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Original Research

Green finance, fintech and environmental protection: Evidence from China

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A B S T R A C T

This paper is one of the first to offer a comprehensive analysis of the impact of green finance related policies in China, utilizing text analysis and panel data from 290 cities between 2011 and 2018. Employing the Semi-parametric Difference-in-Differences (SDID) we show that overall China's green finance related policies have led to a significant reduction in industrial gas emissions in the review period. Additionally, we found that Fintech development contributes to the depletion of sulphur dioxide emissions and has a positive impact on environmental protection investment initiatives. China is poised to be a global leader in green finance policy implementation and regulators need to accelerate the formulation of green finance products and enhance the capacity of financial institutions to offer green credit. While minimizing the systemic risk fintech poses, policy makers should encourage fintechs to actively participate in environmental protection initiatives that promote green consumption.

1. Introduction

China's green finance industry is growing rapidly, transforming the country's financial sector in the process. Although green finance has been a hot topic amongst researchers in recent years, it remains conceptually unclear (Dayong [1]. Green finance refers to financial investments targeted at environmental protection initiatives [2]. There are three main categories of green finance namely green-asset finance, credit & investments [3]. Green finance seeks to engage the private sector in the funding of environmental projects to bridge the gap left by insufficient public budgets (see Fig. 1).

Developing countries face many credit constraints that increase the likelihood of poor environmental performance, hence the need for active green finance policies [4]. It is the prerogative of governments in developing countries to develop and implement policies that promote green finance systems [5]. Financial instruments like green bonds are now being employed to ensure environmental projects are funded in a sustainable way. Green bonds are fixed income instruments aimed at supporting environmental projects. To increase uptake and narrow the green finance gap, these bonds often have several tax incentives attached to them [6].

Green finance has become a key policy concern for emerging economies. China's 13th Five Year Plan proposed the creation of a green financial system that encourages the private sector to play a more active role in sustainable development. Green bonds are favored by shareholders as they have the potential to increase firm value in the long run (J [7]. Although green finance is an increasingly important policy issue in China several barriers still exist at the operational micro and meso levels (M [8].

While there is still a need for greater coordination between policy makers and key stakeholders, green finance in China is already yielding positive results. There is an inverse relationship between green investment and CO_2 emissions [9]. Green financing alone cannot guarantee successful environmental protection initiatives, it has to be augmented by significant investment in both human capital and technological innovation [10]. Green finance is expected to play an important role in the attainment of climate change goals outlined in the Paris Agreement. China is at the forefront of green finance initiatives globally with most beneficiaries being developing countries with a stable political environment with significantly high levels of credit risk [11].

Green finance initiatives face complex risk dimensions that affect their overall performance. For example, carbon financing includes

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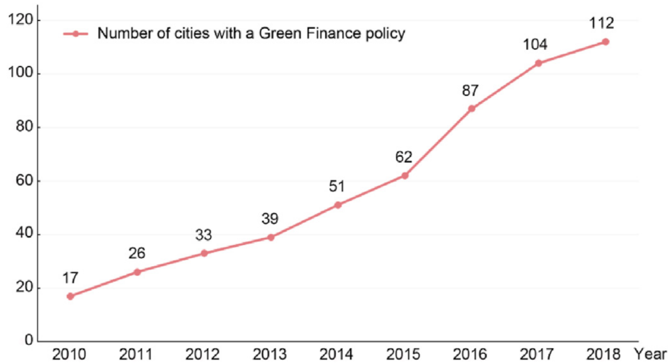

Fig. 1. Number of cities with a green finance related policy initiative
Source: Ruiyan database.

significant risks for financial institutions. To ensure the long-term sustainability of green finance projects, financial institutions need to hedge against associated risks (X [12]. Although green finance significantly reduces emissions, over the short-term it has a negative effect on highly polluting firm performance (D [13].

2. China's green finance gap

Green finance policies play a guiding role in credit supply to enterprises in areas with less developed financial ecosystems as well as state owned enterprises [14]. China is a global leader in green credit policy implementation. It is important for green finance policy to leverage technology and preexisting relationships between banks and enterprises (F [15].

Green finance policies that are based on strict carbon emission regulation often lead to a win-win scenario for both manufacturers and suppliers [16]. Green finance policies also have a positive impact on the manufacturing industry [17]. showed a positive correlation between green finance instruments and firm innovation, further concluding that green finance has the potential to play an imperative role in China's transition to intelligent and sustainable manufacturing. Increased scrutiny on green bonds in global capital markets is facilitating the development of a more dynamic green finance ecosystem in China [18].

In most emerging markets including China, the effectiveness of green finance initiatives is dependent on the level of economic development. Developed regions are more significantly impacted by bank green finance activities (X [19]. Green finance is essential for sustainable and clean production within the economy. By strengthening the integrity of green finance systems, governments can achieve their sustainable development goals [20]. Green finance policies require coordination amongst all stakeholders to improve effectiveness and guarantee continuity which is not always the case [21].

Commercial banks in China greatly value green management. Firms with comprehensive green management strategies can get access to significantly larger lines of credit [22]. Chinese state-owned banks are playing an increasingly leading role in the allocation of green finance in credit markets. This edge has come at a cost, as green finance initiatives tend to be more profitable for private banks than for state owned banks. State own banks are forced to take on greater risk to meet green finance policy objectives [23]. Banks should focus on encouraging green finance targeted at achieving green transitions based on stable prices and mature technology to achieve sustainable environmental outcomes (C [24]. To achieve optimal results, green finance policies should also consider the technology inter-dependencies which influence the whole financial system and value chains [25].

For green finance to achieve its objectives there is need for stronger regulations that remedy information asymmetry and moral hazards, while ensuring an optimal balance between ecology and finance (Y [26]. To close the green finance gap, there is need to develop sustainable investment vehicles based on long-term policy perspectives [27]. China's green transition financing model is one of the most comprehensive in the world and it is on track to be the global leader in green finance [28].

Predicated on the theoretical analysis presented above, we developed the following hypothesis:

I. Green finance policies promote positive environmental outcomes

2.1. Role of fintech in green finance

Fintech is poised to play a leading role in the provision of green finance through leveraging big data analytics and artificial intelligence to foster a green transition amongst consumers and small and medium-sized enterprises (SMEs) [29]. There is a research gap regarding the involvement of fintech in environmental protection efforts in China. This gap is attributed to many fintech companies not being actively involved in these efforts, except for Ant Groups' bespoke Ant Forest initiative. Ant forest is a model example of how fintech platforms can encourage consumers to actively participate in green finance projects. The award-winning initiative encourages a sustainable green transition amongst consumers and SMEs (H [30]. The Ant forest mini program encourages Alipay's consumers to reduce their carbon footprint by rewarding green behaviors such as walking, cycling, taking public transport, and paying utilities online. Users can accumulate these carbon savings and earn green energy which they can use to grow a virtual tree, which Alipay will eventually turn into a real tree as part of a desert reclamation project.

Other fintech companies are actively incorporating “green financial system” measures aimed at using technology to reduce carbon emissions and facilitate efficient resource utilization. Fintech has been credited with promoting the adoption of green agricultural practices in China by ensuring credit availability, addressing information asymmetry, and increasing trust amongst farming communities [31]. Empirical evidence shows that China's internet development has had a noticeable negative impact on energy consumption through promoting financial development and industrial upgrading [21].

As China's fintech ecosystem continues to expand, it is expected to play an important role in the country's transition to a new green financial system. Fintech platforms accelerate both the procurement and deployment of funds earmarked for environmental projects [32]. Green bonds can help boost the financial performance of fintech firms while providing a conduit for long term green investment [33]. Fintechs have the potential to accelerate China's transition to a new green financial system that will promote cleaner production through intelligent manufacturing and other green management processes.

Subsequently, we developed a 2nd and 3rd hypothesis.

II. Fintech development has a negative impact on SO_2 emissions in China
III. Fintech enhances environmental investment initiatives

3. Data and methodology

This study utilizes the research policy text analysis database to identify when related green finance policies were affected across

290 cities in China. The study period ranges from the year 2011–2018. To identify the relevant treatment effects, we utilized the following keywords: green finance, green bonds, green credit, green operations, and carbon finance. These green finance policy initiatives vary across each city, however they all have the same goal which is to promote environment protection initiatives.

Regulators in China are keen on achieving their climate and environmental protection targets and green finance has been identified as a key priority area. China is accelerating its efforts to create a green financial system aimed at helping the country meet its emission reduction targets and transition into a more sustainable model of industrial production. The visualization below shows how rapidly green finance policy initiatives have been enacted across China's cities.

3.1. Base model

Green finance policies in China include several follow up initiatives to ensure set targets are met. To analyze our first hypothesis a semi parametric difference-in-differences (SDID) model is utilized. SDID is best suited for the analysis of treatment effects based on non-experimental panel data with multiple rounds of policy measures [34]. The average treatment effect (ATT) on Chinese cities can be represented by equation (1) below.

$$ATT \equiv \mathbb{E}\left(y_{1t} - y_{0t} \mid d_t = 1\right) \tag{1}$$

Where, y_{1t} denotes the environmental variable of interest after green finance related policies are put into effect at time t and y_{0t} represents the same variable before the treatment effect, d_t shows whether a city enacted a green finance related policy at time t. When $t \neq 0$ after the baseline d is equal to 1.

To address the unevenness of characteristics between treated and untreated groups [35], suggests a reweighted estimate of the ATT given in equation (2).

$$\mathbb{E}\left(\frac{y_t - y_z}{\mathbb{P}(d_t = 1)} \times \frac{d_t - \pi(x_z)}{1 - \pi(x_z)}\right) \tag{2}$$

Abadie's weighted estimate (2) is unbiased if the following equations (3) and (4) hold.

$$\mathbb{E}(y_{1t} - y_{0t} \mid d_t = 1\ ,\ x_z\ ) = \mathbb{E}(y_{0t} - y_{0z} \mid d_t = 0\ ,\ x_z\ ) \tag{3}$$

$$\mathbb{P}(d_t = 1) > 0 \ and \ \pi(x_z)\ < 1 \tag{4}$$

Where, $y_t - y_z$ is the change in our environment interest variable between baseline z and time t. Baseline characteristics of the control variables are represented by x_z. The propensity score which represents the conditional probability of being part of the policy treatment group is denoted by the following identity: $\pi(x_z) \equiv \mathbb{P}(d_t = 1 \mid x_z)$. The propensity score for the SDID estimator can be estimated using a linear probability model (LPM), as suggested by Ref. [35] or a series logit estimator (SLE) postulated by Ref. [36].

The LPM propensity score can be derived from equation (5).

$$\widehat{\pi}(x_z) = \widehat{\gamma}_0 + \widehat{\gamma}_1\ \times\ x_1 + \sum_{i=1}^{k} \widehat{\gamma}_{2i} \times\ x_2^i \tag{5}$$

Where, parameters are estimated using the ordinary least squares (OLS) method and x_1 is a binary variable. The order of polynomial function used to approximate the propensity score for LPM is given as k and x_2^i is a continuous variable represented by the following expression: $x_2^i\ = \prod_{j=1}^{i} x_2$.

The SLE model produces the following propensity score:

$$\widehat{\pi}(x_z) = \wedge\left(\widehat{\gamma}_0 + \widehat{\gamma}_1\ \times\ x_1 + \sum_{k=1}^{k} \widehat{\gamma}_{2k} \times\ x_2^k\right) \tag{6}$$

Where, $\wedge(x)$ is represented by the logistic function (7).

$$\wedge(x) = \frac{e^x}{1 + e^x} \tag{7}$$

To measure the impact of green finance related policies this paper focuses on three environmental interest variables. The dependent variables are highlighted in the following expression; y_{it} [ln $ESO2_{\ it}$, ln DSD_{it} and $lnPSO2_{it}$], where $ESO2_{\ it}$ denotes emissions of industrial sulphur dioxide (SO_2), represents DSD_{it} discharge of industrial smoke and dust and $PSO2_{it}$ is the volume of industrial SO_2 produced. The environmental interest variables are measured in tonnes for each city, I, at time t. The binary treatment variable or time variable in our SDID model takes the value of 1 when a green finance related policy is affected and 0 at baseline (for cities without green finance related policies).

3.2. Control variables

The control variables or x_{it} employed in the model are the level of industrialization in each city, $Ind_{\ it}$, measured as a secondary industry value added as a percentage of gross domestic product (GDP). To control for the level of economic activity and size, we employed the GDP per capita represented by $GDPpc_{\ it}$ and the level of trade openness in each city, TOP_{it}.

3.3. Impact of fintech on environmental protection

China's fintech industry has grown expeditiously in the period under review. Our second hypothesis is dependent on the assumption that the fintech sector growth has contributed significantly to the decline of industrial gas emissions in Chinese cities. Fintech is central to a few green initiatives including the sharing economy. To test our second hypothesis, we utilize the econometric model specified below.

$$SO2_{it} = \alpha_0 +\ \alpha_1 Fintech_{it-1} + \alpha_c Control_{it-1} +\ \varepsilon_{it} \tag{8}$$

Where, the criterion variable $SO2_{it}$ represents SO_2 emissions in city, I, at time t and $Fintech_{it-1}$ is the lagged fintech variable and it is based on the Peking University digital financial inclusion index (PKU-DFIC) [37]. The Index utilizes Ant Group's comprehensive data on fintech usage across China including digitalization levels, coverage breath, usage depth and other key indicators. How these factors are weighted is included in the appendix section. Lagged control variables include city GDP per capita ($GDPpc_{\ it-1}$), level of trade openness (TOP_{it-1}), and industrialization level ($Ind_{\ it-1}$). To capture the state of pollution within each city we also include the current level of discharge of industrial smoke and dust which is represented by DSD_{it}.

$$SO2_{it} = \alpha_0 +\ \alpha_1 Fintech_{it-1} + \alpha_2 DSD_{it} + \alpha_3 GDPpc_{it-1} + \alpha_4 Ind_{it-1} + \alpha_5 TOP_{it-1} +\ \varepsilon_{it} \tag{9}$$

To test our 3rd and final hypothesis, we utilize provincial data on environmental protection investment. Fintech is expected to have a positive impact on environmental protection investment. The following econometric model is employed:

Table 1
Data characteristics.

Variable	Measurement	Source	Obs	Mean	SD	Min	Max
Sulphur Dioxide Emissions (*ESO2*)	Emissions of industrial Sulphur Dioxide in tonnes (log)	EPS (2019)	2,447	10.226	1.154	0.693	13.25
Smoke and Dust Discharge (*DSD*)	Discharge of industrial smoke and dust in tonnes (log)	EPS (2019)	2,186	9.781	1.168	2.398	15.458
Volume of Sulphur Dioxide (*PSO2*)	Volume of industrial Sulphur Dioxide in tonnes savings (log)	EPS (2019)	1,682	11.505	1.298	0.693	14.569
Fintech Index (*Fintech*)	PKU-DFIC (log)	Institute of Digital Finance, PKU (2019)	2,311	4.936	0.514	2.834	5.714
GDP per capita (*GDPpc*)	GDP per capita in RMB (log)	China City Yearbook (2010–2018)	2,528	10.601	0.593	8.576	13.056
Trade Openness (*TOP*)	Actual foreign investment USD 10,000 (log)	EPS (2019)	2,149	10.177	1.728	0.693	14.9469
Industrialization (*Ind*)	Secondary industry value added as a % of GDP (log)	EPS (2019)	2,585	3.843	0.271	2.402	4.497
Green Finance Related policy (*DID*)	Binary variable 1 for cities with policy & 0 for cities without	Research Policy text analysis database	2,601	0.204	0.403	0	1

$$EPI_{jt} = \alpha_0 + \alpha_1 Fintech_{jt-1} + \alpha_c Control_{jt-1} + \varepsilon_{jt} \quad (10)$$

Where, the dependent variable is environmental prevention investment denoted by EPI_{jt} for Chinese province, j, at time t. The level of fintech development in each province is given as $Fintech_{jt-1}$ which is a lagged variable. Control variables are similar to those employed for city level data with the addition of the rate of urbanization which is denoted by Urb_{jt-1}. We also expand our estimation model to include other environmental control variables namely, RRI_{jt}, which represents the recycling rate of solid industrial wastes and IWG_{jt} denoting the industrial waste gas emissions of in each province.

$$EPI_{jt} = \alpha_0 + \alpha_1 Fintech_{jt-1} + \alpha_2 RRI_{jt} + \alpha_3 IWG_{jt} + \alpha_4 GDPpc_{jt-1} + \alpha_5 Ind_{jt-1} + \alpha_6 TOP_{jt-1} + \alpha_7 Urb_{jt-1} + \varepsilon_{jt} \quad (11)$$

3.4. Cross sectional dependency

Panel data analysis cross sectional dependency can lead to spurious estimation results [38]. This study will conduct the Pesaran CD test which holds for fixed values of either T and N [39]. The Pesaran CD statistic is calculated using equation (12).

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \widehat{\rho}_{ij} \right) \xrightarrow{d} N(0,1) \quad (12)$$

Where, $\widehat{\rho}_{ij}$ the error term pairwise-correlation sample estimate. When $T \to \infty$ and $N \to \infty$ the tends to a normal distribution.

4. Results and discussions

This study utilizes City panel data from 290 Chinese cities between the years 2011 and 2018. The research policy text analysis database offers a comprehensive compendium of green finance related policies used as a treatment effect in this study. The text analysis database utilized in this study is the Ruiyan database (2020), published by China's main administrative authorities and regulatory bodies, at the national, provincial, and municipal levels. To determine our treatment group, we collated the following keywords from the database "green credit", "green bond", "green operation", and "carbon finance". Treatment group cities are shown in Table A1 in the appendix section. The earliest time of policy appearance is regarded as the policy initiation point. The table below shows the city data characteristics.

Green finance policies are expected to result in lower industrial gas emissions and lead to more investment in environmental protection projects within China's cities (see Table 1). Our SDID approach seeks to capture how these policies affect environmental outcomes across China. Table 2 below highlights the characteristics of our entire sample.

4.1. Green finance and environmental protection

To test whether or not green finance policies implemented across China's city led to positive environmental outcomes, we use the SDID estimator for both the LPM and SLE approaches. The LPM employed is of order 4. Dependent variables include SO_2 emissions and volume produced as well as discharge of industrial smoke and dust. SDID estimation results for both LPM and SLE are presented in Table 3.

SDID estimation results confirm our first hypothesis that green finance related policies leads to positive environmental outcomes. For both LPM and SLE models, our environmental interest variables have negative significant coefficients. Green finance related policies implemented between the period 2011 to 2018 in Chinese cities have had an overall negative impact on industrial gas emissions. Overall, using SLE results, green finance policies have led to a 38% decline in SO_2 emissions, a 28% decline in industrial gas and smoke discharge, and a 20% decline in the volume of SO_2 produced in China's cities in the period under review.

4.2. Fintech and environmental protection

To analyze the impact of fintech growth on industrial gas emissions outlined in our second hypothesis, we estimate equations (8) and (9) using the fixed effects (FE) model. Hausman test

Table 2
City policy data characteristics.

	Entire Sample	policy	Non-policy	diff.
DiD	0.20			
	[0.40]			
ES02	10.23	9.84	10.32	−0.48***
	[1.16]	[1.20]	[1.12]	(0.06)
DSD	9.78	9.56	9.84	−0.28***
	[1.17]	[1.20]	[1.15]	(0.06)
PSO2	11.51	11.37	11.53	−0.16*
	[1.30]	[1.26]	[1.30]	(0.08)
Ind	3.84	3.8	3.85	−0.05***
	[0.27]	[0.25]	[0.27]	(0.01)
TOP	10.18	10.85	10.02	0.83***
	[1.73]	[1.68]	[1.70]	(0.09)
GDPpc	10.60	10.70	10.58	0.12***
	[0.59]	[0.61]	[0.59]	(0.03)
observations	2601	530	2071	2601

Notes: Standard errors are in parentheses. Significance levels are denoted as follows: *p < 0.10, **p < 0.05, and ***p < 0.01.

Table 3
Effect of Green Finance related policies on environmental interest variables.

Environmental variable (ATT)	LPM			SLE		
	(1)	(2)	(3)	(4)	(5)	(6)
	ESO2	DSD	PSO2	ESO2	DSD	PS02
Constant	−0.432***	−0.349***	−0.211**	−0.381***	−0.281***	−0.199**
	(0.074)	(0.081)	(0.090)	(0.075)	(0.078)	(0.087)
Observations	2047	1771	1571	2066	1791	1590

Notes: Models (1), (2) and (3) are reported using an LPM of degree 4. Models (4), (5), and (6) are reported using default SLE. Standard errors are in parentheses. Significance levels are denoted as follows: *p < 0.10, **p < 0.05, and ***p < 0.01.

Table 4
Pesaran CD test results.

Model A ($SO2_{it}$)		Model B (EPI_{jt})	
CD statistic	P value	CD statistic	P value
88.058 ***	0.0000	−1.006	0.314

Note: H_0 errors are weakly cross-sectional dependent, $CD \sim N(0,1)$ and *** indicates significance at the 1% level.

Table 5
Impact of fintech on industrial gas emissions.

Variables	Criterion ($SO2_{it}$)	
	(1)	(2)
$Fintech_{it-1}$	−0.166***	−0.153***
	(0.060)	(0.049)
DSD_{it}		0.471***
		(0.052)
$GDPpc_{it-1}$	−1.172***	−0.832***
	(0.179)	(0.146)
TOP_{it-1}	0.011	0.014***
	(0.021)	(0.018)
Ind_{it-1}	1.491***	0.999***
	(0.237)	(0.180)
City FE	Yes	Yes
Year FE	Yes	Yes
Observations	1,797	1787
F Statistic	116.54***	133.16***
R^2	0.3774	0.5522

Notes: Standard errors are in parentheses. Model (1) and (2) report FE estimation with clustered standard errors Significance levels are denoted as follows: *p < 0.10, **p < 0.05, and ***p < 0.01.

Table 6
Impact of fintech on provincial environmental protection investment.

Variables	Criterion (EPI_{jt})	
	(1)	(2)
$Fintech_{jt-1}$	0.103**	0.117***
	(0.042)	(0.042)
RRI_{jt}		0.243**
		(0.113)
IWG_{jt}		−0.198
		(0.122)
$GDPpc_{Jt-1}$	0.054***	0.050***
	(0.017)	(0.017)
TOP_{Jt-1}	−0.560**	−0.456*
	(0.255)	(0.260)
Ind_{jt-1}	0.022***	0.016*
	(0.008)	(0.009)
Urb_{jt-1}	0.067***	0.054***
	(0.014)	(0.015)
Province FE	Yes	Yes
Year FE	Yes	Yes
Observations	248	248
F Statistic	16.40***	12.79***
R^2	0.2789	0.2989

Notes: Standard errors are in parentheses. Significance levels are denoted as follows: *p < 0.10, **p < 0.05, and ***p < 0.01.

results confirmed the suitability of our model. We adopted a similar approach to estimate equations (10) and (11) to determine the impact of fintech on environmental protection investment across China's provinces. Provincial data summary statistics are given in the appendix section. We conducted the Pesaran CD test for both models and results are reported in Table 4.

Pesaran CD results reject the null hypothesis for model A. Showing that city panel data errors are not weakly cross sectionally dependent. This result can be attributed to structural factors and economic shocks that affected industrial gas emissions in China's cities during the study period. To account for cross sectional dependency in city data analysis, we report our FE model estimation results with clustered standard errors. Model B shows that for provincial data analysis, we fail to reject the null hypothesis. Estimation results for both city data analysis are shown in Table 5 (see Table 6).

Our estimation results show that fintech development in China's cities has a significant negative impact on industrial gas emissions. Taking model (2) results from Table 5, the fintech variable has a coefficient of −0.153. This values indicates that a 1% increase in fintech development contributes to a 15% decline in SO_2 emissions across China's 290 cities. This result is a novel finding and it points to the role fintech can play in facilitating China's transition to a green financial system. Fintech firms can play an integral role in the provision of green finance and promote environmentally friendly consumption. This result confirms our second hypothesis.

Provincial level estimation results show that fintech promotes environmental protection investment. The fintech coefficient reported above in provincial model (2) is 0.117, which indicates that a 1% increase in fintech development at the provincial level enhances environmental protection investment by 11%. These results show that despite the systemic risks fintech in China poses, it has the potential to promote green finance initiatives that channel the much needed financial resources to fund environmental protection and prevention projects.

5. Conclusion and policy implications

Green finance is not just a global trend, but it has become an important channel for industrialized nations to achieve sustainable growth. China is at the forefront of green finance policy investigation and implementation. Financial regulators in China are investigating how to include green credit in macro prudential policy analysis. The People' Bank of China (PBOC) is working on developing more green finance products that will help accelerate the green transformation of China's financial system. According to PWC (2017), green finance has the potential to reduce credit risk, increase financial openness, and encourage sustainable development.

This paper offers insights on how China is already implementing a variety of green finance related policy initiatives and how that has significantly impacted industrial gas emissions in the period under review. Using the SDID model we proved that overall green finance related policies lead to positive environmental outcomes (i.e., reduction in industrial emissions). Subsequently, the study investigates the role of fintech development in environmental protection. Our novel findings show that fintech development contributes to reduced industrial gas emissions and augments environmental protection investment initiatives. This finding gives rise to the following policy implications:

- Financial regulators need to accelerate the development of green finance products and enhance the capacity of financial institutions to offer green credit.
- There is need for greater investment into fundamental research on how green finance products can be implemented while mitigating associated risks.
- Regulators should encourage fintechs to actively participate in green finance and environmental protection initiatives that promote green consumption, while also minimizing the systemic risk fintech poses.

Our study is not without a few caveats. Limited data availability meant we could not exhaustively study the heterogenous factors that affect our study questions including long-term impacts. The lack of suitable instrumental variables limited our ability to address endogeneity and simultaneity challenges. Despite these aforementioned limitations, this paper offers important insights on how green finance and fintech development can play a vital role in promoting environmental protection and sustainable growth.

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CRediT authorship contribution statement

Tadiwanashe Muganyi: Conceptualization, Methodology, Project administration, Writing – original draft, Software. **Linnan Yan:** Data curation, Investigation, Formal analysis. **Hua-ping Sun:** Methodology, Writing – review & editing.

Declaration of competing interest

We confirm that this paper is our original work with all data acquired by our investigation and there is no plagiarism in it. We also confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ese.2021.100107.

Appendix

A1
Treatment Group Cities

Treatment Group Cities			
Anqing	Huangshi	Qingdao	Xingtai
Anyang	Huizhou	Qingyuan	Xuancheng
Baiyin	Ji'an	Qingyang	Ya'an
Baise	Jinan	Quzhou	Yancheng
Baoding	Jiamusi	Quanzhou	Yangzhou
Beijing	Jiayuguan	Sanmenxia	Yangjiang
Benxi	Jinhua	Sanya	Yangquan
Bozhou	Jingmen	Shanwei	Yichun
Cangzhou	Jingzhou	Shanghai	Yichang
Changzhou	Jingdezhen	Shangrao	Yiyang
Chaoyang	Jiujiang	Shenzhen	Yongzhou
Chenzhou	Jiuquan	Shiyan	Yulin
Chengde	Kaifeng	Shijiazhuang	Yueyang
Chongzuo	Lishui	Shuangyashan	Yunfu
Dazhou	Liuan	Suizhou	Zhangye
Dezhou	Longyan	Taizhou	Changchun
Dingxi	Luohe	Tangshan	Zhenjiang
Dongguan	Ma'anshan	Tianjin	Zhongwei
Ezhou	Maoming	Tianshui	Chongqing
Fuzhou	Meishan	Tonghua	Zhoukou
Fuyang	Meizhou	Tongren	Zhuzhou
Ganzhou	Nanchang	Wulumuqi	Zhumadian
Guangzhou	Nanping	Wuxi	
Guigang	Nanyang	Wuzhong	
Handan	Ningbo	Wuhu	
Heyuan	Ningde	Wuhan	
Heihe	Pingliang	Wuwei	
Hengshui	Pingxiang	Xianning	
Hengyang	Puyang	Xiangyang	
Huanggang	Qinzhou	Xinxiang	

Source : Ruiyan Database

A2
Provincial data summary statistics.

Variable	Measurement	Source	Obs	Mean	Std. Dev.	Min	Max
Fintech	PKU-DFI (log)	Institute of Digital Finance, PKU (2019)	248	4.676796	1.038375	1.345218	5.819044
IWG	Industrial waste gas emissions (100M cubic meters (Log)	EPS (2019)	248	9.590395	1.137573	4.733563	11.50336
RRI	Recycling rate of industrial solid waste	EPS (2019)	248	4.065193	0.644419	0.405465	4.831793
EPI	Environmental prevention investment 100 million Yuan (log)	EPS (2019)	248	5.320464	0.927774	1.386294	7.050077
Ind	Secondary industry value added as a % of GDP (log)	EPS (2019)	248	45.53116	8.434547	19.01	59
TOP	Actual foreign investment USD 10,000 (log)	EPS (2019)	248	0.281506	0.329081	0.016706	1.58716
Urb	Provincial urbanization rate (log)	China Statistical Yearbook (2010-2018)	248	55.00306	13.6115	22.67	89.6
GDPpc	GDP per capita in RMB (log)	China Statistical Yearbook (2010-2018)	248	9.780281	2.833834	-2.5	17.4

A3
Fintech Index weight vectors.

Dimension	Weight Vector
Coverage Breadth	54%
Depth of Usage	30%
Level of Digitalization	16%
Depth of Usage Service Dimensions	**Weight Vector**
Payment	4%
Money Funds	6%
Credit Investigation	10%
Investment	25%
Insurance	16%
Credit	38%
Digitalization Service Dimensions	**Weight Vector**
Mobility	50%
Credit	10%
Convenience	16%
Adorability	25%

Source: The Peking University digital financial inclusion index (PKU-DFIC) (Guo et al., 2019).

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