentives, chief among them the Accelerated Depreciation Policy for Fixed Assets. Launched in 2014 and later extended to all manufacturing

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firms by 2019, the policy lets companies shorten depreciation schedules or adopt accelerated methods. In effect, it defers tax payments and acts like an interest-free loan, which helps ease the financing squeeze that typically comes with risky, long-horizon green R&D. Drawing on signaling theory and the financing constraints view, the extra cash flow should encourage firms to spend more on R&D and tech upgrades. We therefore expect tax incentives to boost green innovation.

On the stick side, the 2015 New Environmental Protection Law marked a turning point. Daily fines, administrative detention, and the power to seal plants or shut down production all raised the cost of non-compliance sharply. Under the Porter Hypothesis, such tough rules can push firms toward cleaner technologies to cut emissions and dodge penalties, sparking innovation in the process. So we also expect environmental regulation to promote green innovation by forcing firms to go green to stay compliant.

Where it gets interesting is how these two interact. Tax incentives raise disposable cash, but environmental rules set a compliance floor. Our argument is that once firms clear that regulatory bar, the tax savings need not flow into additional green R&D. Because tax incentives are largely unrestricted, firms may redirect the funds elsewhere, crowding out green investment to some extent. This points to an offsetting effect-regulation dampens the innovation boost from tax breaks. Hence, while each policy works on its own, their combination may produce a weaker net effect than either alone.

3. Research design

3.1. Model design

To estimate the causal effects of the Accelerated Depreciation Policy and the New Environmental Protection Law, we employ a Difference-in-Differences (DID) framework. As the depreciation policy was implemented in phases starting in 2014, we utilize a multi-period DID model. In contrast, the New Environmental Protection Law took effect uniformly in 2015, allowing for a standard single-period DID estimation. To assess the synergistic (or offsetting) effects of the policy combination, we construct an interaction term within a multi-period DID model. The baseline specification is as follows:

$$GI_{it} = \alpha_0 + \beta_0 DID1_{it} + X_{it} + \mu_i + \eta_i + \varepsilon_{it} \tag{1}$$

$$GI_{it} = \alpha_0 + \beta_1 DID2_{it} + X_{it} + \mu_i + \eta_i + \varepsilon_{it} \tag{2}$$

$$GI_{it} = \alpha_0 + \beta_0 DID1_{it} + \beta_1 DID2_{it} + \beta_2 DID2_{it} \times DID2_{it} + X_{it} + \mu_i + \eta_i + \varepsilon_{it} \tag{3}$$

In the model, Y_{it} represents the green innovation level of company i in year t, and α_i is the intercept term. In Model (1), the impact of the policy of accelerated depreciation of fixed assets on green innovation is estimated. In Model (2), the impact of the implementation of the new Environmental Protection Law on green innovation is estimated. $DID1_{it}$ indicates whether company i implemented the policy of accelerated depreciation of fixed assets in year t, taking the value of 1 if yes, and 0 otherwise. $DID2_{it}$ indicates whether company i was affected by the new Environmental

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Protection Law in year t, taking the value of 1 if yes, and 0 otherwise. The core estimated coefficient is in Model (3), representing the interactive effects between tax incentives and environmental regulation policies. Xit represents a set of control variables, including company size, logarithm of revenue, cash flow status, level of financing constraints, growth opportunities, separation of control rights and cash flow rights of the actual controller, and equity balance. μ_i represents individual fixed effects, λ_t represents time fixed effects, and ε_{it} represents the random error term.

3.2. Data source and variable measurement

3.2.1. Data source

Our empirical work covers all A-share listed firms from 2008 to 2021. The raw data come from several mainstream databases—CSMAR and EPS for firm-level financials, the CICC database and the State Intellectual Property Office (SIPO) for patent records. We then applied a few cleaning steps. First, we dropped financial firms such as banks and insurers, along with any company labeled ST, ST*, or PT. Second, for variables with missing entries due to gaps in statistical yearbooks, we filled them in through interpolation. Third, we removed any firm-year observation that lacked values for the dependent variable, key independent variables, or controls. After all of this, we ended up with 27,295 firm-year observations.

3.2.2. Measurement of green innovation level

We measure green innovation at the firm level by counting green patent applications. In line with how WIPO classifies green patents, our count includes invention patents, utility models, and design patents. Patent counts are notoriously right-skewed, so we take logs of the raw number plus one. This helps tame outliers and pulls the distribution toward something closer to normal.

3.2.3. Control variables

To guard against omitted variable bias, we control for a range of firm-level characteristics. Specifically, we include firm size measured as the log of total assets, revenue captured by the log of operating income, cash flow defined as operating cash flow scaled by total assets, and financing constraints proxied by the SA index. Growth opportunities enter the model as the revenue growth rate, while the separation of ownership and control is captured through the SEP index. We also control for equity balance, which we construct as the ratio of the combined holdings of the second through fifth largest shareholders to that of the largest shareholder.

4. Examination results and analysis

4.1. Benchmark regression

Table 1 presents the baseline results. Columns (1) and (2) look at each policy on its own, while Column (3) adds their interaction. In Column (1), we estimate Model (1) with full controls. The DID1 coefficient comes out positive and significant, meaning the accelerated depreciation policy does push green innovation—firms filed roughly 18.6% more green patents as a result. Column (2) shows Model (2), where DID2 is also positive and significant. The new Environmental Protection Law clearly spurs green patenting too, with an estimated 6.8% uptick, which lines up with what the Porter Hypothesis would predict. Now, Column (3) is where it gets interesting. The interaction term

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DID1 times DID2 is negative and significant, which tells us the two policies do not simply add up. Instead, there appears to be a substitution effect at work—when both the carrot and the stick are in play at the same time, the marginal gain from either one shrinks.

Table 1. Baseline estimates

Variable	(1) GI	(2) GI	(4) GI
DID1	0.186***		0.356***
	(0.023)		(0.028)
DID2		0.068**	0.345***
		(0.028)	(0.039)
DID1*DID2			-0.499***
			(0.046)
Control variables	YES	YES	YES
Constant	-0.808	-1.261**	-0.972*
	(0.547)	(0.548)	(0.547)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	27295	27295	27295
R-squared	0.744	0.743	0.745

Note: Robust standard errors are given in parentheses. *** p < 0.01. ** p < 0.05. * p < 0.1.

4.2. Robustness tests

4.2.1. Parallel trends test

We adopt an event-study framework to check whether the parallel trends assumption holds. The specification is as follows:

$$GI_{it} = \alpha_0 + \sum_{k\geq-7,k\neq-1}^{3} \beta_k DID1_{it}^k + \sum \lambda_j X_{it} + \mu_i + \nu_i + \varepsilon_{it} \tag{4}$$

$$GI_{it} = \alpha_0 + \sum_{k\geq-7,k\neq-1}^{3} \beta_k DID2_{it}^k + \sum \lambda_j X_{it} + \mu_i + \nu_i + \varepsilon_{it} \tag{5}$$

Figure 1 plots the dynamic coefficients around the rollout of the accelerated depreciation policy. After the policy was introduced, the treatment group's coefficients jump up and stay significantly positive relative to the control group, confirming that the parallel trends condition holds.

Figure 2 does the same thing for the new Environmental Protection Law. Again, the pre-treatment coefficients all contain zero within their 95% confidence bands, so there is no evidence that the two groups were on different innovation trajectories before the law took effect. Once the regulation was enforced, the treatment group shows a clear uptick in green innovation coefficients, which further supports the credibility of our identification strategy.

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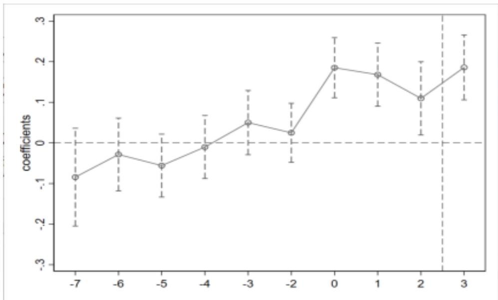

Figure 1. The mpact of accelerated depreciation of fixed assets on green innovation

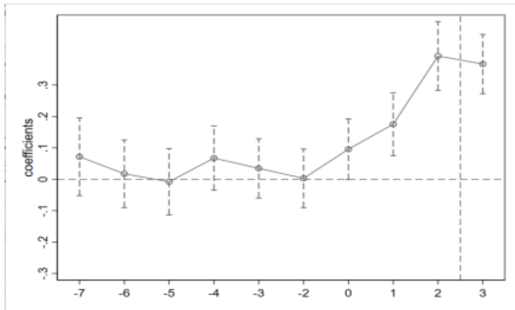

Figure 2. The impact of the new Environmental Protection Law on green innovation

4.2.2. Placebo test

We further check whether our baseline findings could be driven by chance. The idea is simple: we randomly pick a fake treatment group of the same size as the real one, rerun the regression, and do this 500 times. If the original results are genuine, the placebo coefficients should scatter around zero with no real pattern. Figures 3 and Figures 4 show the kernel density plots of the t-values from these 500 runs. For both the depreciation policy and the Environmental Law, the distributions are nicely centered at zero and look roughly normal. That rules out the possibility that our main results are just noise, lending further credibility to the causal claims we make in the baseline model.

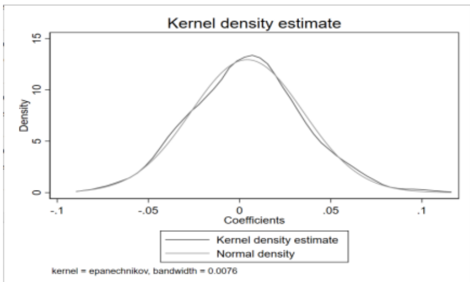

Figure 3. placebo test for the accelerated depreciation of fixed assets policy

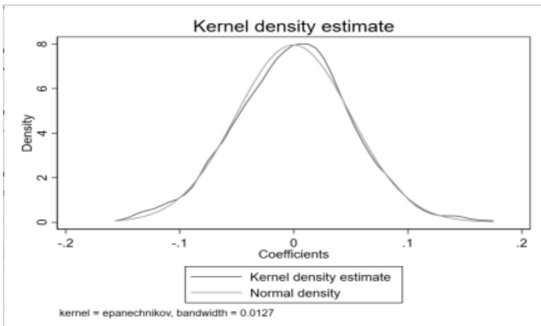

Figure 4. placebo test for the implementation of the new environmental protection law

4.2.3. Other robustness tests

We also run a battery of robustness checks, all reported in Table 2. Column 1 shows PSM-DID estimates. After matching firms on observables, both the depreciation policy and the Environmental Law still push green innovation in a significant way, and the negative interaction between them remains. Column 2 narrows the focus to green invention patents only, rather than all green patents. The results look essentially the same—both policies help, but they partially offset each other. In Column 3, we winsorize the dependent variable at the 1st and 99th percentiles to deal with extreme outliers. Even with this tighter sample, the positive policy coefficients and the negative interaction term both stay significant. Column 4 drops firms with missing years, giving us a balanced panel

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from 2008 to 2021. The story is unchanged, which adds further confidence to what we find in the baseline.

Table 2. Other robustness tests

Variable	(1) GI	(2) GI	(3) GI	(4) GI
	PSM-DID	Replace explained variable	Extreme values moderated	Balanced panel
DID1	0.371***	0.220***	0.341***	0.570***
	(0.028)	(0.016)	(0.027)	(0.053)
DID2	0.359***	0.123***	0.362***	0.572***
	(0.039)	(0.022)	(0.038)	(0.066)
DID1*DID2	-0.511***	-0.314***	-0.489***	-0.820***
	(0.046)	(0.026)	(0.045)	(0.083)
Control variables	YES	YES	YES	YES
Constant	-0.753	-0.140	-1.659***	3.551***
	(0.587)	(0.314)	(0.532)	(1.199)
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Observations	26,828	27,295	27,295	7,210
R-squared	0.727	0.704	0.729	0.709

5. Crowding-out effect of other additional investments on green investments by enterprises

Based on the previous analysis, the implementation of the new Environmental Protection Law sets a clear compliance floor for enterprises.If the Environmental Law indeed sets a compliance floor, then the cash flow unlocked by tax incentives is no longer compelled to go toward green R&D—it can be redirected elsewhere. Under this logic, firms for which the policy combination produces a larger crowding-out effect on green innovation should also be the ones that ramp up spending on non-green projects.

To check whether this is the case, we build an interaction term between the policy combination and a proxy for other investment. The proxy is constructed by taking total investment expenditure, subtracting green investment, and then logging the remainder. We drop this interaction into the baseline specification and rerun the regression. The results appear in Column (1) of Table 3. The interaction term comes out negative and significant at the 1% level, which means that as firms pour more money into non-green investment, the offsetting effect of the two policies on green innovation gets even stronger. This is precisely what our theoretical argument would predict—once the regulatory floor is in place, the cash flow benefit from tax incentives tends to be spent on something other than green innovation.

Table 3. Further analysis tests

Variables	(1) New investment expenditure Green patent
Accelerated depreciation of fixed assets	0.362***

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Table 3. (continued)

	(0.046)
Implementation of the new Environmental Protection Law	0.351***
	(0.066)
Policy mix	-0.509***
	(0.073)
New investment expenditure * policy mix	-0.166***
	(0.026)
Control variables	YES
Constant term	-0.824
	(1.176)
Observations	27,295
R-squared	0.704

6. Conclusion and policy implications

This paper looks at how tax incentives and environmental regulations work together to shape green innovation. The main takeaway is that while both the accelerated depreciation policy and the new Environmental Protection Law push firms toward green patents on their own, putting them together actually weakens the overall effect. The reason seems to be a crowding-out channel—once the regulatory floor is in place, the extra cash flow from tax breaks gets spent on other things rather than green R&D.

Three implications stand out. One, policymakers should not assume that stacking more tools always means more innovation. The two instruments we study here clearly do not complement each other, and in some cases they work against each other. Two, if regulators want to avoid this offset, environmental rules need to be paired with incentive mechanisms that reward firms for going beyond mere compliance, not just meeting the minimum standard. Strict enforcement matters, but so does giving firms a reason to innovate rather than just conform. Three, there is no single policy mix that fits every firm. Tailoring the combination of instruments to firm-specific conditions is likely to yield better outcomes than a blanket approach.

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