Greening through finance?

Fan et al. (2021)

Env Climate discussion group S33

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Introduction

Research question: how does green credit regulation affects firms' loan conditions and their economic and environmental performance?

Theoretical model:

- theoretical model: strengthened green credit regulation,
  $\Rightarrow$ banks: higher interest rates to nonabatement firms;
  $\Rightarrow$ firms must redetermine their abatement and production

Empirical evidence: using firm-level data,

- after the reinforcement of green credit regulation: noncompliant firms saw a larger increase in interest rates, decrease in loan amounts, and more difficulty in access to loans
- different impacts on large and small firms in terms of their loans and their financial and economic responses
- emission reduced but realized in different ways:
  large firms reduced their emission intensity by investing more in adopting abatement facilities, while small firms simply choose to produce less

Background

China's strengthened enforcement of green credit regulations in 2012:

- 1995 - 2007: relevant policies that were meant to be compulsory, but implementation was voluntary
- 2012: Guideline on Green Credit $\Rightarrow$ pressure on banks that are obliged to account for environmental risks (firms' environmental performance becomes critical to banks when setting differentiated loan amounts, interest rates, capital allocation and so forth)
  - related to the extra-regulatory force exerted on banks from the government; complementary rules and regulations that are subsequently enacted
  - indicators on social responsibility with environmental protection to be evaluated for bank achievement; Opinion on Green credit in 2013: include green credit into daily regulations and operations; mandate on collecting data $\Rightarrow$ bank accountability
  - banks might bear additional costs for lending to non-abatement firms $\Rightarrow$ charge higher rates

Model

Static, firms & banks:

- firms: heterogeneous productivity (idiosyncratic following a distribution), capital fully funded by bank loans
- emissions: proportional to output (θy), abatement ξ also reduces emissions proportionally $e = (1-\xi)\theta y$
- pollution tax: te with t = tax rate on pollution
- costs of abatement: $a\xi^b y + f$, variable + fixed
- No abatement: a probability p of being punished with a loss of ϕ of the annual profits
- profit functions:
  for firms with abatement: $\pi(z) = zk^\alpha - rk - te - a\xi^b y - f$
  for firms without abatement: $E\tilde{\pi}(z) = (1-p\phi)(zk^\alpha - rk - te)$

firm's optimal abatement level

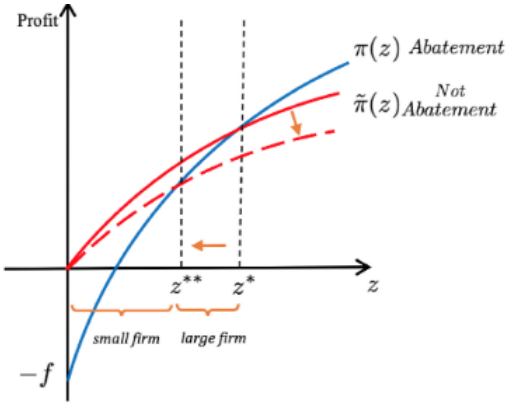
Due to fixed cost: firms first decide whether to abate or not.
If choose to abate: which level.
$\longrightarrow$ Separately for firms with and without abatement.

If abatement, the optimal abatement is $\xi^* = (\frac{t\theta}{ab})^{\frac{1}{b-1}}$:
positively depending on the emission intensity θ and the pollution tax t
negatively depending on abatement cost parameters a and b.
and the profit is then $\pi(z) = \mu z k^{\alpha} - rk - f$ where $\mu = 1 - t\theta + \frac{(b-1)\xi^*}{b} t\theta$.
The optimal demand for capital is $k(r,z) = (\frac{\mu z \alpha}{r})^{\frac{1}{1-\alpha}}$

If no abatement, choose the capital to maximize $\tilde{\pi}(z)$: $\tilde{k}(r,z) = (\frac{\tilde{\mu} z \alpha}{r})^{\frac{1}{1-\alpha}}$ where $\tilde{\mu} = 1 - t\theta$.

Comparative:
The capital demand of the firm without abatement is relatively small $\tilde{\mu} < \mu$ because firms with green technology pay less polluting tax and hence produce more.

steeper slope for abatement firms: $\mu > \tilde{\mu}$



Notes: The solid blue line corresponds to profit of firms with abatement, while the solid red line corresponds to profit of firms without abatement when there is no green credit regulation. The dashed red line corresponds to profit of firms without abatement when there is green credit regulation.

Fig. 1. The impact of green credit regulation.

Bank's problem: determine interest rate

Assuming banks have full bargaining power to set a loan rate for each borrower.

In the absence of green credit regulation:
Given a firm's loan demand, $\max_r (r - r^d) k^d(r, z)$ where r^d is the deposit rate (exogenous).

Optimal: $r = \frac{1}{\alpha} r^d \longrightarrow$ banks set an identical loan rate for each firm regardless of the pollution emission level.

And the optimal demand for capital can be written as

$$k = \begin{cases} \left(\frac{\alpha^2 \mu z}{r^d}\right)^{\frac{1}{1-a}}, & \text{if abatement} \\ \left(\frac{\alpha^2 \widetilde{\mu} z}{r^d}\right)^{\frac{1}{1-a}}, & \text{if no abatement} \end{cases}$$

(and accordingly the optimal output, profit and emissions for a firm adopting abatement technology or not adopting abatement technology can be derived)

The marginal firm: a threshold of productivity z^*

The marginal firm is indifferent between adopting abatement technology or not:

$$(1-\alpha)(z^*\mu)^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f = (1-p\varphi)(1-\alpha)(z^*\widetilde{\mu})^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}},$$

which further implies

$$z^* = \left[\frac{f}{(1-\alpha)\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}\left(\mu^{\frac{1}{1-\alpha}} - (1-p\varphi)\widetilde{\mu}^{\frac{1}{1-\alpha}}\right)}\right]^{1-\alpha}.$$

For any firms above the threshold: choose to abate; otherwise, no abatement.

$$\xi = \begin{cases} \xi^* & \text{if } z > z^* \\ 0 & \text{otherwise} \end{cases}$$

Impact of green credit policy

Additional cost is incurred for a bank providing a loan to a firm without abatement:

- For firms adopting clean technology through abatement, their loans from banks are not affected by the policy.
- For firms without abatement: assuming a linear form, $g(e) = \psi e$ with $\psi > 0$.

The new maximization problem: $\max_r (r - r^d) k^d(r, z) - g(e)$, and the optimal condition implies that $r(\psi) = \frac{1}{1-\psi\frac{\theta}{\alpha\tilde{\mu}}} \frac{r^d}{\alpha}$. $\Rightarrow$ the green credit policy increases the loan rate because $\psi > 0$.

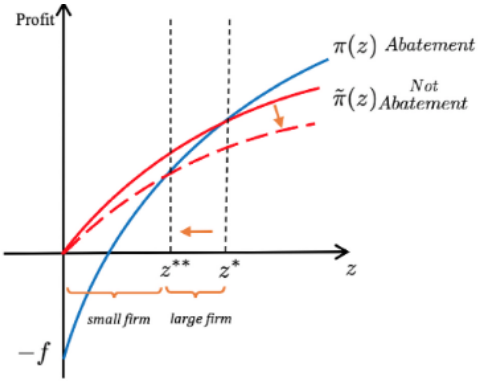
The new productivity threshold is now determined by $z^{**} < z*$:

$$(1-\alpha)(\mu z^{**})^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f = (1-p\varphi)(1-\alpha)\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right]^{\frac{\alpha}{1-\alpha}} (\tilde{\mu} z^{**})^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}. \tag{29}$$

The above equation determines the productivity threshold z^{**} for the abatement decision, which satisfies

$$z^{**} = \left\{ \frac{f}{(1-\alpha)\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} \left[\mu^{\frac{1}{1-\alpha}} - \left(1-\psi\frac{\theta}{\alpha\mu}\right)^{\frac{\alpha}{1-\alpha}} (1-p\varphi)\tilde{\mu}^{\frac{1}{1-\alpha}}\right]} \right\}^{1-\alpha} \tag{30}$$

impact of green credit policy on firm abatement



Notes: The solid blue line corresponds to profit of firms with abatement, while the solid red line corresponds to profit of firms without abatement when there is no green credit regulation. The dashed red line corresponds to profit of firms without abatement when there is green credit regulation.

Fig. 1. The impact of green credit regulation.

- polluting firms profit curve move downwards.
- new cutoff: previously indifferent firms redecide wether to continue not to abate
- firms $\in [z^{**}, z^{*}]$ are affected by the policy: from nonabatement type to the abatement type [decrease emission intensity by investing in abatement]

Theoretical predictions

Propo. 1 More stringent green credit regulation induces large incompliant firms to adopt abatement technologies; and their loans are thus less impacted by the policy.However, for small firms that are still unwilling to improve their environmental performance, their loan costs will be more affected.

Propo. 2 The negative impact of the green credit policy on firms' sales and investments is stronger for small nonabatement firms. The negative impact on profits is unrelated to firms' size.

Propo. 3 More stringent green credit regulation reduce firms' pollution emissions, and this effect is stronger for large firms. As for the emission intensity, only large non-abatement firms decline it by investing into abatement technology.

Discussion on identification

Challenge: enforcement is strengthened uniformly for all firms after 2011.

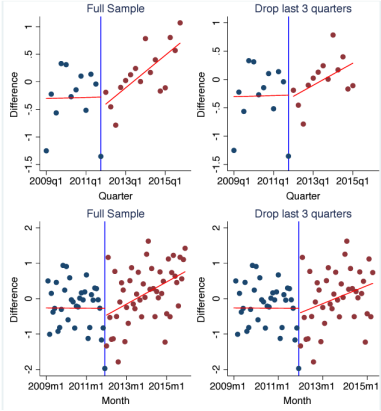
Use observed violations of environmental laws to identify the causal effects of the green credit policy:

- firms' violations of environmental laws and regulations are directly indicative of their compliance and abatement status
- firms' past and future violations are autocorrelated: firms with past violations are more likely to be punished in the future, while law-abiding firms will be more likely to be obedient or trusted by the administrator
- firms' initial violations are unrelated to the enactment of the new law on green credit

Facts

Evidence shows:

- no trend break for either the total number of incompliant cases or the number in the regression sample around 2012
  $\Rightarrow$ the Chinese government did not change other environmental regulations around 2012 in a manner related to noncompliance with the green credit regulation
- before 2012, the differences between those punished by administrative agencies due to breaches of the law and those not punished were randomly distributed around zero
- Shortly after the first quarter of 2012, the float of the interest rate of loans borrowed by firms with environmental noncompliance records grew increasingly higher than that of law-abiding firms.



Empirical strategy (1)

$$Floating_{fctmp} = \beta_0 \text{Punish}_{ft} + \beta_1 \text{Punish}_{ft} \times \text{Post}_{tm} + \sum_t \gamma_t Z_f \times \phi_t + \phi_f + \phi_{ctm} + \phi_p + \varepsilon_{fctm},$$

where

- $Floating_{fctmp}$: floating ratio of the interest rate charged on loans to firm f in year t and month m from sub-branch bank c with maturity p, ratio= $\frac{float}{benchmark}$
- $Punish_{ft}$: dummy variable that equals 1 when firm f is punished by an administrative agency **in year t and onward** and equals 0 otherwise
- $Post_{tm}$: 0 before Feb 2012 and 1 from Feb 2012
- fixed effects: firm, sub-branch times year-month pair, and maturity fixed effects

β_1: the effect of green credit on firms' loan costs, positive according to model predictions

Empirical strategy (2)

$$Y_{ft} = \beta_0 \text{Punish}_{ft} + \beta_1 \text{Punish}_{ft} \times \text{Post}_t + \sum \gamma_t Z_f \times \phi_t + \phi_f + \phi_t + \varepsilon_{ft}$$

where Y_{ft} refers to firms' financial (liability, total assets, fixed assets and investments), economic (sales, profits, and employment) and environmental indicators (total emissions and emissions intensity)

Data

- The bank loan data from 2009 to 2015 are provided by one of China's "Big Five" banks
- To obtain information about a firm's initial performance, merge the bank loan data with the Annual Survey of Industrial Firms (ASIF)
- The data on firms' environmental penalties are collected by a well-known Chinese environmental NGO the Institute of Public and Environmental Affairs (IPEA). The database thus provides detailed information from 2004 onward on illegal acts triggering environmental penalties, types of penalties, values of monetary fines, and sanctions of firms due to their illegal polluting activities.
- Data on firms' pollution emissions are collected from the Annual Environmental Survey of Polluting Firms (AESPF) of Chin

Empirical results

Table 1
Baseline results.

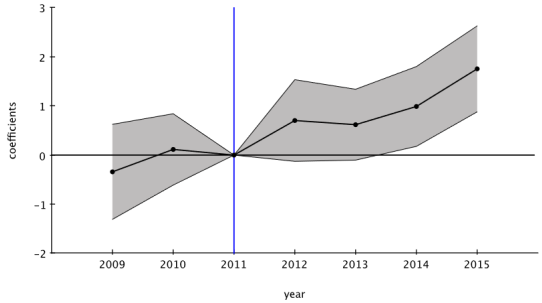
	(1)	(2)	(3)	(4)
	Floating	Floating	Floating	Floating
Punish × Post	0.837***	1.020***	0.826**	1.012***
	(0.322)	(0.328)	(0.322)	(0.328)
Punish	−0.398	−0.544	−0.398	−0.545
	(0.493)	(0.489)	(0.494)	(0.490)
Sub-Branch × Year-Month FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Maturity FE	No	No	Yes	Yes
Firm-level Controls	No	Yes	No	Yes
Observations	126,994	120,821	126,994	120,821
R-squared	0.692	0.694	0.692	0.694

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels. Robust standard errors corrected for clustering at the firm level are shown in parentheses. Sub-branch times year-month pair fixed effects, firm fixed effects, maturity fixed effects and firm-level controls are sequentially controlled from Columns (1) to (4). Firm-level controls include firms' initial variables (the log of fixed assets, log of labor employment).

- Consistent with Proposition 1, the strength of green credit regulation positively affects the spread of a firm's loan interest rate
- Col (4): strengthened green credit regulation can explain an extra 1.012% of the floating ratio in the loan interest rate for firms with higher environmental credit risks.
- A back-of-the-envelope calculation reveals that, combined with the 9.911% average floating ratio, the reinforced implementation of green credit regulations is responsible for an approximately 10.2% increase in the floating ratio of a firm's loan interest rate.

DID parallel trends assumption

Replace the interaction between the punish dummy and post dummy with the sum of the interaction terms between the punish dummy and all of the year dummies.



Notes: This figure shows the dynamic impact of green credit regulation on firms' loan rate. The x-axis denotes the year; the y-axis denotes the estimated coefficients of each year. The area in shadow describe the 95 percent confidence intervals. The base year is 2011.

robustness of the baseline estimates

- Alternative measures of firms' loan costs:
  - the actual interest rate charged on a firm's loans borrowed from commercial banks
  - float of interest rate
  $\Longrightarrow$ consistent with the baseline results
- add relative loan amount to better determine the impact of green credit regulations on loan amounts that firms could borrow from the bank
  $\Longrightarrow$ In comparison to firms obeying environmental laws, firms with violation records experienced a significantly larger decrease in the amounts of loans that they could successively borrow from banks after 2012.
  $\Longrightarrow$ in addition to raising firms' loan costs, banks are also responding to the policy reform by approving smaller loans to absorb firms' environmental credit risks.
- firms might borrow from a certain subbranch bank more than once in reality, also test the impact on the averaged floating ratio of firms' loan rates
  aggregate the sample into month-firm level, quarter-firm level, and year-firm level
  $\Longrightarrow$ robust

robustness of the baseline estimates

- Alternative measures of firms' environmental credit risk:
  - industry-level pollution intensity as replacements, by the share of waste water over total emissions, shares of waste air over total emissions, wastewater per unit of output, and waste air per unit of output
  - whether a firm belongs to a heavily polluting and resource-consuming industry
  - introduce an interaction between whether firms operate in "two high, one overcapacity" industries and a post year dummy
- to rule out potential influence from change of punishment probability: re-define the punish variable by treating firms punished before the Guideline consistently as 1 throughout the whole sample period.

Endogeneity issues

- employ the PSM method to address potential endogeneity concerns raised by the nonrandom selection of governmental sanctions. (yearly one-toone match without replacement based on firms' characteristics, including profits, sales, employment, total assets and total liabilities.)
- a placebo test by randomly selecting firms and designating them as "firms punished" by authorities 5000 times and repeatedly running regressions
  the significant effect of strengthened enforcement of green credit regulation on a firm 's loan cost is unlikely driven by chance as true estimates fall far beyond the 95th percentile of the 5000 estimates.
- several instrumental variables to implement the tests.

$$IV_{c,i,t} = \frac{Punish_{c,i}}{\sum_{c,i} Punish_{c,i} \sum_{c,i} Punish_{c,i,t}}, \tag{43}$$

where $\frac{Punish_{c,i}}{\sum_{c,i} Punish_{c,i}}$ indicates the ratio of the punished firm number in city c and industry i to the total number of punished firms in the initial year, while $\sum_{c,i} Punish_{c,i,t}$ denotes the total number of punished firms over the years. It is rational that the original characteristics could impact the

- shift-share IV:

- IV2: the average number of administrative punishment on firms excluding the focal firm in city c and industry i

Heterogeneous effects

- different ownership types: SOEs, private firms, and foreign firms
  the effect of green credit regulation on floating ratio of firms' loan rate is significantly positive for POEs relative to SOEs
- different sizes: a triple interaction term Punish $\times$ Post $\times$ Size
  the increase in the loan interest rate spread due to green loan regulation is less shouldered by larger punished firms (small firms with noncompliance records with environmental regulations saw a larger increase in the interest rate after 2012)

Extensive margin

LoanDummy: dummy variable equalling 1 if firm f still have access to a bank loan at year t and 0 otherwise
Findings:
- notably decreased chances for firms with terrible environmental performance to borrow from banks
- the larger that the firm is, the weaker the negative impact is of green credit regulation on punished firms' access to loans.

Issue: whether the effect of green credit regulation is brought by this extensive margin adjustment.
Use the balanced sample to re-estimate the benchmark model $\Longrightarrow$ robust

Effects on firms' economic and environmental performance

Impact of green credit on firm's financial and economic performances.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Liability	TA	FA	Investment	Sale	Profit	Employment
Panel A: Firm's performance							
Punish × Post	−0.107***	−0.0919***	−0.0667**	−0.141	−0.157***	−0.150**	−0.163***
	(0.0249)	(0.0192)	(0.0300)	(0.102)	(0.0253)	(0.0592)	(0.0250)
Punish	0.00153	0.0220	0.0568	0.163	−0.0331	−0.00310	−0.0426
	(0.0475)	(0.0379)	(0.0578)	(0.383)	(0.0525)	(0.107)	(0.0619)
Observations	30,658	30,703	30,325	8098	30,668	27,114	29,777
R-squared	0.919	0.950	0.901	0.754	0.890	0.823	0.795
Panel B: Firm's performance by size							
Punish × Post × lnTA	0.0396**	0.0297**	0.0351*	0.128**	0.0350**	−0.0122	0.0233
	(0.0155)	(0.0118)	(0.0193)	(0.0641)	(0.0145)	(0.0331)	(0.0172)
Punish × Post	−0.573***	−0.436***	−0.464*	−1.680**	−0.560***	0.0804	−0.363*
	(0.196)	(0.147)	(0.245)	(0.790)	(0.179)	(0.407)	(0.206)
Punish × lnTA	0.0195	0.0121	0.0196	0.419	−0.0314	−0.0131	−0.145***
	(0.0323)	(0.0255)	(0.0363)	(0.319)	(0.0304)	(0.0655)	(0.0508)
Post × lnTA	−0.0264***	−0.0249***	−0.0410***	−0.0533**	−0.0325***	−0.0941***	−0.105***
	(0.00585)	(0.00431)	(0.00671)	(0.0247)	(0.00531)	(0.0107)	(0.00574)
Punish	−0.236	−0.125	−0.182	−5.011	0.351	0.147	1.724***
	(0.402)	(0.316)	(0.461)	(3.761)	(0.388)	(0.827)	(0.614)
Observations	30,658	30,703	30,325	8098	30,668	27,114	29,777
R-squared	0.919	0.950	0.901	0.755	0.890	0.824	0.800
Panels A and B:							
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 10
Impace of green credit on firms' total emissions.

	(1)	(2)	(3)	(4)
	Wastewater	COD	NH3	SO2
Panel A: Firm's emission				
Punish × Post	−0.093***	−0.108***	−0.066***	−0.058***
	(0.018)	(0.017)	(0.021)	(0.014)
Punish	−0.048	−0.061	−0.151*	0.074
	(0.063)	(0.063)	(0.083)	(0.046)
Observations	149,046	147,141	111,503	121,464
R-squared	0.892	0.892	0.866	0.913
Panel B: Firm's emission by size				
Punish × Post × lnTA	−0.025**	−0.039***	−0.044***	−0.002
	(0.012)	(0.011)	(0.014)	(0.009)
Punish × Post	0.204	0.346***	0.455***	−0.030
	(0.139)	(0.133)	(0.166)	(0.102)
Punish × lnTA	−0.012	0.021	−0.086	−0.048
	(0.045)	(0.043)	(0.054)	(0.034)
Post × lnTA	−0.014**	−0.004	0.009	−0.012***
	(0.006)	(0.006)	(0.006)	(0.005)
Punish	0.095	−0.301	0.872	0.639
	(0.513)	(0.499)	(0.636)	(0.404)
Observations	139,915	138,137	104,901	114,099
R-squared	0.889	0.889	0.862	0.911
Panels A and B:				
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

The end!