No. 2109 [EN]

IMI Working Paper

Greening Through Finance?

Fan Haichao, Peng Yuchao, Wang Huanhuan and Xu Zhiwei

INTERNATIONAL MONETARY INSTITUTE

Journal of Development Economics 152 (2021) 102683

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Regular Article

Greening through finance?☆

Haichao Fan[a,*], Yuchao Peng[b], Huanhuan Wang[c,e], Zhiwei Xu[d]

[a] Institute of World Economy, School of Economics, Fudan University, Shanghai, China
[b] Belt & Road Finance Institute and School of Finance, Central University of Finance and Economics, Beijing, China
[c] School of Law, East China Normal University, Shanghai, China
[d] Antai College of Economics and Management, Shanghai Jiao Tong University, Shanghai, China
[e] Center for China Economic Research, School of Economics, East China Normal University, China

ARTICLE INFO

JEL classification:
G32
Q52
K32
G41

Keywords:
Green credit
Loan rate
Environmental penalty
Firm size

ABSTRACT

This paper investigates how green credit regulation affects firms' loan conditions and their economic and environmental performance. In a simple theoretical model, with strengthened green credit regulations, banks raise loan interest rates to nonabatement firms. Firms that were formerly indifferent to pollution abatement must redetermine their abatement and production strategies. Using disaggregated firm-level data, we find that, 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. We further find different impacts on large and small firms in terms of their loans and their financial and economic responses. Regarding the impact on firms' environmental performance, although all of these firms reduced their total emissions, the reductions are realized in dissimilar ways; large firms reduced their emission intensity by investing more in adopting abatement facilities, while small firms simply choose to produce less.

1. Introduction

Under the notion that financial markets can play an important role in environmental performance, green credit, which essentially involves capital allocation under environmental constraints, has been widely developed by banking sectors worldwide.[1] This process generally requires integration of environmental risks into banks' strategies and risk management systems. Firms' environmental credit risk, as indicated by their environmental performance and compliance with environmental laws and regulations, thus becomes precondition of banking loans. The consequently changed financial conditions should, in turn, influence firms' behaviors. However, analysis of the impact of green credit has faced particular challenges due to the scarcity of reliable measure of firm-specific loan information.

Facilitated by a set of comprehensive firm-level loan data, we are able to perform these analyses. The loan data are provided by one of China's "Big Five" banks covering firms in 31 provinces with different credit ratings, sizes, ownership types and sectoral distributions. The data record detailed information about each loan issued to firms. Therefore, our analysis is about loaning to all firms rather than the loans with

☆ We thank the editor and three anonymous reviewers for their constructive comments. All remaining errors are ours. Authors are listed in alphabetical order. The authors acknowledge financial support by the Shanghai Institute of International Finance and Economics, the Ten Thousand Talents Program (Young Talents) of China, the Youth Innovative Team on Humanities and Social Sciences of Fudan University, the National Science Foundation of China (No.72022011, No. 71903208) and the Program for Innovation Research in Central University of Finance and Economics.

* Corresponding author.
E-mail addresses: fan_haichao@fudan.edu.cn (H. Fan), yuchao.peng@cufe.edu.cn (Y. Peng), hhwang@law.ecnu.edu.cn (H. Wang), xuzhiwei09@gmail.com (Z. Xu).

[1] For example, the Equator Principle, which is a risk management framework for determining, assessing and managing environmental and social risk in projects, has been currently adopted by 116 financial institutions in 37 countries.

https://doi.org/10.1016/j.jdeveco.2021.102683
Received 20 April 2020; Received in revised form 26 April 2021; Accepted 14 May 2021
Available online 26 May 2021

specific environmental ends. This study relates to how banks integrate firms' environmental risks into the loan issuing process when lending to dirty firms which is subject to the environmental laws and regulations.

China's substantially strengthened enforcement of green credit regulations in 2012 further provide an excellent opportunity to identify the causal effect of green credit on firms' external financial conditions through a difference-in-difference strategy. Given the limited regulatory capacity of governments,[2] the potential of the financial sector in environmental protection was re-affirmed and substantially enhanced by the Guideline on Green Credit, enacted in February 2012 in China. In contrast to pure market mechanisms spontaneously adopted by banks, such as the Equator Principle, green credit in China features pressures on banks which are obliged to account for environmental risks. Any failure to adhere to the rules might trigger sanctions on banks and are likely to detrimentally impact banks' achievement assessments, which serve as important bases for governmental regulatory ratings of banks, banks' market access and their managers' achievement evaluation. Therefore, echoing Foster and Gutierrez (2013) who find that voluntary certification can provide an important complement to mandatory inspections as a basis for environmental regulation in low-income countries, our investigation on the effect of green credit in the context of China's green credit mechanism also helps to determine the role that financial markets can play, especially in an environment with limited government capacity.

In this research, we intend to find out how financial markets internalize the potential adverse cost of firm's environmental credit risk on the margins of a borrowing firm, and how the increased loan costs further affect firms' economic and environmental performance. To begin, we build a static model, in which firms can autonomously choose to abate the pollution or not. At the same time, in order to maximize their profits, banks choose the optimal float rate of loans over the benchmark interest rate set by the central bank. When the enforcement of green loan regulations is strengthened, banks increase their loan rates to firms without abatement. As a result, a new cutoff of firm productivity emerges for those indifferent to pollution abatement since firms without abatement will face greater financing cost. We derive several testable propositions from the model. First, more stringent green loan regulations induce 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 cost will be substantially and positively affected. Second, in regard to the economic performance, the negative impact of the green credit policy on firms' sales and investments is stronger for small nonabatement firms. Third, when it comes to the environmental performance, although all of these firms have reduced their pollution emissions, this effect is stronger for large firms. Furthermore, only large non-abatement firms decrease their pollution by investing in abatement technology.

To test these predictions, we construct a rich firm-level dataset. We draw from multiple sources: firm-level economic data from the Annual Survey of Industrial Firms (ASIF); bank loan data from one of China's five largest state-owned commercial banks; firm-level pollution data from the Annual Environmental Survey of Polluting Firms (AESPF); and firms' environmental penalty data from the Dataset on Environmental Penalty. The merged dataset contains information on 130,000 unique firm loans, accounting for approximately half of the total loan value issued to manufacturing firms by banks and covering firms with different credit ratings in all provinces, firms of differing sizes and ownership characteristics, and firms operating in different sectors.

We then employ a difference-in-difference strategy to examine the impact of green credit, conditional on the environmental law compliance status of borrowers, on the loan costs and on firms' economic and environmental performance within the context of a prominent increase in enforcement stringency of the Chinese green credit regulation in 2012. Basically, our baseline results reveal that, after 2012, strengthened green credit regulations explain 10.2% of the increase in the floating ratio of the loan rate for firms with noncompliance records relative to their law-abiding counterparts.[3] Later, we demonstrate the robustness of our results by conducting several tests to address potential endogeneity issues. Moreover, we study the heterogeneous effects across different types of firms. We find the effects to be more pronounced for privately owned firms (POEs). Additionally, small firms with records of noncompliance with environmental regulations saw a larger increase in the interest rate after 2012. In addition to the above intensive margin effect, we also find out the extensive margin effect, that is, strengthened green credit regulation impedes non-compliant firms' access to loan.

Finally, we assess the impact of green credit regulations on firms' operations and emissions. To better explore the underlying mechanism, we consistently take firm size into account. We find that large punished firms experience a relatively smaller decrease in liabilities, compared with small punished firms. Their total assets, fixed assets, investments, and operational performance, including sales and employees, are also less negatively impacted. However, there is no observable difference pertaining to the impact on profits of firm varied by their sizes. When it comes to the environmental performance, although all of these firms reduced their pollution emissions, how the reductions were realized is dissimilar: large firms place a large proportion of their investment into emission control by, for example, adopting more abatement facilities, while small firms simply choose to produce less. Stated differently, upon the green loan regulations, the large noncompliant firms responsively upgrade pollution cleaning technology thus turning green; while small noncompliant firms are forced to produce less due to less loans with higher costs. In a certain sense, financial markets are able to internalize the potential adverse costs of environmental fines on the margins of a borrowing firm. And it would be seen as a sound complementary mechanism to administrations, especially in countries with limited government capacity.

This paper contributes to the growing body of literature on green or climate finance (Heinkel et al., 2011; Hong et al., 2019). These studies shed light on the impact of a firm's environmental and climate risks on financial markets and their participants, including bond markets (Sharfman and Fernando, 2008; Bauer and Hann, 2010; Baker et al., 2018), stock markets (Hong and Kacperczyk, 2009), shareholders (Tang and Zhang, 2020), institutional investors (Krueger et al., 2019), mutual funds (Riedl and Smeets, 2017), and private banks (Goss and Roberts, 2011). In particular, this paper is most closely related to the work of Chava (2014) who offers evidence for the impact of a firm's environmental profile on its cost of equity and debt capital and finds that lenders charge a significantly higher interest rate on bank loans issued to firms with environmental concerns. Another work by Goss and Roberts (2011) also finds that firms with below-average social responsibility performance are associated with higher premiums on their costs of private bank debt. Our research differs from these works in the following

[2] Like other developing countries, environmental agencies in China, especially those at the base layer, are often hampered by inadequate executive capacities. Moreover, the administrative agencies in charge of enforcement are obliged to adhere to the laws and regulations passed by the legislature. The provisions in laws and regulations always set clear limitations both on the punishable offense and on the discretionary power of penalty that the government might levy on violators. One of the prominent examples is the Songhua River water pollution incident in 2006. A rough calculation showed that the direct economic loss caused by this catastrophic water pollution was approximately 70 million RMB. The polluter, Jilin Petrochemical Company, surprisingly only received a fine of one million RMB, imposed by the National Environmental Protection Agencies.

[3] The floating ratio of a firm's loan rate is the ratio of the float of the loan rate over the benchmark interest rate set by the People's Bank of China (China's central bank) when commercial banks borrow from it.

aspects. First and foremost, in contrast to Chava (2014) and Goss and Roberts (2011), we go beyond cross-sectional comparisons by considering the enactment of the rigorously enforced Guideline on Green Credit in China as an exogenous regulation shock to analyze the impacts of green credit regulation on firms' loan rates. Second, we analyze the heterogeneous impacts on firms varying by their size and find that the loan rate spread charged on small firms is more strongly affected. Third, we further discuss the consequent influences on firms' economic and environmental performance caused by this increased loan cost. Interestingly, we find that upon the green loan regulations, large noncompliant firms responsively upgrade abatement technology, thus turning green; while small noncompliant firms are forced to produce less due to fewer loans with higher costs. Last but not the least, we also provide a theoretical model to rationalize our empirical findings.

This research also contributes to the literature on the effects of environmental regulations on pollution emissions and environmental quality improvement (Nelson et al., 1993; Chay and Greenstone, 2005; Greenstone and Hanna, 2014) and on the microeconomic activities of regulated firms, including their employment (Henderson, 1996; Greenstone, 2002; Walker, 2013), firm productivity (Berman and Bui, 2001; Greenstone et al., 2012), industrial locations (Henderson, 1996; Becker and Henderson, 2000; Chen et al., 2018), trade-environment links (Gutiérrez and Teshima, 2018), and exports and foreign direct investment (Keller and Levinson, 2002; Cai et al., 2016; Shi and Xu, 2018), among others. Different from the above researches, which mainly focus on governmental regulation, we show how banks charge the interest rates of loans conditional on borrowers' compliance with environmental laws and regulations. It would be seen as a sound complementary mechanism to administrations, especially in countries with limited government capacity.[4]

The remainder of the paper is arranged as follows. Section 2 provides a relevant institutional background of green credit practices in China. Section 3 presents the theoretical model used and discusses testable implications. Section 4 describes our empirical specifications and data. Section 5 provides the empirical results on the impacts on firm loan costs, followed by Section 6 on the further impacts on a firm's economic and environmental performance. Section 7 concludes.

2. Institutional background

China's first attempt to explore the potential of bank loans in environmental protection can be traced back to as early as 1995. At that time, the Central People's Bank required bank sectors to treat natural reserves and pollution abatement as one of the considerations when issuing loans. Relevant policies was made from time to time thereafter. The Opinion on Enforcing Environmental Regulation to Control Debt Risk jointly enacted by National Bureau of Environmental Protection and China Banking Regulatory Commission in 2007 reaffirmed banks' responsibility in this respect. In practice, despite that the green loan initiative should be compulsorily executed, banks actually implemented them voluntarily. Notably, the outcomes apparently fell short of expectations. One of the reasons is that, out of concern for profit maximization, banks sometimes are more prone to lending to highly polluting or energy-intensive firms considering their greater payment capacities, especially when lacking sufficient oversight on banks. For example, the credit balances of highly polluting or energy-intensive industries in May 2009 reached 2.3 trillion RMB, thereby exceeding the value in the same period of 2008 by 23.43%, as reported by the Ministry of Environmental Protection (MEP, 2010).

In response, the former China Banking Regulatory Commission (CBRC, now the China Banking and Insurance Regulatory Commission) enacted the Guideline on Green Credit in February 2012, which has been generally viewed as the foundation of the green credit regime in China. Under the guideline, banking sectors are obliged to effectively identify, assess, monitor, control and mitigate environmental and social risks during crediting business and to accordingly improve their crediting rules and procedures.[5] In addition to outlining corresponding organizational changes and policy promulgation and capacity building plans, the directive establishes concrete procedures for incorporation of environmental risk into credit approval procedures. Among other factors, creditors must scrutinize borrowers' compliance with environmental laws to identify clients "with major environmental and social risks" to clarify appropriate levels of approval authority and to establish separate underwriting procedures" for restricted industries under state regulation and industries with major environmental and social risks."[6] Firms' environmental performance then becomes critical to banks when setting differentiated loan amounts, interest rates, capital allocation and so forth.

One of the largest improvements in the Guideline in 2012 is not how prescriptive it is, but is rather related to the extra-regulatory force exerted on banks from the government. In addition to banks' discretion in green credit provided by the guideline, there are also provisions requiring that financial sectors' achievements in green credit practice constitute important determinants of governmental regulatory ratings on banks, as well as banks' market access and their managers' performance evaluations. To this end, a series of complementary rules and regulations are subsequently enacted. Among others, the Guideline on Performance Evaluation of Banking Sectors in 2012 incorporates indicators on social responsibility with environmental protection as a key item when evaluating banks' achievements. The Opinion on Green Credit in 2013 urges regulators and banks at all levels to include the notion of green credit into daily regulations and operations. Later in the same year, China Banking Regulatory Commission built up the Statistical System on Green Credit, mandating that all banks should collect statistics on loans relating to debtors with high environmental and safety risks and then report to the Commission biannually. The key indicators on the implementation of green credit were soon enacted by China Banking Regulatory Commission to provide a comprehensive evaluation index for rating banks' achievements in screening debtors' environmental and social risks. Banks' accountability explicated in the guidelines and the intense adoption of complementary rules have substantially strengthened banks' willingness to implement the green credit regulations.

Banks might be sanctioned when violating the green loan regulations. For example, Ping An Bank, one of China's largest joint-stock commercial banks, was imposed with a 500 thousand RMB fine by Tianjin Banking Regulatory Bureau for issuing loans to firms violating emission standards without discretionary preload investigation.[7] The

[4] By testing firms' varied internal reactions in response to external financial support constrained by environmental risks, our paper is also related to the literature on firms' environmental responses to financial constrains. The closely related research is Andersen (2016) who finds that reduced credit constraints increase the scale of production, reduce emissions per unit of output and promote firms' clean technology upgrading.

[5] Pursuant to Article 4 of the Green Credit Guidelines, "Environmental and social risks refer to the possible risks and harms that might be exerted on the environment and society in the construction, production, and business operations of firms within areas of energy consumption, pollution, land, health, safety, ecological protection, and climate change."

[6] Article 17 of the Guideline prohibits banks from issuing credit to clients that severely violate relevant regulations on environmental and social performance. In accordance with this prohibition, the dynamic evaluation and classification of borrowers' environmental risks must be executed on a regular basis as fundamental determinants for credit ratings, credit access, management and exit.

[7] https://m.hexun.com/bank/2018-07-10/193415945.html.

legal basis for this penalty is the Guideline in 2012.[8] Therefore, banks might bear additional costs when lending to non-abatement firms under the condition of the green loan policy. Breaking of the green credit regulations might result in lower competency evaluations of banks and their managers and limitations on banks' business scopes.[9]

Banks decide the interest rates of firms' loans based on the benchmark lending interest rate set by the People's Bank of China (PBoC) plus/minus a float within the ceiling restriction regulated by the PBoC.[10] Therefore, we should expect that, to account for the environmental credit risk of firms, the most straightforward way for banks to balance credit risk is to price loans with much higher rates than the benchmark rate to guarantee their profits. Overall, in our research, we attempt to determine the impact of green credit, conditional on the environmental law compliance status of borrowers, on the loan cost and on firms' economic and environmental performance within the context of stricter enforcement of Chinese green credit regulations in 2012. We provide theoretical evidence and empirical support for this effect in subsequent sections.

3. Model

In this section, we consider a static model with firms and banks to analyze the impact of environmental credit regulation on loan rates and economic decisions.

3.1. Firm problems

We consider firms with heterogenous productivity. A firm uses capital k to produce final goods. We assume that physical capital is fully financed from a bank loan at interest rate r. Production involves the Cobb-Douglas production:

$$y = zk^{\alpha}, \tag{1}$$

where z is an idiosyncratic productivity which follows a CDF $\mathbf{F}(z)$ on the support $[z_{\min}, z_{\max}]$, and $\alpha \in (0,1)$. Following Annicchiarico and Di Dio (2015), we assume that emission e is proportional to output:

$$e = (1-\xi)\theta y, \tag{2}$$

where ξ denotes the adoption of pollution abatement measures, and $\theta > 0$ denotes emission per unit of output without pollution abatement. The firm must always pay a polluting tax, which is linear in relation to total pollution, te. Here, t indicates the tax rate on pollution. The cost of abatement is $a\xi^b y + f$, where $a > 0$, $b > 1$ and $f > 0$. That is, when abating the pollution, firms must pay not only a variable cost ($a\xi^b y$) but also a fixed cost (f), which represents the investment in technology, machines and equipment. The profit function for firms turning to adopt abatement technology is defined as:

$$\pi(z) = zk^{\alpha} - rk - te - a\xi^b y - f, \tag{3}$$

where e is defined in Equation (2).

For firms without abatement (i.e., $\xi = 0$), they would not need to pay abatement costs. However, they face a probability of being punished. Following Qi et al. (2021), we assume that firms not adopting abatement technology will be inspected by the environmental agencies with a probability p, and a proportion φ of their annual profits will be confiscated under such circumstances. Hence, the expected profit function for firms without abatement is[11]

$$\widetilde{\pi}(z) = (1-p\varphi)(zk^{\alpha} - rk - te) \tag{4}$$

We now discuss firms' optimal abatement decisions, considering the loan rate r as given. Next, we discuss the determination of the equilibrium loan rate through the bank's lending decisions. Due to the fixed abatement cost, firms must first decide whether to adopt abatement technology or not, and then decide the level of pollution abatement. To maximize its profits, if the firm decides to adopt the abatement, the optimal pollution abatement is

$$\xi^* = \left(\frac{t\theta}{ab}\right)^{\frac{1}{b-1}}, \tag{5}$$

which positively depends on emission intensity parameter θ and punishment parameter t, and it negatively depends on abatement cost parameters a and b. The profit then can be expressed as:

$$\pi(z) = \mu zk^{\alpha} - rk - f, \tag{6}$$

where $\mu = 1 - t\theta + \frac{(b-1)\xi^*}{b} t\theta$. Thus, the optimal demand for capital is

$$k(r,z) = \left(\frac{\mu z\alpha}{r}\right)^{\frac{1}{1-\alpha}}. \tag{7}$$

The optimal profit for a firm with abatement is given by

$$\pi(z) = (1-\alpha)\mu^{\frac{1}{1-\alpha}} z^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} - f. \tag{8}$$

Regarding a firm without abatement, it chooses the capital k to maximize its profit function $\widetilde{\pi}(z)$. The optimal capital demand is

$$\widetilde{k}(r,z) = \left(\frac{\widetilde{\mu} z\alpha}{r}\right)^{\frac{1}{1-\alpha}}, \tag{9}$$

where $\widetilde{\mu} = 1 - t\theta$. Compared to the firm with abatement, given the productivity z, the capital demand of the firm without abatement is relatively small as $\widetilde{\mu} < \mu$. This is because firms with green technology pay less polluting tax to the government and hence produce more. The optimal profit for firms without the abatement is given by

$$\widetilde{\pi}(z) = (1-p\varphi)(1-\alpha)\widetilde{\mu}^{\frac{1}{1-\alpha}} z^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}. \tag{10}$$

Equations (6) and (10) imply that $\pi(z)$ and $\widetilde{\pi}(z)$ are both increasing in z. As shown in Fig. 1, the slope of $\pi(z)$ is steeper than that of $\widetilde{\pi}(z)$ since $\widetilde{\mu} < \mu$. Fig. 1 illustrates the predicted firm responses to the green credit regulation. In this figure, the solid blue line corresponds to the profit of firms with abatement, while the solid red line corresponds to the profit of firms without abatement.

3.2. Model without green credit policy

To determine the interest rate, we assume that an individual bank has full bargaining power to set a loan rate for each borrower. In particular, the bank selects a loan rate to maximize its profit given a firm's loan demand

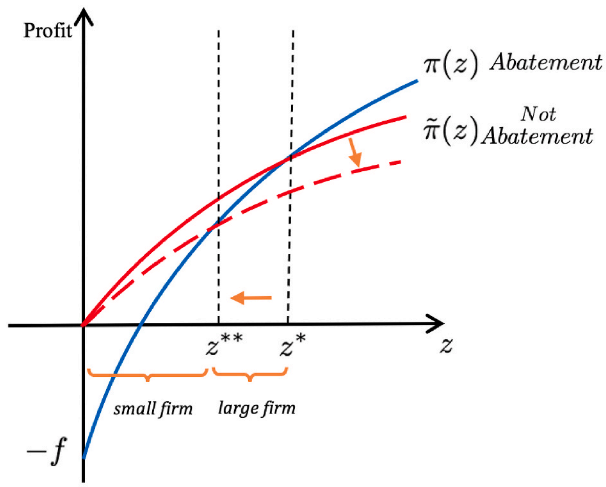
$$\max_r \left(r - r^d\right) k^d(r,z), \tag{11}$$

[8] Similar evidence could also be found now and then according to the governmental information disclosure and the news reports. See, e.g., http://www.njdaily.cn/2018/1221/1743467.shtml.

[9] For instance, according to the official document enacted by the Banking Regulatory Bureau of Jiangxi Province, banks failing to achieve the green loan targets might face severer inspections in the form of limited business scope, ceasing setup of new branches and official discourse, among others. http://www.xinhuanet.com/fortune/2017-08/14/c_1121480233.htm.

[10] While China underwent an interest rate liberalization process in 2015, the "benchmark rate adjusted by a certain float" pattern in determining interest rates charged on bank loans to firms has not been substantively altered. The pricing of deposit interest rates is still under the soft regulation of window guidance and self-regulatory market interest rate pricing mechanisms.

[11] The probability of the firm succeeding in evading the inspection is $1 - p$.



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.

where $k^d(r,z)$ is given by Equation (7) or (9), and r^d is the deposit rate, which is exogenously given. The optimal condition for a loan rate is given by:

$$r = \frac{1}{\alpha} r^d. \tag{12}$$

The above equation indicates that, in the absence of green credit policy, banks will set an identical loan rate for each firm regardless of the pollution emission level.

The optimal demand for capital is given by:

$$k = \begin{cases} \left(\frac{\alpha^2 \mu z}{r^d}\right)^{\frac{1}{1-\alpha}}, & \text{if abatement} \\ \left(\frac{\alpha^2 \widetilde{\mu} z}{r^d}\right)^{\frac{1}{1-\alpha}}, & \text{if no abatement} \end{cases} \tag{13}$$

The optimal output, profit and emissions for a firm adopting abatement technology are given by:

$$y(z) = z^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2 \mu}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{14}$$

$$\pi(z) = (1-\alpha)(z\mu)^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f, \tag{15}$$

$$e(z) = (1-\xi)\theta y = (1-\xi)\theta z^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2 \mu}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{16}$$

For a firm that does not adopt abatement technology, we have

$$\widetilde{y}(z) = z^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2 \widetilde{\mu}}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{17}$$

$$\widetilde{\pi}(z) = (1-p\varphi)(1-\alpha)(z\widetilde{\mu})^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{18}$$

$$\widetilde{e}(z) = \theta z^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2 \widetilde{\mu}}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{19}$$

where $\widetilde{\mu} < \mu$.

We now discuss the decision on adopting abatement technology for a marginal firm that is indifferent with abatement or not. We have the condition for the threshold of productivity z^*

$$(1-\alpha)(z^*\mu)^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f = (1-p\varphi)(1-\alpha)(z^*\widetilde{\mu})^{\frac{1}{1-\alpha}} \left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{20}$$

which further implies

$$z^* = \left[\frac{f}{(1-\alpha)\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} \left(\mu^{\frac{1}{1-\alpha}} - (1-p\varphi)\widetilde{\mu}^{\frac{1}{1-\alpha}}\right)}\right]^{1-\alpha}. \tag{21}$$

For any firm with $z > z^*$, it would choose to abate pollution, otherwise, the firm would not abate.[12] Therefore, we can write the optimal abatement decision as

$$\xi = \begin{cases} \xi^* & \text{if } z > z^* \\ 0 & \text{otherwise} \end{cases} \tag{22}$$

Therefore, as shown in Fig. 1, when there is no strict green loan regulation, whether firms choose to abate depends on the cutoff Z^*. Apparently, large firms are more likely to adopt the abatement technology and have relatively lower emission intensity. This prediction is not only consistent with the facts (see Figure A1), but it also accords with the literature (Qi et al., 2021).[13]

3.3. Impact of green credit policy

We now introduce the green credit policy into the banking sector. An

[12] Note that if the relative fixed cost for abatement f is sufficiently large such that $z^* > z_{\max}$, then none of the firms will adopt green technology.
[13] As shown in Figure A1 about the relationship between a firm's emission intensity and its size, we similarly find that the larger that the firm is, the lower that its emission intensity becomes.

additional cost is incurred for a bank providing a loan to a firm without abatement.[14] For firms adopting clean technology through abatement, their loans from banks are not affected by the policy. For analytical convenience, we assume that the cost function takes a linear form, i.e., $g(e) = \psi e$, where $\psi > 0$. The optimization problem for an individual bank to offer loans to firms without abatement now becomes[15]

$$\max_r (r - r^d)k^d(r,z) - g(e), \tag{23}$$

where $k^d(r,z)$ is given by Equation (9). The optimal condition implies that:

$$r(\psi) = \frac{1}{1-\psi\frac{\theta}{\alpha\tilde{\mu}}}\frac{r^d}{\alpha}. \tag{24}$$

Obviously, the green credit policy increases the loan rate because $\psi > 0$. Given the loan rate, we can apply the previous analysis to derive the firm's optimal profit. It can be shown that the optimal capital, output and profit and emission for firms without abatement are, respectively, given by

$$\tilde{k}(z) = \left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right]^{\frac{1}{1-\alpha}}\left(\frac{\tilde{\mu}z\alpha^2}{r^d}\right)^{\frac{1}{1-\alpha}}, \tag{25}$$

$$\tilde{y}(z) = \left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right]^{\frac{\alpha}{1-\alpha}} z^{\frac{1}{1-\alpha}}\left(\frac{\tilde{\mu}\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}, \tag{26}$$

$$\tilde{\pi}(z) = (1-p\varphi)(1-\alpha)\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right]^{\frac{\alpha}{1-\alpha}}(\tilde{\mu}z)^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} \tag{27}$$

$$\tilde{e}(z) = \theta\tilde{y}(z) \tag{28}$$

The productivity of the marginal firm, which is indifferent with abatement or not, is now determined by:

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

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

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

implying that the new threshold z^{**} is less than the original threshold z^* since $\left(1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right)^{\frac{\alpha}{1-\alpha}}$ is less than one. As illustrated in Figure 1, when green credit policy comes, formerly polluting firms will face increased financing costs and subsequently decreased profits. Their profit curve denoted by the solid red line starts to move downward toward the dashed red line. The new cutoff immediately causes firms that are indifferent with pollution abatement to redecide whether to continue not to abate pollution, to be punished by the government and then face disadvantages in soliciting loans, or to begin to abate pollution to receive more opportunities for loans with lower costs in return.

For any firm with productivity $z \in (z^{**}, z^*)$, the green credit policy shifts these firms from the nonabatement type to the abatement type. Therefore, their changes in the optimal decisions are given by[16]

$$\Delta\log r^H = 0, \tag{31}$$

$$\Delta\log y^H = \frac{\alpha}{1-\alpha}\log\frac{\mu}{\tilde{\mu}}, \tag{32}$$

$$\Delta\log k^H = \frac{1}{1-\alpha}\log\frac{\mu}{\tilde{\mu}}, \tag{33}$$

$$\Delta\log\pi^H = \log\left[\frac{(1-\alpha)(\mu z)^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f}{(1-p\varphi)(1-\alpha)(z\tilde{\mu})^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}}\right], \tag{34}$$

$$\Delta\log e^H = \log(1-\xi^*) + \frac{\alpha}{1-\alpha}\log\frac{\mu}{\tilde{\mu}}. \tag{35}$$

For the pollution intensity, the change is given by $\log(1-\xi^*)$, which is less than zero. That is, they decrease their emission intensity by investing in abatement.

For any firm with productivity z that satisfies $z < z^{**}$, the green credit policy will not change its abatement strategy. Therefore, the changes in the optimal decisions are given by:

$$\Delta\log r^L = -\log\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right], \tag{36}$$

$$\Delta\log y^L = \frac{\alpha}{1-\alpha}\log\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right], \tag{37}$$

$$\Delta\log k^L = \frac{1}{1-\alpha}\log\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right], \tag{38}$$

$$\Delta\log\pi^L = \frac{\alpha}{1-\alpha}\log\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right], \tag{39}$$

$$\Delta\log e^L = \frac{\alpha}{1-\alpha}\log\left[1-\psi\frac{\theta}{\alpha\tilde{\mu}}\right] \tag{40}$$

For the pollution intensity, the change is simply zero. That is, the emission intensity of these firms would not change.

From Equations (31) and (36), we immediately have $\Delta\log r^L > \Delta\log r^H = 0$. Then, as for the impact on loan conditions of firms without pollution abatement, we have the following proposition:

Proposition 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.*

It is straightforward to show that $\Delta\log y^L < 0 < \Delta\log y^H$ and $\Delta\log k^L < 0 < \Delta\log k^H$, implying that the impact of green credit policy is stronger for small nonabatement firms. Moreover, if the number of firms switching from non-abatement to abatement is relatively small, the anti-pollution credit policy would reduce the average sales and investments

[14] According to the Guideline on Green Credit of 2012, banks' achievement assessments relating to the implementation of green credit regulation serve as an important basis for governmental regulatory ratings on banks, as well as banks' market access and their managers' achievement. Naturally, as for banks, additional costs such as loan risks, compromised institutional and personal reputations, and the narrowing of certificated business scopes might be generated when lending to firms with high environmental credit risks.

[15] The optimization problem for banks to lend to firms with abatement is the same as Equation (11). Therefore, firms already adopting abatement would not change their behavior even after the green credit policy shock.

[16] The changes in output stem from Equations (14) and (17); the change in profit comes from Equations (15) and (18); and the change in total emission stems from Equations (16) and (19).

of firms. As for the change in profit, both $\Delta \log \pi^H$ and $\Delta \log \pi^L$ are less than zero.[17] However, their relationship is ambiguous. To summarize, regarding the impact on economic performance of firms without pollution abatement, we have the following proposition:

Proposition 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.*

From the above discussion, we know that, compared with small firms, large firms decrease their pollution intensity relatively more by investing in abatement technology. As a result, how the total pollution emissions are reduced is dissimilar: large firms reduce their pollution emission by declining their pollution intensity (see Equation (35)); small firms reduce their pollution emission by declining their output (see Equation (40)). When ξ^* is close to one, total emission reduction by large firms is relatively high. Therefore, in terms of the impact on environmental performance of firms without pollution abatement, we have the following proposition when ξ^* is large enough:

Proposition 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.*

3.4. Discussion

Micro-foundation for the bank-firm regulation structure To align our model settings with green credit practices in China, the above model does not examine a pure market response. Banks, as required by their regulators, should take into account of environmental risk. In the online Appendix B, we provide a formal delegation theory based upon Aghion and Tirole (1997) to rationalize the regulatory structure related to green credit in China.[18] As long as banks' lending policies can reduce pollution through the credit allocation channel, the central government can benefit more than directly monitoring the firms by itself because the regulation by itself might not be effective due to the sufficiently weak monitoring capacity of the government. Government agencies, especially those at the base layer, are often hampered by inadequate executive capacities. Without sufficient funding, personnel and effective operational structures, governmental branches are incapable of persistently inspecting firms, whereas, the commercial banks have information advantage regarding firm-level decisions. Banks are empowered with better ability to collect full information about the borrowers before them. Incorporating environmental consideration, which was formerly omitted into routine pre-loan investigation, does not necessarily increase too much burden on banks; rather, the outcomes might be equivalent to much severer environmental regulation. Capital flow will thus be restrained from banks into more polluting firms without governmental expenditures. In this sense, green loan scheme is not a substitution but a sound complementary mechanism to administrative governance.

Identify the causal effects of the green credit policy When attempting to identify the causal effects of the green credit policy, the major challenge is that enforcement is strengthened uniformly for all firms after 2011. According to our theoretical model, green credit policy only increases the loan rates of firms without abatement, and this impact is stronger for small nonabatement firms because firms without abatement generally have higher environmental risk. Naturally, firms that are reluctant to abate pollution will be more prone to being punished by the government and thus have worse compliance records. Therefore, to overcome the above challenge, we take advantage of firms' observed violations of environmental laws to identify the causal effects of green credit regulation on firms' loan conditions and their economic and environmental responses. The reasons are threefold. First, firms' violations of environmental laws and regulations are directly indicative of their compliance and abatement status. When approving loans, banks are obliged to collect information to identify borrowers with major environmental and social risks. Further, banks should be more prudent in lending to these borrowers to avoid being deterred by banking regulators. Second, firms' past and future violations are autocorrelated. When testing the probability that firms might be punished again in a certain year after 2011 if they were or were not punished before 2011, we find that 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.[19] Last but not the least, firms' initial violations are unrelated to the enactment of the new law on green credit. As shown in Figure A2 in the online Appendix, even though environmental regulation has become increasingly stringent in recent years with steadily increasing administrative penalty cases, there is no trend break for either the total number of incompliant cases or the number in the regression sample around 2012, the enactment year of the Guideline on Green Credit. This evidence also demonstrates that the Chinese government did not change other environmental regulations around 2012 in a manner related to noncompliance with the green credit regulation.[20]

Provided that firms' past and future violations are autocorrelated and that firms' initial violations are irrelevant to the enactment of the new law, firms' observed violations of environmental laws are constructed as the basis for such a green credit policy. Before the empirical analysis, as an initial step, we divide firms borrowing from commercial banks into two groups: those punished by administrative agencies due to breaches of the law and those not punished. After controlling for the sub-branch-year fixed effect, quarter fixed effect and firm fixed effect, the residual of interest floating between the two groups is presented in Figure A3 in the online Appendix.[21] The figure clearly shows that, before the effective date of the Guideline on Green Credit in February 2012, differences between the two groups 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

[17] $\Delta \log \pi^H$ is less than zero because $(1-\alpha)(z\mu)^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}} - f < (1-p\varphi)(1-\alpha)(z\widetilde{\mu})^{\frac{1}{1-\alpha}}\left(\frac{\alpha^2}{r^d}\right)^{\frac{\alpha}{1-\alpha}}$ when $z \in (z^{**}, z^*)$.

[18] The main idea of our theory is that the government and the commercial banks cannot directly observe the firms' pollution level. The government suffers a more severe information friction, thus has a relatively high monitoring cost (or weak monitoring capacity) for the environmental regulation. Whereas, the commercial banks are able to collect firm's financial variables and thus have information advantage regarding the firms' production/investment and can infer the firms' polluting behaviors. As a result, delegating the regulatory authority to the commercial banks could be an optimal choice for the central government. Note that if the government's cost for monitoring micro-level pollution is sufficiently large, it is rational for the government to allocate the regulation right to commercial banks despite the agency problem between the government and the commercial banks.

[19] Column (1) of Table A1 in the Appendix corresponds to the probability that a firm is punished in the years after 2011 if it has not been punished before 2011; Column (2) shows the probability that a firm is punished in the years after 2011 if it has been punished earlier; and Column (3) is the difference between them. The much greater probability in Column (2) compared with that in Column (1) proves that violators are more prone to breaking the law again.

[20] Furthermore, we test the growth rate of the numbers of incompliant manufacturing firms in provinces across years and the change in case numbers before and after 2012. The ambiguous regression results in all of the columns in Table A2 in the Appendix suggest that the severity of sanction did not suddenly increase around 2012. Overall, there were not changes in the nature and quantity of violations after the introduction of the new law.

[21] Figure A3 shows the loan rate gap between punished and nonpunished firms at quarterly and monthly frequencies, respectively. The left two figures include all samples, while the right panels exclude samples in the last three quarters to eliminate possible disturbance brought by the last three points in the right side of the vertical line.

grew increasingly higher than that of law-abiding firms.

Motivated by our theoretical model and these facts, we execute a serial of rigorous empirical tests in the next section to analyze the relationship more formally.

4. Empirical strategy

4.1. Empirical specification

We consider the following specification for our empirical investigation:

$$Floating_{fctmp} = \beta_0 \text{Punish}_{ft} + \beta_1 \text{Punish}_{ft} \times \text{Post}_{tm} + \sum_t \gamma_t Z_f \times \phi_t + \phi_f + \phi_{ctm} + \phi_p + \varepsilon_{fctm}, \tag{41}$$

where $Floating_{fctmp}$ is the 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, calculated as the ratio of the float of the loan rate over the benchmark interest rate set by the People's Bank of China to the benchmark interest rate.[22] It reflects banks' measurements of the credit risk of borrowers when issuing loans. $Punish_{ft}$ is a dummy variable that equals 1 when firm f is punished by an administrative agency in year t and onward and equals 0 otherwise.[23] $Post_{tm}$ is also a dummy variable which takes the value of 0 for all times preceding February 2012, the effective date of the Guideline on Green Credit in China, and takes the value of 1 from February 2012 onward. Z_f is a set of initial performance metrics for firm f, including fixed assets and labor employment. ϕ_f, ϕ_{ctm}, and ϕ_p represent firm, sub-branch times year-month pair fixed effect, and maturity fixed effects, respectively.[24] ε_{fctm} is the error term that captures all unobserved factors that influence $Floating_{fctmp}$. We are interested in coefficient β_1, which estimates the effect of green credit on firms' loan costs. The value of β_1 should be positive according to our model predictions. Grounded in the design, we also use alternative measurements of firms' loan costs and environmental credit risk to examine the robustness of our results.

Further, based on Equation (4.1), we estimate the following equation to identify the profound consequences that China's tightened green credit regulations might have on the financial, economic and environmental performance of firms:

$$Y_{ft} = \beta_0 \text{Punish}_{ft} + \beta_1 \text{Punish}_{ft} \times \text{Post}_t + \sum_t \gamma_t Z_f \times \phi_t + \phi_f + \phi_t + \varepsilon_{ft} \tag{42}$$

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). Other controlling terms included in Equation (4.1) are similar to those used in Equation (4.1).

[22] The benchmark rate is a percentage value that the central bank sets as a reference rate for financial sectors to define the price of credit in the country. For example, when a firm borrows from a commercial bank at interest rate 6%, its floating ratio with respect to benchmark loan interest rate 5% is 20 with a unit of percentage.

[23] To grasp the impact of green credit regulation more accurately by excluding the potential influence confounded by change of punishment probability, we omit observations regarding firms punished after 2012 from our sample.

[24] In general, bank loans in China are lent with maturity term of less than 3 months, 3–6 months, 6 months to 1 year, and more than 1 year.

4.2. Data

4.2.1. Firms' bank loan and economic data

The bank loan data from 2009 to 2015 are provided by one of China's "Big Five" banks.[25] The data are representative of Chinese banks' credit practices since they cover firms in 31 provinces with different credit ratings, with different sizes and ownership features and operating in different sectors.[26] The data record detailed information on loans issued to firms, including the value of loans approved, interest rates, maturity, dates of lending, overdue values, and credit ratings, among others.

To obtain information about a firm's initial performance, we merge the bank loan data with the Annual Survey of Industrial Firms (ASIF), which is one of the most comprehensive and widely used Chinese firm-level datasets maintained by the National Bureau of Statistics of China (NBSC). The ASIF is an unbalanced panel providing comprehensive information on above-scale enterprises for 1998 to 2013 with 3,964,478 observations.[27] It contains detailed information on each Chinese firm including data on ownership structures, employment, capital stock, gross output, value added, and firm identification (e.g., company name), as well as complete information on the three major forms of accounting statements (i.e., balance sheets, profit and loss accounts, and cash flow statements).

In the absence of consistent firm identification codes, we merge the bank loan data with ASIF data using firms' names. The merged dataset contains information about approximately 130,000 unique firm loans made from 2009 to 2015, accounting for approximately half of all loans issued to manufacturing firms by a given bank.

4.2.2. Firms' environmental penalty data

As the most comprehensive and easily accessible source to evaluate firms' compliance with laws, data on environmental administrative penalties are used to construct measures of firm environmental credit risk in our study. The data on firms' environmental penalties are collected by a well-known Chinese environmental NGO the Institute of Public and Environmental Affairs (IPEA), as administrative authorities are obliged to disclose information on environmental penalties they levy on firms, persons or other organizations through several channels including the Internet. In China, when contravening the law, firms may be given warning, fine, compliance order, or some combination thereof by the government to enforce compliance with regulatory legislation. 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. In integrating these data with the above merged dataset by firm name, we can identify borrowers engaged in illegal conduct and those that are not.

[25] The Industrial and Commercial Bank of China (ICBC), the Bank of China (BOC), the Construction Bank of China (CBC), the Agricultural Bank of China (ABC), and the Bank of Communications (BOC) are the top five commercial banks in China. They are also state-owned banks. In our analysis, to rule out impact from the introduction of green credit practice in 2007, we start our analysis from 2009.

[26] To determine whether one of the "Big-five" banks in our dataset is preferably lending to certain sectors, we plot the sectoral distribution of its loans. As we can tell from Figure A4 in the Appendix, regardless of the loan number share or loan amount share, the loans are distributed across all sectors without being targeted to a certain few sectors.

[27] Until 2007, these surveys cover all state-owned enterprises as well as large and medium-sized non-state-owned enterprises with annual sales of above five million RMB (approximately 770,000 US dollars under the current exchange rate). After 2007, smaller state-owned enterprises with annual sales of below five million RMB are excluded from the surveys. From 2011 onward, the ASIF surveys only cover manufacturing firms with annual sales above 20 million RMB. The data panel covers all state-owned and non-state-owned industrial firms with annual sales above 5 million RMB.

4.2.3. Firms' pollution data

To assess the impact of punitive green credit on firms' environmental performance, we use environmental data at the firm level.[28] Data on firms' pollution emissions are collected from the *Annual Environmental Survey of Polluting Firms* (AESPF) of China. Established by the Ministry of Ecology and Environment (Formerly as the Ministry of Environmental Protection) in the 1980s in a bid to document the state of environmental pollution and abatement in China, the AESPF provides rich information on firms' environment-related performance, including data on emissions of main pollutants (including COD, NO_x, SO_2, NH_3, dust, solid waste, noise etc.), pollution abatement equipment (such as sewage treatment devices and air cleaning devices), and energy consumption (such as the use of freshwater, recycle water, and coal), among other data. In terms of the survey's scope, firms are surveyed as long as one of their emitted pollutants fall within the top 85% of the total emissions volume of that pollutant at the county level.[29] These firms are included in a key-point environmental survey list. Once listed, they are obliged to complete uniform statistical statements sent by environmental authorities to report a broad range of environmental information.

5. Empirical results

5.1. Baseline results

Table 1 presents the estimation results of Equation (4.1). In Column (1), to capture the different effects of green loan regulation within firms across time upon borrowing from a certain sub-branch bank, we control for the firm fixed effect and sub-branch times year-month pair fixed effect.[30] Column (2) adds a set of initial characteristics of firms closely related to their loans (fixed assets and labor employment) to the equation, while Column (3) alternatively adds maturity fixed effect since the interest rate charged on loans is positively associated with the length of loan maturity. Column (4) adds all of the above fixed effects and controls. In all of the columns, our estimates of β_1 in Equation (4.1) are significantly positive.[31] Consistent with Proposition 1, we find that the strength of green credit regulation positively affects the spread of a firm's loan interest rate.[32]

Taking Column (4) as our preferred baseline results, we find that 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% (1.012/9.911) increase in the floating ratio of a firm's loan interest rate.

As an important assumption of our DID identification strategy, different over-time changes are solely caused by the reinforcement of green credit regulations in 2012 and not by any pre-existing differential time trend across firms. To test this assumption, we replace the interaction between the punish dummy and post dummy in Equation (4.1) with the sum of the interaction terms between the punish dummy and all of the year dummies. In Fig. 2, we plot estimated yearly effects of whether a firm has been punished on the floating ratio of the interest rate upon borrowing from banks. We see that the correlation between punishment and the outcome variables displays no significant pretrends before 2012, but it undergoes a sharp and permanent break after 2012. These results support the parallel trends assumption and imply that our estimated effects of firms' punishment and the floating of their bank loan rates are indeed driven by heterogeneous change occurring around that time.

Table 1
Baseline results.

	(1) Floating	(2) Floating	(3) Floating	(4) 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).

5.2. Robustness of baseline results

In this subsection, we test the robustness of the baseline estimates using alternative measurements of the dependent variable and independent variable. We also employ three different sets of empirical exercises to address potential endogeneity issues.

5.2.1. Alternative measures of firms' loan costs

We first substitute other measures of firms' loan costs for the floating ratio of loan rate to the benchmark interest rate $Floating_{fctmp}$ used in the baseline regression and re-estimate Equation (4.1). In Table 2, the dependent variables in Columns (1) and (2) are the first alternative measures of firms' loan costs using the actual interest rate charged on a firm's loans borrowed from commercial banks. Columns (3) and (4) estimate the impact on the float of interest rate (i.e., the gap between the loan rate and benchmark interest rate).[33] As shown in Columns (1) to

[28] We merge these data with firms' environmental penalty data by firm name to identify the impact of green credit policy on firms' environmental performance.

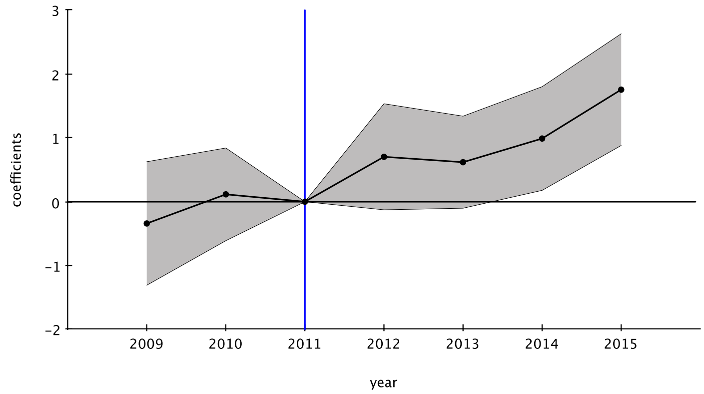
[29] In early phases, the data only covered enterprises and other entities (at or above the county level) that emit pollutants; township enterprises were included in the database starting in 1997. From 2001, the scope, frequency, main indicators, and reporting methods of the environmental survey have stabilized; i.e., the basic 85% selection principle for sources of industrial pollution remains unchanged.

[30] The inclusion of month in the fixed effect is due to variation in the bank's willingness to lend across different months. As observed by Cao et al. (2018), banks are particularly reluctant to lend at the end of each year upon achievement evaluation.

[31] As seen in Table 1, the estimated coefficients of β_0 are negative but insignificant, which might occur because green finance had not been seriously implemented by commercial banks before the Guideline on Green Credit of 2012. In addition, since firms with greater paying ability due to abundant assets secured are all too often more polluting firms, banks tend to lend to them out of profit maximization.

[32] In addition to clustering over firms in the baseline results, we also calculate standard errors by clustering over industries, sub-branches, and two-way clustering over sub-branches and industries, sub-branches and firms, and industries and firms. These estimates are reported in Columns (1) to (5) of Table A3 in the Appendix, respectively. Our baseline results are robust to these alternative clustering methods.

[33] Suppose that a firm borrows from bank at a 6% interest rate while the benchmark loan interest rate is 5%, then the float of interest rate is 1 percentage whereas the loan rate here is 6 percentage. The floating ratio of the interest rate should be 20%, which equals the float of interest rate divided by the benchmark loan interest rate.



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.

Fig. 2. Year-by-year dynamic effects of green credit regulation on firms' loan rate.

Table 2
Alternative measure of firm's loan costs.

	(1)	(2)	(3)	(4)	(5)	(6)
	Loan Rate		Float of Rate		Loan Amount	
Punish × Post	0.0528***	0.0591***	0.0479***	0.0553***	−0.113***	−0.0963***
	(0.0188)	(0.0190)	(0.0185)	(0.0188)	(0.0264)	(0.0266)
Punish	−0.0246	−0.0338	−0.0224	−0.0304	0.0855***	0.0909***
	(0.0282)	(0.0276)	(0.0279)	(0.0273)	(0.0302)	(0.0303)
Sub-Branch × Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Maturity FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level Controls	No	Yes	No	Yes	No	Yes
Observations	126,994	120,821	126,994	120,821	126,994	120,821
R-squared	0.866	0.869	0.702	0.706	0.863	0.866

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels. Robust standard errors are corrected for clustering at the firm level in parentheses. Sub-branch times year-month fixed effects, firm fixed effects, maturity fixed effects and firm-level controls are controlled in all Columns. Firm-level controls including firms' initial variables (the log of fixed assets, log of labor employment) are only included in the even columns.

Column (4), the coefficients remain significantly positive. They are also consistent with our model predictions and with the baseline results shown in Table 1.

Later, to better determine the impact of green credit regulations on loan amounts that firms could borrow from the bank, we use relative loan amount as the dependent variable.[34] Our estimates in Columns (5) and (6) of Table 2 show that, 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. Therefore, 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.

Second, considering that firms might borrow from a certain sub-branch bank more than once in reality, we also test the impact on the averaged floating ratio of firms' loan rates. Rather than treating each loan separately, as in our baseline regression, we aggregate the sample into month-firm level, quarter-firm level, and year-firm level and present the estimates in Columns (1)–(2), Columns (3)–(4), and Columns (5)–(6) of Table 3, respectively. The odd columns take simple average ratios for aggregation, while floating ratios in the even columns are weighted averages using the loan amount as the weight. Columns (1) to (6) of Table 3 show that our baseline results are robust to these adjustments.

5.2.2. Alternative measures of firms' environmental credit risk

Since our focus is on the effect of green credit regulations on firms' access to financial support from banks, it is important to show that our results are robust to different ways of measuring the environmental credit risk faced by firms. We hereby conduct two sets of exercises.

First, we show the robustness of our results using industry-level pollution intensity as replacements. In addition to firms' compliance with environmental regulations and laws, whether a firm belongs to a heavily polluting and resource-consuming industry should also be an important determinant for issuing loans, as stipulated by the Guideline on Green Credit and by related regulatory documents. We therefore introduce an interaction between whether firms operate in "two high, one overcapacity" industries and a post year dummy and obtain the

[34] Here, the relative loan amount is calculated by the amount of each loan divided by total loan amount issued by its corresponding lending sub-branch bank then times 100.

Table 3
Robustness check by loan rate averaged by maturity-firm-time.

	(1)	(2)	(3)	(4)	(5)	(6)
	Monthly Average		Quarterly Average		Yearly Average	
	Simple	Weighted	Simple	Weighted	Simple	Weighted
Punish × Post	0.973***	0.990***	0.962***	1.025***	0.764**	0.836**
	(0.319)	(0.319)	(0.331)	(0.332)	(0.340)	(0.344)
Punish	−0.787*	−0.802*	−1.012**	−1.106**	−1.056**	−1.175**
	(0.469)	(0.469)	(0.475)	(0.475)	(0.514)	(0.518)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Maturity FE	Yes	Yes	Yes	Yes	Yes	Yes
Sub-Branch × Year-Month FE	Yes	Yes	No	No	No	No
Sub-Branch × Year-Quarter FE	No	No	Yes	Yes	No	No
Sub-Branch × Year FE	No	No	No	No	Yes	Yes
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	80,898	80,780	57,323	57,236	38,938	38,905
R-squared	0.676	0.676	0.669	0.669	0.665	0.664

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. Firm fixed effect and maturity fixed effect are controlled for in all columns. Sub-branch times year-month fixed effects, Sub-branch times year-quarter fixed effects and Sub-branch times year fixed effects are controlled for in Columns (1)–(2), (3)–(4) and (5)–(6), respectively. Firm level controls include firms' initial variables (log of fixed assets, log of employment).

Table 4
Alternative measures of firms' environmental credit risks.

	(1)	(2)	(3)	(4)	(5)
	Floating	Floating	Floating	Floating	Floating
Two-High-One-Overcap × Post	1.241***				
	(0.436)				
Pollution_Intensity × Post		6.708***	5.639***	2.721	34.74**
		(2.101)	(2.176)	(1.687)	(15.12)
Sub-Branch × Year-Month FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Maturity FE	Yes	Yes	Yes	Yes	Yes
Firm-level Controls	Yes	Yes	Yes	Yes	Yes
Observations	120,821	120,821	120,821	120,821	120,821
R-squared	0.694	0.694	0.694	0.694	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 fixed effects, firm fixed effects, maturity fixed effects and firm-level controls are controlled for in all columns. Firm-level controls include firms' initial variables (the log of fixed assets, log of labor employment).

coefficient presented in Column (1) of Table 4.[35] The coefficient is positive and significant at 1% level, the magnitude of which also barely changed. Columns (2) to (5) of Table 4 present estimates of the regression using industrial pollution intensity by the share of wastewater over total emissions, shares of waste air over total emissions, wastewater per unit of output, and waste air per unit of output, respectively.[36] In all columns and across all specifications, our estimates are positive and significant. Overall, firms in industries with higher pollution intensity experience a significant relative increase in their loan costs after 2012.

Second, to rule out potential influence from change of punishment probability, we re-define the punish variable by treating firms punished before the Guideline consistently as 1 throughout the whole sample period. In this alternative measure, the punish variable is not time-varying.[37] The impact of green loan regulations should increase the loan rates of firms with past violations since they are more likely to be punished in the future (see the above discussion in Subsection 3.4). As shown in Table A4, our results remain consistent and are comparable to those in the baseline table (0.987 in Column 4 of Table A4 versus 1.012 in Column 4 of Table 1).

5.2.3. Endogeneity issues

Till now, one might still concern that whether our key explanatory variable, *punish*, is exogenous to individual firms. To alleviate this concern and others like it, we conduct several different empirical exercises thereafter.

First, we employ the PSM method to address potential endogeneity concerns raised by the nonrandom selection of governmental sanctions. To find the closest group from the sample of non-punished firms to compare to the sample of punished firms, we execute the yearly one-to-one match without replacement based on firms' characteristics, including profits, sales, employment, total assets and total liabilities. After obtaining comparable firm pairs with similar characteristics on grounds of estimated propensity scores, we examine differential responses of the floating ratio of the loan rate among punished and non-punished firms using the matched sample. Table A5 shows the summary statistics of the PSM. It indicates that the distribution of

[35] "Two high, one overcapacity" sectors are heavily polluting and energy-consuming sectors or industries with overloaded production capacity. Whether firms operate in "two high, one overcapacity" sectors could easily be identified according to clear guidance by regulatory agencies. For example, the Catalogue for Guiding Industry Restructuring in China provides detailed lists on production (products, specifications, and techniques) that must be encouraged, restricted or eliminated. In the Green Credit Implementation Key Standards introduced by the CBRC in 2014, Appendix II on the Audit Standards includes a list of high-risk projects that are subject to special rules, and Appendix III includes a basic rating system for banks to use in assessing borrowers' environmental and social risk management practices. We mainly rely on Appendix IV, which provides a recommended list of "two high, one over-capacity" sectors and their industry codes to identify whether firms operate in these industries.

[36] Here, the share of wastewater (waste air) is the proportion of industrial wastewater (waste air) to total wastewater emissions (waste air) of all manufacturing industries. Wastewater (waste air) pollution per unit is the industrial emissions of wastewater (waste air) relative to output of all manufacturing firms.

[37] If we use this alternative measure of the punish variable as the baseline results, all of our following empirical tests remain unchanged. These results will be provided upon request.

observations in the matched treatment and comparison group is balanced. Table 5 presents our estimates of the matched sample of firm pairs. The coefficient, 1.766, in Column (4) which aggregately adds all of the fixed effect and controls, is comparable to that of Column (4) in the baseline results (1.012) in Table 1, suggesting that, even after controlling for potential selection bias, there is still strong evidence in favor of our model predictions.

Then, we conduct a placebo test by randomly selecting firms and designating them as "firms punished" by authorities 5000 times and repeatedly running regressions following Equation (4.1). Figure A5 in the online Appendix presents the distribution of estimated coefficients for the 5000 rounds of estimations. The mean value of estimated coefficients is 0.0022, while the standard deviation is 0.3678. Since our true estimates (e.g., 1.012 in Column (4) of Table 1) fall far beyond the 95th percentile of the 5000 estimates, the significant effect of strengthened enforcement of green credit regulation on a firm's loan cost is unlikely driven by chance. In other words, our results are not biased due to any omitted variables.

Furthermore, we employ several instrumental variables to implement the tests. In the first place, we use shift-share instrumental variables to run two-stages-least-square (2SLS) regressions. The variable $IV_{c,i,t}$ is constructed as follows,

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

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 punishment probability in later years, but these factors are less likely to directly cause the change in loan cost (Egger et al., 2019; Amiti and Konings, 2007). As shown in the results for the first stage regression of the instrumental variables reported in Table A6 in the online Appendix, the estimates indicate that our instrument significantly predicts firms' violation of environmental laws. Columns (1) and (2) in Table 6 report our second-stage estimates. Consistent with our model predictions, the estimated coefficients are significantly positive.

In the second place, we use the average number of administrative punishment on firms excluding the focal firm in city c and industry i as instrumental variables to run the 2SLS regressions. The results are respectively shown in Columns (3) and (4) in Table 6. In both columns, our estimates are positive and significant, supporting positive effects of strengthened environmental credit regulation on firms' borrowing costs.

Table 5
Results of propensity score matching.

	(1) Floating	(2) Floating	(3) Floating	(4) Floating
Punish × Post	1.866**	1.777**	1.853**	1.766**
	(0.850)	(0.795)	(0.849)	(0.793)
Punish	0.467	1.122	0.423	1.074
	(1.409)	(1.598)	(1.402)	(1.593)
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	11,223	11,193	11,223	11,193
R-squared	0.847	0.849	0.847	0.849

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 fixed effects, firm fixed effects are controlled for in all columns. Maturity fixed effects are only controlled for in Columns (3) and (4). Firm-level controls including firms' initial variables (the log of fixed assets, log of labor employment) are only added in even columns.

Table 6
Results using instrumental variables estimation.

	(1) Floating	(2) Floating	(3) Floating	(4) Floating
Punish × Post	4.441***	4.754***	1.043**	1.271***
	(1.603)	(1.543)	(0.452)	(0.467)
Punish	−5.284	−6.165	−0.001	−0.108
	(5.665)	(6.375)	(0.808)	(0.809)
Sub-Branch × Year-Month FE	Yes	Yes	Yes	Yes
Fim FE	Yes	Yes	Yes	Yes
Maturity FE	Yes	Yes	Yes	Yes
Firm-level Controls	No	Yes	No	Yes
Observations	119,895	113,923	126,994	120,821
Kleibergen-Paap rk LM statistic Chi-sq(1)	11.729	9.458	202.27	203.06
Kleibergen-Paap Wald rk F statistic	4.417	3.600	414.63	406.04
Cragg-Donald Wald F	291.600	228.676	35,132.81	33,115.28

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 fixed effects, firm fixed effects, maturity fixed effects are controlled for in all columns. Firm-level controls including firms' initial variables (the log of fixed assets, log of labor employment) are only added in even columns.

5.3. Heterogeneous effects

Our sample covers firms of different ownership types. There are also substantial differences in firm productivity levels within industries. Given these rich variations in firms' characters, it is interesting to examine the heterogeneous effects of strengthened green credit regulation on firms' bank loan costs.

In China, state-owned enterprises (SOEs) might enjoy much easier access to external financing provided by state-owned banks due to their tighter connection with the government, while privately-owned enterprises (POEs) might not.[38] Therefore, we predict stronger impacts of green credit regulation on POEs.[39] To examine the effect of green credit regulation on firms varied by ownership, we introduce a triple interaction term *Punish* × *Post* × *POE*, where *POE* is a dummy variable equaling 1 for POEs and 0 otherwise. As shown in Columns (1) and (2) of Table 7, the effect of green credit regulation on floating ratio of firms' loan rate is significantly positive for POEs relative to SOEs. Consequently, POEs become more burdensome when exposed to the policy reform.

In addition to the heterogeneous responses of firms brought by ownership difference, firms' size might also matter. It is conspicuous that firm size is closely related to a firm's productivity, profitability, and in the end, ability to pay bank loans. More importantly, based on our theoretical model, faced with strengthened green credit regulation, larger formerly incompliant firms will begin to adopt abatement technologies and their loans will be less impacted by the policy, as Proposition 1 predicts. However, for small firms who are still unwilling to improve their environmental performance, their loan costs will be more affected by the shock.

To study the different effects of green credit regulations on firms

[38] For example, Boyreau-Debray and Wei (2005) point out that Chinese banks - mostly state owned - tend to more easily offer credit to SOEs. Song et al. (2011) also showed that SOEs finance more than 30% of their investments through bank loans compared to the value of less than 10% for domestic private firms in China.

[39] The identification of firms' ownership relies on their registered information during loan applications.

Table 7
Heterogeneous effects of green credit on loan.

	(1)	(2)	(3)	(4)	(5)	(6)
	Ownership		log(Fixed Asset)		log(Total Asset)	
	Floating	Floating	Floating	Floating	Floating	Floating
Punish × Post × POE	1.387*	1.383*				
	(0.800)	(0.789)				
Punish × Post × Size			−0.305*	−0.311*	−0.404**	−0.414**
			(0.173)	(0.172)	(0.191)	(0.188)
Punish × Post	−0.328	−0.171	4.389**	4.435**	5.993**	6.115**
	(0.713)	(0.708)	(1.959)	(1.945)	(2.397)	(2.376)
POE × Post	−0.268	−0.368				
	(0.289)	(0.298)				
Punish × POE	−4.378***	−3.899***				
	(1.444)	(1.414)				
Punish × Size			0.831***	0.628**	0.736**	0.589*
			(0.302)	(0.295)	(0.326)	(0.317)
Size × Post			−0.199***	0.587***	−0.178**	0.112
			(0.0754)	(0.140)	(0.0850)	(0.163)
Punish	3.208**	2.685**	−9.470***	−7.376**	−9.493**	−7.795**
	(1.352)	(1.322)	(3.290)	(3.222)	(4.005)	(3.912)
Sub-Branch × Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Maturity FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level Controls	No	Yes	No	Yes	No	Yes
Observations	123,664	117,605	126,500	120,821	126,994	120,821
R-squared	0.690	0.691	0.692	0.694	0.692	0.694

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. Sub-branch times year-month fixed effects, firm fixed effects, maturity fixed effects are controlled in all columns. Firm-level controls including firms' initial variables (the log of fixed assets, log of labor employment) are only added in even columns.

varied by size, we introduce a triple interaction term *Punish* × *Post* × *Size*, where *Size* is indicated by logarithm of firms' fixed assets in Columns (3) and (4) of Table 7, then by logarithm of firms' total asset in Columns (5) and (6) of Table 7, respectively.[40] The negative estimates from Columns (3) to (6) show that, the increase in the loan interest rate spread due to green loan regulation is less shouldered by larger punished firms. In other words, consistent with Proposition 1, small firms with noncompliance records with environmental regulations saw a larger increase in the interest rate after 2012.

5.4. Extensive margin

The strengthened green credit regulation could also exert extensive margin effects, along with the above intensive margin effects, as banks would probably to stop lending to firms with significant environmental risks. To further test that, in Table 8, the dependent variable *LoanDummy* is a dummy variable equalling 1 if firm *f* still have access to a bank loan at year *t* and 0 otherwise.[41] The significantly negative coefficients for the interaction term Punish × Post in Columns (1) and (2) indicate the notably decreased chances for firms with terrible environmental performance to borrow from banks.[42] In Columns (3) and (4), the estimated coefficients of the triple interaction term, where *size* is indicated by the logarithm of firms' total assets, are significantly positive.[43] This outcome means that the larger that the firm is, the weaker the negative impact is of green credit regulation on punished firms' access to loans. Small firms unsurprisingly face more hurdles when soliciting financial support from banks. Hence, green credit regulation indeed exerts a negative shock on the intensive and extensive margins of firms' loans borrowed from banks, and those effects are much stronger for small

Table 8
Impace of green credit on firms' access to loan.

	(1)	(2)	(3)	(4)
	LoanDummy	LoanDummy	LoanDummy	LoanDummy
Punish × Post	−0.0622***	−0.0491***	−0.378***	−0.291**
	(0.0181)	(0.0187)	(0.137)	(0.139)
Punish	0.0313	0.0361	0.727***	0.582***
	(0.0249)	(0.0255)	(0.188)	(0.195)
Punish × Post × lnTA			0.0281**	0.0205*
			(0.0110)	(0.0111)
Punish × lnTA			−0.0580***	−0.0453***
			(0.0151)	(0.0157)
Post × lnTA			−0.0337***	−0.0600***
			(0.00368)	(0.00726)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Firm-level controls	No	Yes	No	Yes
Observations	56,541	53,249	56,541	53,249
R-squared	0.423	0.426	0.426	0.428

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. All regressions include controls for year fixed effects and firm fixed effects. Firm-level controls (log of fixed asset and log of employment) are added in all even columns.

[40] The average impacts shown by coefficients in Columns (4) and (6) equal to −0.311*10.239+4.435=1.251 and −0.414*11.624+6.115=1.303 respectively, where 10.239 and 11.624 are the mean of (log) fixed asset and total asset respectively. These values are comparable with the coefficient in the benchmark table. Similar pattern also exists in the impact on extensive margin.

[41] The dependent variable *LoanDummy* is constructed at firm-year level. Hence, we add firm fixed effects and year fixed effects in the empirical regression.

[42] In Figure A6 in the Appendix, we plot the yearly estimated effect of green credit regulation on firms' access to loan. Similarly, we observe no significant pre-trends before 2012 but a break in trend in 2012.

[43] When using fixed assets to indicate firms' sizes, our results still hold. Due to space limitation, we only use the logarithm of firms' total assets to denote *size* in the subsequent analyses.

firms.

Here, another issue related is whether the effect of green credit regulation is brought by this extensive margin adjustment. To address this question, we use the balanced sample to re-estimate Equation (4.1). Only firms existing throughout the sample period are selected in the new sample. As shown in Table A7 in the online Appendix, our empirical results are still robust to this sample adjustment.

6. Effects on firms' economic and environmental performance

Section 5 verifies the causality between green credit regulation stringency and increase in firms' external financing burdens. The significantly enlarged barrier to bank loans should thus influence firms' operations. To this end, we present a series of tests in this section to further assess the impacts of green credit regulation on the financial, economic and environmental performances of firms. Noting the key role of firm size in the effect of green loan regulation according to our model predictions and the initial findings in Section 4, we therefore perform the subsequent analyses by considering firm size.

6.1. Firms' financial and economic performance

In Table 9, estimates reported in Columns (1) to (7) of Panel A reveal the overall effect of green loan regulation on firms' liabilities, total assets, fixed assets, investments, sales, profits, and employment, respectively, while the results in Panel B underline the firms' responses varied according to their size. Year fixed effects and firm fixed effects are controlled for in all of the columns of both panels. As shown in Column (1) in Panel A, after the reinforcement of green credit regulation in 2012, firms have less liabilities due to increased loan costs, decreased loan amounts and less accessible bank loans. The weakened external financial support further reduces their total assets, fixed assets and investments. We then turn to examine impacts on firms' operational performance. The dependent variables in Columns (5) to (7) in Panel A are the logarithm of sales, logarithm of profits, and logarithm of the employee number, respectively. Estimated coefficients are negative with statistical significance. The results show that, for firms regulated by green loans policies, their sales, profits, and employees have consistently decreased. Stated differently, with lessened financial support, firms with more environmental credit risk are experiencing difficulties in expanding their operations and production.

However, a different story unfolds when distinguishing the reactions of firms with different sizes. We hereby introduce a triple interaction term $Punish \times Post \times lnTA$, where firm size is denoted by the natural logarithm of its total assets. As shown by the positive coefficient of the triple term in Column (1) in Panel B of Table 9, after 2012, large punished firms experience a relatively small decrease in liabilities, compared with small punished firms. The impacts on their total assets, fixed assets, investments, and their operational performance including sales and employment, as shown by the triple interaction terms in Columns (2) to (5) and (7) in Panel B, are also less negatively impacted.[44] However, there is no observable difference pertaining to the impacts on profits of firms varied by their size (see Column (6) in Panel B). Consistent with our theoretical predictions, the plausible explanation is that, large firms might expend more on emission reduction investment to guarantee their better environmental compliance in the loan application.[45] Facilitated by improved environmental performance, large firms are more likely to access loans with relatively low interest rates, further justifying the smaller impact on their total liability.

6.2. Firms' environmental performance

By urging banks to incorporate environmental credit risks into their lending activities, the goal of strengthening the enforcement of green credit regulations is to promote greening of the economy. Has the goal yet been achieved?

We first examine the emission reduction effect of green loan regulation. The negative and statistically significant estimates in Columns (1) to (4) in Panel A of Table 10 show that, in comparison with law-abiding firms, those with poor compliance records considerably reduce their pollution emissions after 2012. Additionally, the mostly negative and economically significant estimates in Panel B suggest that large firms are reducing their emissions relatively more. These results are highly consistent with our model's predictions.

More stringent enforcement of green finance regulation in China seems to be promoting the "greening" of manufacturing production, as observed from firms' emissions reductions in the foregoing analyses. It is thus natural to ask: are firms truly actively becoming environmentally conscious? What inherent mechanisms play roles in these effects?

To answer these questions, we examine the impacts on firms' pollution intensity and pollution abatement endeavors. Dependent variables applied in Columns (1) to (5) of Table 11 are wastewater per unit of output, COD per unit of output, NH3–N per unit of output, SO2 per unit of output, and water pollutant treatment facilities per unit of output respectively. Overall, the strengthened green credit regulation has ambiguous impacts on firm's emission intensity of main pollutants according to Columns (1) to (4) in Panel A of Table 11. Firms are reluctant to adopt more end-of-pipe pollution abatement facilities, as evidenced by the insignificant coefficients in the last column of Panel A. This outcome, jointly with the significantly decreased outputs as shown in Table 9 implies that, emission reductions are merely a natural consequence of output decreases.

When attempting to explore firms' adjustments in pollution intensity differentiated by their size, we find that large firms are more responsive to the green loan regulation. The estimated coefficients for triple interaction term in Columns (1) to (4) in Panel B are negative and significant at the 1% or 5% level. Moreover, according to Column (5) in Panel B of Table 11, large punished firms tend to adopt more pollution abatement facilities, better echoing the significantly negative coefficients of the triple term in Columns (1) to (4) of this table. That is, among firms with unsatisfying legal compliance records, large ones will start to abate pollution in response to the shock of green loan regulation.

Combining all of the estimated results from Table 9 to Table 11, we find that, as for large and small firms, the economic and environmental impacts from green loan regulation and the mechanisms underlying the impacts are different. Due to the new policy shock, only small firms with records of noncompliance with environmental regulations saw a larger increase in the interest rate, decrease in loans, as well as decrease in investment and sales. Their total emissions are lowered due to output reductions, while pollution intensity remains unchanged. Large firms with poor performance in legal compliance choose to invest in pollution abatement, which helps them to avoid being "punished" by banks when borrowing from them and hence are not affected in terms of loan rate and access to loans after the reinforcement of green credit regulation. Relative to the small firms, their liabilities, total assets, fixed assets, investments and sales are less impacted. As a result, the strengthened

[44] The average impacts shown by coefficients in Panel B are dominated by the impact on small firms. For example, the average impact on Liability implied by Panel B equals 0.0396*11.624–0.573 = −0.113, where 11.624 is the mean of (log) total assets. This average value is comparable with the coefficient of the interaction term in Panel A. A similar pattern also exists in the subsequent Tables 10 and 11.

[45] As our theoretical model predicts, firms' investment into abatement weaken the negative effect of green credit policy on their loan, investment and output. However, the impact on profit is ambiguous.

Table 9
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

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. All regressions include controls for year fixed effects and firm fixed effects.

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

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. All regressions include controls for year fixed effects and firm fixed effects.

regulation improves large firms' environmental performance by scaling back their overall pollution emissions and pollution intensity. This outcome might occur because large firms place a large proportion of their investments into emission control by, for example, adopting more abatement facilities. Therefore, this strengthened green credit regulation effectively motivates large formerly noncompliant firms to responsively upgrade emission technology thus turning green; while small noncompliant firms are forced to produce less due to fewer loans with higher costs.

7. Conclusion

Under the notion that financial markets can play an important role in environmental performance, green credit initiatives have been widely adopted across countries. However, evidence for how firms' environmental credit risk has been translated into their loan costs and how the changed costs further impact firms' performances remains scant. This paper estimates the impact of green credit, which is conditioned on the environmental performance of borrowers, on the credit conditions and firms' economic and environmental performance. Essentially, we want to test how financial markets internalize the potential adverse costs of environmental penalties on borrowing firms.

We first present a simple theoretical model. In our model, a bank chooses to float a firm's loan rate over the benchmark interest rate set by the central bank to absorb the firm's environmental risk. When the enforcement of green loan regulation is strengthened, banks raise their loan rates to firms without abatement. As a result, a new cutoff of firm productivity thus emerges for those that are indifferent with pollution abatement since firms without abatement will face raised financing costs. More stringent green loan regulation induces large incompliant firms to adopt abatement technologies, and their loans are thus less impacted by the policy than those of their counterparts. However, for small firms that remain unwilling to improve their environmental performance, their loan costs will be more affected.

We then perform the empirical analysis within the context of an increase in the degree of the enforcement of the Chinese green credit policy in 2012. Using disaggregated firm-level data and a DID strategy, we find that, after 2012, firms with a record of noncompliance with

Table 11
Impace of green credit on firms' emission intensity.

	(1)	(2)	(3)	(4)	(5)
	Wastewater	COD	NH3–N	SO2	Water Equip
Panel A: Firm's emission intensity					
Punish × Post	−0.015	−0.030*	0.005	0.033**	0.001
	(0.019)	(0.017)	(0.022)	(0.015)	(0.005)
Punish	−0.083	−0.099	−0.194**	0.026	0.045***
	(0.065)	(0.064)	(0.084)	(0.048)	(0.016)
Observations	149,034	147,129	111,495	121,454	112,256
R-squared	0.888	0.892	0.865	0.909	0.843
Panel B: Firm's emission intensity by size					
Punish × Post × lnTA	−0.047***	−0.060***	−0.064***	−0.020**	0.006*
	(0.012)	(0.012)	(0.014)	(0.009)	(0.004)
Punish × Post	0.523***	0.657***	0.745***	0.247**	−0.068*
	(0.144)	(0.139)	(0.171)	(0.110)	(0.040)
Punish × lnTA	0.013	0.046	−0.057	−0.032	−0.008
	(0.045)	(0.043)	(0.055)	(0.035)	(0.011)
Post × lnTA	0.037***	0.046***	0.058***	0.037***	0.001
	(0.006)	(0.006)	(0.007)	(0.005)	(0.002)
Punish	−0.229	−0.636	0.479	0.402	0.138
	(0.520)	(0.507)	(0.655)	(0.417)	(0.124)
Observations	139,905	138,127	104,895	114,091	106,292
R-squared	0.886	0.889	0.862	0.907	0.839
Panels A and B:					
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

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. All regressions include controls for year fixed effects and firm fixed effects.

environmental regulations saw a larger increase in the interest rate, decrease in loans, and more difficulty in access to loans. Basically, our baseline results reveal that strengthened green credit regulation explains a 10.2% increase in the floating ratio of the loan rate for firms with noncompliance records relative to their law-abiding counterparts. We find the effects to be more pronounced for POEs and small firms. We further prove that large punished firms experience a relatively smaller decrease in liabilities, compared with small punished firms. Their total assets, fixed assets, investments, and operational performance including sales and employees, are also less negatively impacted. In regard to the environmental performance, although all of these firms have reduced their pollution emission, how the reductions are realized is dissimilar: large firms place a large proportion of their investments into emission control by, for example, adopting more abatement facilities while small firms simply choose to produce less. Stated differently, upon the green loan regulation, the large noncompliant firms responsively upgrade emission technology, thus turning green, while small noncompliant firms are forced to produce less due to smaller loans with higher costs. In a certain sense, financial markets are able to internalize the potential adverse costs of environmental fines of borrowing firms. Further, green credit would be seen as a sound complementary mechanism to administrations, especially in countries with limited government capacity.

Our empirical findings about the effects of strengthened green loan regulation and the underlying mechanism varied by firms' sizes have important policy implications, especially for developing countries often bothered with weak environmental regulation capacities. First, the green credit policy, which attempts to integrate the environmental credit risk into the loan conditions of all borrowing firms, is potentially promising in pollution reduction. More stringent green credit regulation effectively induces large incompliant firms to responsively upgrade emission technology, thus turning green. However, as for small penalized firms, their emission reductions are brought by reductions in output. Therefore, to design finer green loan policies, developing countries need to consider the different reactions of large firms and abundant long tail small firms. On the one hand, a punitive green credit program might be more efficient for large firms, while on the other hand, to improve small firms' environmental performance without shrinking production, perhaps a preferential loan policy specifically helping small firms to upgrade their emission reduction technologies and adopt pollution abatement facilities should be adopted.[46] Perhaps a possible solution is to use the combination of these two tools thereof.

Another important implication of our research concerns how to reshape the institutional structure between the government and banks. The success of the green loan program in China is partly due to the additional force on banks from the government. In addition to banks' duties set in the guidelines, there are also provisions providing that financial sectors' achievement in green credit practices constitutes an important determinant of the achievement assessment of banks and their managers. To this end, a series of rules and regulations and the key indicators of implementation of green credit were subsequently enacted. Banks might also be sanctioned when violating the green loan regulations. Due to the different regulatory structures and government-bank relationships, other developing countries should consider their own characteristics when developing their own green loan programs.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jdeveco.2021.102683.

[46] Broadly speaking, green credit includes incentive green credit and punitive green credit. The former one aims to provide preferential financial support for natural conservative projects including projects to better manage natural resources and biodiversity protection. Meanwhile, the latter one aims to reduce the return on investment of polluting projects by raising the cost and compliance hurdle to finance polluting projects. It needs integration of environmental risks into banks' strategies and risk management systems and thus becomes relying on firms' environmental performance. Green credit system in this research belongs to the latter category.

References

Aghion, Philippe, Tirole, Jean, 1997. Formal and real authority in organizations. J. Polit. Econ. 105 (1), 1–29.

Amiti, Mary, Konings, Jozef, December 2007. Trade liberalization, intermediate inputs, and productivity: evidence from Indonesia. Am. Econ. Rev. 97 (5), 1611–1638.

Andersen, Dana C., 2016. Credit constraints, technology upgrading, and the environment. Journal of the Association of Environmental and Resource Economists 3 (2), 283–319.

Annicchiarico, Barbara, Di Dio, Fabio, 2015. Environmental policy and macroeconomic dynamics in a new Keynesian model. J. Environ. Econ. Manag. 69, 1–21.

Baker, Malcolm, Bergstresser, Daniel, George, Serafeim, Wurgler, Jeffrey, 2018. Financing the Response to Climate Change: the Pricing and Ownership of US Green Bonds. Technical Report. National Bureau of Economic Research.

Bauer, Rob, Hann, Daniel, 2010. Corporate Environmental Management and Credit Risk. Maastricht University.

Becker, Randy, Henderson, Vernon, 2000. Effects of air quality regulations on polluting industries. J. Polit. Econ. 108 (2), 379–421.

Berman, Eli, Bui, Linda TM., 2001. Environmental regulation and productivity: evidence from oil refineries. Rev. Econ. Stat. 83 (3), 498–510.

Boyreau-Debray, Genevieve, Wei, Shang-Jin, 2005. Pitfalls of a State-Dominated Financial System: the Case of China. Technical Report. national bureau of Economic research.

Cai, Xiqian, Lu, Yi, Wu, Mingqin, Yu, Linhui, 2016. Does environmental regulation drive away inbound foreign direct investment? Evidence from a quasi-natural experiment in China. J. Dev. Econ. 123, 73–85.

Cao, Yiming, Raymond, Fisman, Lin, Hui, Wang, Yongxiang, 2018. Target Setting and Allocative Inefficiency in Lending: Evidence from Two Chinese Banks. NBER Working Paper No. 24961.

Chava, Sudheer, 2014. Environmental externalities and cost of capital. Management science. Manag. Sci. 60 (9), 2223–2247.

Chay, Kenneth Y., Greenstone, Michael, 2005. Does air quality matter? Evidence from the housing market. J. Polit. Econ. 113 (2), 376–424.

Chen, Zhao, Kahn, Matthew E., Liu, Yu, Wang, Zhi, 2018. The consequences of spatially differentiated water pollution regulation in China. J. Environ. Econ. Manag. 88, 468–485.

Egger, Peter H., Erhardt, Katharina, Lassmann, Andrea, 2019. Immigration and firms' integration in international production networks. Eur. Econ. Rev. 111, 1–34.

Foster, Andrew D., Gutierrez, Emilio, May 2013. The informational role of voluntary certification: evidence from the Mexican clean industry program. Am. Econ. Rev. 103 (3), 303–308.

Goss, Allen, Roberts, Gordon S., Jul 2011. The impact of corporate social responsibility on the cost of bank loans. J. Bank. Finance 35 (7), 1794–1810.

Greenstone, Michael, 2002. The impacts of environmental regulations on industrial activity: evidence from the 1970 and 1977 clean air act amendments and the census of manufactures. J. Polit. Econ. 110 (6), 1175–1219.

Greenstone, Michael, Hanna, Rema, 2014. Environmental regulations, air and water pollution, and infant mortality in India. Am. Econ. Rev. 104 (10), 3038–3072.

Greenstone, Michael, List, John A., Syverson, Chad, 2012. The Effects of Environmental Regulation on the Competitiveness of US Manufacturing. NBER Working Paper (NO.18392).

Gutiérrez, Emilio, Teshima, Kensuke, 2018. Abatement expenditures, technology choice, and environmental performance: evidence from firm responses to import competition in Mexico. J. Dev. Econ. 133, 264–274.

Heinkel, Robert, Kraus, Alan, Zechner, Josef, Dec 2011. The effect of green investment on corporate behavior. J. Financ. Quant. Anal. 36 (4), 431–449.

Henderson, J Vernon, 1996. Effects of air quality regulation. Am. Econ. Rev. 86 (4), 789–789.

Hong, Harrison, Kacperczyk, Marcin, 2009. The price of sin: the effects of social norms on markets. J. Financ. Econ. 93 (1), 15–36.

Hong, Harrison, Andrew Karolyi, G., Scheinkman, José A., 2019. Climate Finance. Review of Financial Studies.

Keller, Wolfgang, Levinson, Arik, 2002. Pollution abatement costs and foreign direct investment inflows to US states. Rev. Econ. Stat. 84 (4), 691–703.

Krueger, Philipp, Sautner, Zacharias, Starks, Laura T., 2019. The Importance of Climate Risks for Institutional Investors. Review of Financial Studies.

Mep, 2010. Enterprise Social Responsibility Report. Technical Report. Ministry of Environmental Protection.

Nelson, Randy A., Tom, Tietenberg, Donihue, Michael R., 1993. Differential environmental regulation: effects on electric utility capital turnover and emissions. Rev. Econ. Stat. 75 (2), 368–373.

Qi, Ji, Tang, Xin, Xi, Xican, 2021. The size distribution of firms and industrial water pollution: a quantitative analysis of China. *American Economic Journal: Macroeconomics*, January 13 (1), 151–183.

Riedl, Arno, Smeets, Paul, 2017. Why do investors hold socially responsible mutual funds? *The Journal of Finance*, Sep 72 (6), 2505–2550.

Sharfman, Mark, Fernando, Chitru S., 2008. Environmental risk management and the cost of capital. Strat. Manag. J. 29 (6), 569–592.

Shi, Xinzheng, Xu, Zhufeng, 2018. Environmental regulation and firm exports: evidence from the eleventh five-year plan in China. J. Environ. Econ. Manag. 89, 187–200.

Song, Zheng, Storesletten, Kjetil, Zilibotti, Fabrizio, 2011. Growing like China. Am. Econ. Rev. 101 (1), 196–233.

Tang, Dragon Yongjun, Zhang, Yupu, 2020. Do shareholders benefit from green bonds? J. Corp. Finance, 101427.

Walker, W Reed, 2013. The transitional costs of sectoral reallocation: evidence from the clean air act and the workforce. Q. J. Econ. 128 (4), 1787–1835.