

The impact and channel effects of banking competition and government intervention on carbon emissions: Evidence from China[☆]

Yitian Xiang^{a,1,*}, Haotian Cui^{b,c,1,**}, Yunxiao Bi^d

^a School of Finance, Renmin University of China, Beijing, 100872, China

^b State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China

^c University of Chinese Academy of Sciences, Beijing, 100049, China

^d School of Public Finance and Taxation, Central University of Finance and Economics, Beijing, 102200, China

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ABSTRACT

Carbon-emission reduction has become a consensus among the international community. In this study, we consider prefecture-level cities in China from 2000 to 2017 as the object, and use a bidirectional fixed-effects model, instrumental variables, and differential difference methods to examine the impact of banking competition on carbon emissions and the role of government intervention in China. The results show that intensifying banking competition will eventually increase Chinese cities' carbon-emission levels. Increasing banking competition can not only promote investment into fixed assets, which will increase carbon emissions, but also facilitate technological innovation to reduce carbon emissions. Government intervention in the market is an important reason for this phenomenon, and will distort bank-credit behavior and amplify the effect of banking competition in promoting carbon emissions. The findings of this study enrich relevant theories and empirical evidence, as well as provide new perspectives and policy suggestions for emission-reduction practices in China and other emerging economies.

1. Introduction

Since the industrial revolution, human activities have gradually increased fossil-fuel consumption, resulting in greater emissions of carbon dioxide (CO₂) and other greenhouse gases (GHGs), which has significantly contributed to climate change (Dong et al., 2018; Zhao et al., 2021a). The total amount of global carbon emissions has increased rapidly from 25.72 Mt in 2003 to 33.4 billion Mt in 2020 (Sesso et al., 2020). The steady intensification of the greenhouse effect has led to melting glaciers and a rising sea level (Zhao et al., 2021b), which may have a disastrous impact on the development of human society (Liobikiene and Butkus, 2019). The signing of the Paris Agreement shows that carbon-emission mitigation targets had become an important challenge faced by all countries globally (Liu et al., 2020; Peters et al., 2020). The three largest emitters of GHGs (the European Union, China, and the United States (US)) have now explicitly set carbon neutrality goals.

China is the largest producer of industrial goods, with an average annual rate of more than 11% in carbon emissions between 2000 and 2016 (World Bank, 2021). The Chinese government has recently announced ambitious goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 (Mallapaty, 2020). To fulfill the international obligations for emission reduction, China is also under the pressure of domestic transformation and the upgrading of its economic, financial, and industrial infrastructure. Therefore, it is necessary to deeply explore the relationship between carbon emissions and socio-economic development.

Economic development is a complex process that includes many underlying forces that may affect economic growth as well as the environment. The financial sector plays a vital role in economic activities, such as mobilizing savings, risk sharing, and promoting investment and innovation (Levine, 2005). A high level of financial infrastructure can develop banks and capital markets, which can also affect energy

[☆] Renmin University and Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences contributed equally to this study.

* Corresponding author.

** Corresponding author. State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China.

E-mail addresses: xiangyitian741@163.com (Y. Xiang), htcui_st@rcees.ac.cn (H. Cui).

¹ These authors contributed equally to this work.

demand and carbon emissions (Sadorsky, 2010; Abbasi and Riaz, 2016; Bekhet et al., 2017; Zaidi et al., 2019). Measures of financial development are diverse, and include domestic credit, foreign direct investment, and both stock market and banking competition et al. Previous studies focused more on total credit, stock market size, or comprehensive indicators of financial development (Acheampong, 2019; Zafar et al., 2019); however, few considered the role of banking competition (Coban and Topcu, 2013; Kim et al., 2021). Indeed, many developing countries' financial systems are based on banks, which is different from Britain's and the US' market-oriented systems, while China is a typical bank-oriented country. At the end of the second quarter of 2022, the banking sector's assets in China amounted to 367.68 trillion-yuan, accounting for 90% of financial institutions' total assets (People's Bank of China, 2022). Meanwhile, market competition in the banking industry is intensifying, while the number of small and medium-sized banks (SMBs) is increasing (Fig. 1). We obtained financial license information from the government website and count the number of different types of bank legal persons by year. Theoretically, it has been demonstrated that banking competition significantly changes the accessibility of credit to enterprises and households; however, the direction of the change and its mechanism remain controversial (Love and Martínez Peria, 2015; Ayalew and Zhang, 2019). It means that banking competition may affect carbon emissions while its final impact remains unknown. Therefore, using China samples to study the relationship between banking competition and carbon emissions has great scientific significance for similar emission-reduction practices globally.

Banking competition has different impacts on multiple dimensions of economic activities; that is, it may have multiple influence channels on carbon emissions. However, previous studies appeared to ignore the underlying mechanisms and specific channels and have provided little information on alternative policies available to governments. Previous researches focused on the relationship between carbon emissions and their driving factors, such as energy and industrial structure, economic growth, technological innovation, and population size (Dong et al., 2018; Tian et al., 2019; Shahbaz et al., 2020; Zheng et al., 2020). Among these, energy transition and industrial restructuring are mainly driven by technological innovation, which promotes economic growth without ultimately marginalizing environmental attributes (Balsalobre-Lorente et al., 2018). Industrial restructuring and technological innovation are closely related to enterprises' investment levels and fields. When funds are invested in research and development (R&D) activities, technological innovation can be promoted (Mairesse and Mohnen, 2004; Sharma,

2012), which may serve as a catalyst for the subsequent mitigation of emissions (Su et al., 2022a; Paramati et al., 2017). When funds are invested in energy-intensive industries, such as traditional energy or real estate, this will create fixed assets for expansion, which in turn leads to higher energy consumption and carbon emissions (Abbasi and Riaz, 2016; Al-Mulali et al., 2016). Furthermore, banking competition will change the financing constraints faced by enterprises and individuals, such as credit availability, loan scale, and credit interest rate, which influence their investment scales and direction (Eren et al., 2019; Naeem and Li, 2019), thus bringing about technological innovation and industrial restructuring (Liu and Li, 2020).

Therefore, two channels are proposed through which banking competition affects carbon emissions: "technological progress" and "fixed capital formation". Through the first channel, banking competition promotes technological progress and thus impacts carbon emissions. Through the second channel, banking competition impacts enterprises fixed-asset investment, especially investment in energy-intensive industries or outdated production capacity; thus, the channel is represented by a change in fixed-asset formation. To provide macro policies to achieve sustainability and carbon reduction, we focus on the channel effects of banking competition and empirically evaluated their contribution to carbon emissions.

It is worth noting that the impact of government intervention in the market on banking competition cannot be ignored in most developing countries, as it will significantly determine the channel through which the credit funds generated by banking competition will flow. Typically, banks are unlikely to support backward production capacity or inefficient enterprises with loans (Houston et al., 2022; Kim et al., 2022). Nevertheless, local governments in China, faced with county competition and GDP "championship" or power rent-seeking (Tang et al., 2018), often encourage or even force local banks to lend to backward industries through government guarantees, fiscal subsidies, and administrative orders (Shen and Chen, 2017; Chang et al., 2021). This distorts factor markets, creates zombie enterprises, and protects energy-intensive enterprises (Imai, 2016; Acharya et al., 2021), which can consume credit resources and inhibits technological progress (Caballero et al., 2008). This kind of interference usually exists in various economic fields in developing countries, which causes a moderating effect on the relationship between banking competition and carbon emissions.

Based on the above discussion, the three interesting questions that must be explored are as follows: (1) Is there a general positive or negative impact between the intensification of banking competition and carbon emissions? (2) Does banking competition have influence channels on carbon emissions and what are their driving mechanisms? (3) Will Chinese local governments' micro-intervention in the market operation have an impact on the carbon-emission effect? Therefore, using Chinese prefecture cities' annual data from 2000 to 2017, this study evaluates the impact of banking competition on carbon emissions, demonstrates the existence of the technological progress and fixed-capital formation channels, and examines the moderating effect of government micro-intervention.

This study contributes to the literature in several ways. First, this is the only study in China that uses prefecture-city data to relate banking competition to carbon emissions, contributing to the literature on the impact of financial development on climate change, which provides a new perspective for developing countries dominated by banking systems. Second, the study focuses on the channel effect of banking competition on carbon emissions, which has been neglected in previous studies. Third, in contrast to many studies that only emphasize the impact of macro environmental policies, the current one evaluates the moderating effect of local government intervention on the relationship between banking competition and carbon emissions, which is conducive to optimizing carbon-emission reduction policies from a micro-economic perspective. Fourth, to describe the causal relationship between banking competition and carbon emissions more accurately, an instrumental variable (IV) method incorporating a two-stage least

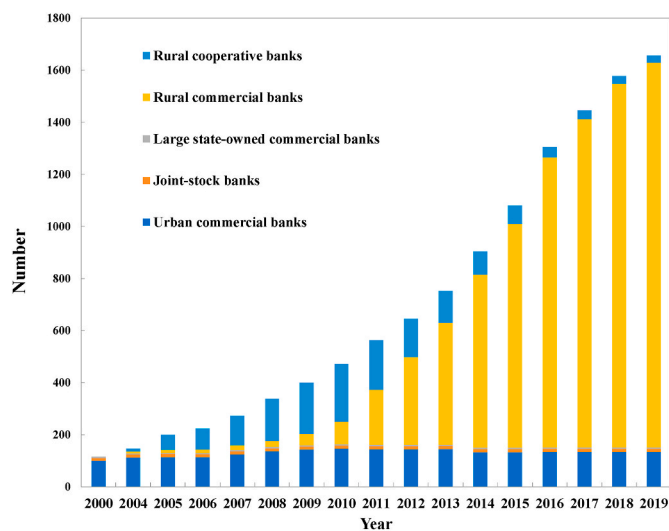


Fig. 1. The number of different bank types. Data source: Official website of China Banking and Insurance Regulatory Commission. <https://xkz.cbirc.gov.cn/jr/>.

squares (IV+2SLS) model is adopted to solve the endogeneity problem. Last, we search for an effective exogenous policy shock, and then apply difference-in-differences estimation (DID). Prior to this study, few studies have conducted causal inference on the relationship between banking competition and carbon emissions (excluding correlation and Granger causality) through quasi-natural experiments. This study will provide new scientific insights for the development of the banking industry, improving energy efficiency and facilitating energy transition.

2. Literature review

2.1. Financial development and carbon emissions

The formulating of reduction policies is premised on accurately identifying the drivers of carbon-emission intensity. Existing studies have confirmed that per capita GDP, population growth rate, and energy intensity all impact carbon emissions (Zheng et al., 2020). Empirically, the relationship between financial development and carbon emissions has attracted attention in recent years, with mixed results. On the one hand, studies have shown that financial development provides more credit to enterprises and individuals, expands the scale of production, and leads to increased energy consumption and carbon emissions (Javid and Sharif, 2016; Gök, 2020). For example, through a boundary co-integration test using an autoregressive distributed lag (ARDL) model, Shahbaz (2010) considered the case of Pakistan and found that financial development positively impacted energy consumption and carbon emissions. Ziaei (2015) applied a panel vector autoregression model (PVAR) and found that financial development had a stimulating effect on carbon emissions in East Asian countries but no significant effect in European countries. Acheampong (2019) used the system generalized method of moments (GMM) method to analyze the direct and indirect effects of financial development on carbon emissions in 46 African countries, and found that financial development increased energy consumption, which led to increased emissions; however, the author found different mechanisms in different regions with different income levels. Kayani et al. (2020) collected panel data on the world's top 10 carbon-emission countries and found, through a vector error-correction model (ECM), that financial development and urbanization led to higher carbon emissions. Qin et al. (2022) performed the time-varying parameter-stochastic volatility-vector auto-regression (TVP-SV-VAR) model and found that the development of sustainable finance could facilitate U.S. carbon neutrality.

On the other hand, financial development can provide financial support for enterprises' R&D to reduce energy consumption and carbon emissions by improving the technology level (Bello and Abimbola, 2010). In addition, a developed financial market is conducive to the optimal allocation of funds. When society has certain requirements for environmental protection, funds will flow to environmentally friendly enterprises, while enterprises will expend efforts to reduce environmental pollution (Rjoub et al., 2021). Tao et al. (2022) found that Fin-tech development can help to reduce the greenhouse gas emissions under some appropriate control variables. Jalil and Feridun (2011) tested an ARDL model to show that financial development could inhibit the growth of carbon emissions. Saidi and Mbarek (2017) found that financial development and reforms were effective paths to mitigate emissions in 19 emerging economies between 1990 and 2013. Omoke et al. (2020) used a nonlinear ARDL model to find that financial development in Nigeria could reduce the carbon footprint. Through a panel error-correction model using provincial data from 2001 to 2015 in China, Zhao and Yang (2020) empirically found that financial development mitigated carbon emissions. As one of the results of financial development, the expansion of green credit can improve environmental quality (Su et al., 2022b).

In contrast to countries dominated by direct finance, most developing countries, represented by China, have banking as a pillar of financial structure. However, relevant studies have focused more on a

comprehensive measurement of financial development, with only a few studies focusing on the impact of banking competition on carbon emissions. Using a sample of developed and developing countries for the period 1989–2013, Kim et al. (2021) empirically tested for a nonlinear, inverted, U-shaped relationship between banks' market power, competitiveness, and carbon emissions using the system GMM model. The main differences between this study and Kim et al.'s (2021) are as follows: (1) We use a sample of Chinese prefecture cities, with a larger volume of data, stronger representativeness, and less information loss, and focus on the characteristics of developing countries. (2) Government intervention is included in the model to investigate its impact on the emission effect of banking competition. (3) A lagged term of banking competition is used as the IV in the GMM model of Kim et al. (2021); thus, it is difficult to effectively solve the endogeneity problems caused by reverse causality and missing variables (Bellemare et al., 2017). In addition to re-selecting the IVs for moment estimation, this study use exogenous policy shocks to conduct a quasi-natural experiment.

2.2. Effects of banking competition

The effects of financial development and banking competition on carbon emissions are complex and uncertain, which can facilitate the upgrading of industrial structure, promote technological progress, change the structure of energy consumption, and improve energy efficiency to reduce carbon emissions. However, simultaneously, they ease financing constraints and promote the expansion of production scale. Some studies have explored the channel effect of financial development on carbon emissions (Shahbaz et al., 2013; Kim et al., 2021); however, generally, research in this area remains relatively scarce. Therefore, we focused on the impact of banking competition on technological progress and enterprise investment. The current research believes that banking competition will achieve the impact by changing the degree of enterprises' financing constraints and propose two opposing theories: the "market-power" and "information-asymmetry" hypotheses.

At the core of the market-power hypothesis is the notion that banking competition will weaken banks' monopoly power in the credit market, thereby reducing the credit interest rate and easing financing constraints (Amore et al., 2013; Love and Martine Peria, 2015), which is an industrial organization theory. Increased banking competition means that the number of banks available for loans has increased (Braggion and Ongena, 2019): banks must lower interest rates to compete for high-quality customers (Lian, 2018; Gao et al., 2019); it forces banks to improve risk-management technology and governance (Dick and Lehnert, 2010; Rice and Strahan, 2010); it can lower the threshold for mortgage assets and loan approval standards (Chong et al., 2013; Leon, 2015); and an increase in the number of bank branches will shorten the distance between banks and enterprises and reduce the cost to banks of obtaining enterprise information (Hollander and Verriest, 2016).

The information-asymmetry hypothesis proposes that fierce banking competition tightens enterprises' financing constraints, making it difficult for them to establish long-term stable relationships with banks. Banks cannot share enterprises' long-term earnings; thus, there is no incentive for them to search for enterprises' "soft information" to engage in relationship lending (Dell' Ariccia and Marquez, 2006; Owen and Pereira, 2018). Banks will raise interest rates to cover risks in the short term, while adverse selection will force high-quality enterprises out of the market (Marquez, 2002). Meanwhile, banks rely more on "hard information" and transaction lending, which does not make it easy for small and medium-sized enterprises (SMEs) to obtain loans (Zhang et al., 2019). Some studies combine the two hypotheses and believe that banking competition has a heterogeneous impact. For example, González and González (2014) proposed that only competition dominated by SMBs could help enterprises obtain credit.

A mitigation of financing constraints can improve enterprises' investment levels and efficiency (Guariglia and Yang, 2016; Naeem and Li, 2019), including R&D investment, thus indirectly promoting

technological progress (Hall et al., 2016). Findings in studies focusing on enterprises in the Organisation for Economic Co-operation and Development (OECD) countries support both hypotheses, whether it is technological innovation (Cornaggia et al., 2015; Hombert and Matray, 2017; Bai et al., 2018) or enterprise investment (Kandilov et al., 2016; González, 2016). Empirical evidence from China mostly supports the market-power hypothesis. Zhang et al. (2019) used China's commercial bank-branch location information and a sample of listed companies from 2000 to 2015 to show that banking competition could significantly ease constraints on corporate financing. Based on data on industrial enterprises in China above a designated size, Liu and Li (2020) found that banking competition could improve enterprises' innovation levels, especially those of private enterprises with strong financing constraints. Gao et al. (2019) demonstrated that banking competition had significantly improved Chinese enterprises fixed-asset investment scales and promoted their profitability and productivity.

Based on the conclusion from Chinese samples and the fact that competition in China's banking industry mainly emanates from numerous SMBs, we support the market-power hypothesis. The hypothesis proposes that banking competition can ease enterprises' financing constraints, thereby promoting technological innovation and fixed-asset investment, and ultimately affecting carbon emissions. The studies cited above provide theoretical support for exploring the effects of banking competition channels. In addition, this study does not directly use an indicator for industrial structural change because both channels can affect it, while data are available on only three industry sectors (agriculture, manufacturing, and service industries), based on which we cannot separate the impact of the two channels.

2.3. Moderating effect of government intervention

Government intervention in the economy can alter banks' credit behavior (scale and direction), thereby affecting the carbon-emission effects of banking competition. We define government intervention in this study in terms of local governments' use of their own power or financial tools to reallocate regional resources to pursue some political goals and policy burdens (Shleifer, 1998), or when officials are strongly motivated to pursue political promotion goals, distorting the micro operation of the economy and market. This kind of intervention, unlike industrial and economic policies, can harm local sustainable development.

The main motivations for government intervention are performance pressure and promotion tournaments. Especially when the local fiscal deficit is severe, the unemployment rate high, and the government faces the pressure of fiscal decentralization and performance evaluation, will the local government be strongly motivated to intervene in local economic activities (Shleifer and Vishny, 1994, 1998), particularly in regional credit and enterprise investment. For example, the Four-Trillion Economic Stimulus Plan is aimed at reviving the economy by promoting investment in priority areas (Deng et al., 2017). The investment was financed mainly by bank loans rather than by internal cash flows. Most of these funds flowed to manufacturing and backward production-capacity enterprises, although their post-investment performance was poor (Huang et al., 2020). In addition, local government officials participate in regional competition at the cost of local industry and enterprise performance (Chen et al., 2011). Therefore, under the dual effects of government intervention and spontaneous market forces, resource allocation may be distorted (Bond and Goldstein, 2011; Lin and Huang, 2022).

Government intervention leads to the misallocation of credit resources mainly through two channels. On the one hand, it protects the existing, inefficient enterprises and decreases relevant enterprises' interest-rate sensitivity, so that too many resources are allocated to enterprises with low productivity (Huang et al., 2020). On the other hand, if new enterprises are prevented from entering, credit resources cannot be allocated to some potential entrants with higher productivity

(Liu et al., 2020). The intensification of competition has compressed banks' profits and made them more willing to lend to enterprises with lower interest-rate sensitivity to obtain higher rates. In addition, given the lack of high-quality enterprises, the government intervention has directed the credit generated by banking competition more to low-efficiency and high-energy consumption enterprises.

Although domestic and foreign scholars have explored and researched factors of carbon emissions, they have not considered government intervention behavior; thus, it is impossible to assess how government intervention affects the channel effect of banking competition on carbon emissions. China is promoting deep economic transformation, reducing unnecessary government intervention, and eliminating the resource misallocation caused by policy distortion, which is of great significance in increasing the country's growth potential and achieving carbon neutrality. Therefore, it is necessary to answer the question of how government intervention affects the relationship between banking competition and carbon emissions, which is one of the purposes of this study.

2.4. Literature gaps

Based on the above review of existing research, we find some gaps in the literature. First, few studies have examined the relationship between banking competition and carbon emissions, while national-level data have mainly been used, which ignores the regional differences in financial development. To the best of our knowledge, no study has analyzed the relationship using prefecture-level city data in China. We enrich the relevant evidence. Second, most previous studies are theoretical analyses of banks' competitive channel effect, lacking empirical tests. This study demonstrates the existence of the technological-progress and fixed-asset formation channels. Third, the literature ignores the low degree of marketization of developing countries' economies, while governments' micro intervention can significantly affect banks' business behavior. The study evaluates the moderating effect of government intervention on the relationship between banking competition and carbon emissions, filling the gap in the literature. Last, the literature does not adequately deal with endogeneity problems. There is a reverse causality between financial development and carbon emissions. Countries and regions with developed industries typically attract more financial resources, which leads to severe endogeneity problems. This can only demonstrate the correlation and constitutes an obstacle to the test of causality. Some studies that are based on macro econometric methods (vector autoregressive (VAR), ARDL, and ECM) use the Granger test; however, the test can only show the sequence of two variables in a time series, and is not a real causal identification; although micro metrology research mostly relies on the system GMM model, it is mainly used to alleviate the endogeneity problems caused by the lagged term of the explained variable. Based on micro data, this study uses two classical methods to infer causality: one is the IV method with two steps (IV+2SLS), which requires IVs for banking competition; and the other is to find an exogenous policy impact, such as the deregulation of cross-regional banking operations, to build a DID model for quasi-natural experiments.

2.5. Transmission mechanism

To sum up, this study explores the transmission mechanism for the impact of banking competition on carbon emissions as follows: First, according to the market-power hypothesis, banking competition will lower the threshold for loan approval and credit interest rate and improve the availability of loans, which ease enterprises' financing constraints. This will not only increase investment in R&D, accelerating technological progress, but will also promote enterprises' expansion of fixed-asset investment and production scale.

Thereafter, technological progress, especially green innovation, can improve enterprises' production efficiency and optimize the industrial

structure, which reduce the intensity and level of carbon emissions; new investment and production capacity can marginally increase carbon emissions, especially for enterprises with backward production capacity. Therefore, banking competition can change carbon emissions through two channels: technological progress and fixed-asset formation.

Last, government intervention in the market will protect enterprises with backward production capacity and prevent efficient enterprises from entering the regional market. Under intensified competition, banks are more willing to provide loans to enterprises that with government guarantees and insensitive interest rates; thus, government intervention has a positive moderating effect. The road map shown in Fig. 2 describes the overall conceptual framework for the impact mechanism of banking competition on carbon emissions. Meanwhile, to further explain this mechanism, we build the banking competition theoretical model that is presented in the Supplementary Information.

3. Methods

Based on the Cournot-equilibrium form of the classic Monti-Klein model (Freixas and Rochet, 2008), the study builds a theoretical model with some corollaries (shown in Supplementary Method). For the empirical tests, we first use two-way fixed effects (FEs) to test the relationship between banking competition and carbon emissions. By changing the proxy variables for banking competition and using IVs and DID estimation, we generate a sensitivity test and solve the endogeneity problem effectively. We then apply the mediating-effect model to demonstrate the technological progress and fixed-capital formation channels. Last, we analyze the effect of local government intervention on the relationship between banking competition and carbon emissions.

3.1. Benchmark model

There are several methods of analyzing the drivers of carbon emissions, such as the Kaya identity, structural decomposition analysis (SDA), and regression analysis. We choose the regression method based on micro data because it is usually applied for causal inference and contains more information. Based on previous studies (Grossman and Helpman, 1991; Robaina Alves and Moutinho, 2013; Xu et al., 2014; Wang and Wang, 2021), we construct the following benchmark model with an FE:

$$\ln CO_{2it} = \beta_0 + \beta_1 BC_{it} + \beta_2 Control_{it} + \omega_i + \nu_t + \mu_{it} \quad (1)$$

where i denotes the city and t the year. The explained variable, $\ln CO_{2it}$, is

the logarithm of carbon emissions per capita in city i in year t . The main explanatory variable, BC_{it} , represents the banking competition degree in city i in year t . $Control_{it}$ represents the vector of control variables, while ω_i and ν_t represent the individual and time FEs, respectively, that need to be controlled for to mitigate endogeneity problems; μ_{it} is the residual term. If $\hat{\beta}_1$ is significant and positive (negative), Equation (1) shows that banking competition in a city positively (negatively) impacts its carbon emissions. The robust standard errors are clustered at the city level.

The carbon emissions, CO_{2it} , represents the carbon emissions per capita in city i in year t , in tons per capita. The emission inventory is compiled based on the latest, revised energy data of the Chinese Bureau of Statistics and is calculated using the apparent-emissions accounting method. The ratio, Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS), for a city's night-light intensity, was used as the weight to estimate the prefecture-level energy efficiency in its province because the yearbooks contained only provincial data (Li et al., 2021).

The main explanatory variable, banking competition, can be measured using many different methods, such as the Lerner index, H-statistic, and market-concentration indicators that include HHI , $cr3$, and $cr5$ (Su et al., 2020). Because the first two indexes are mainly applied at the bank-level and banks often operate across cities, the $1-HHI$ index is chosen as the proxy variable for the degree of banking competition in a city, while other market-concentration indicators (such as $cr3$, $cr5$, and $cr7$) are used in the sensitivity test. The reason for the choice of the HHI index rather than others is the highly concentrated structure of the Chinese banking market, which we will explain in the section on descriptive statistics. The HHI index is constructed based on the number of each bank's branches and can reflect a region's banking structure and competition degree (Craig and Dinger, 2013; Xia and Liu, 2022). The formula is as follows:

$$HHI_{it} = \sum_{m=1}^M \left(\frac{branch_{m,i,t}}{\sum_{m=1}^M branch_{m,i,t}} \right)^2 \quad (2)$$

where $branch_{m,i,t}$ denotes the number of a banking institution's branches in city i in year t , and M is the total number of banks that operate in city i in year t . The value of the index ranges from 0 to 1: the more concentrated a city's banking industry, the closer the index value is to 1. Consequently, the HHI index is inversely proportional to the degree of banking competition (BC_{it}), and we use $1 - HHI_{it}$ for the sake of

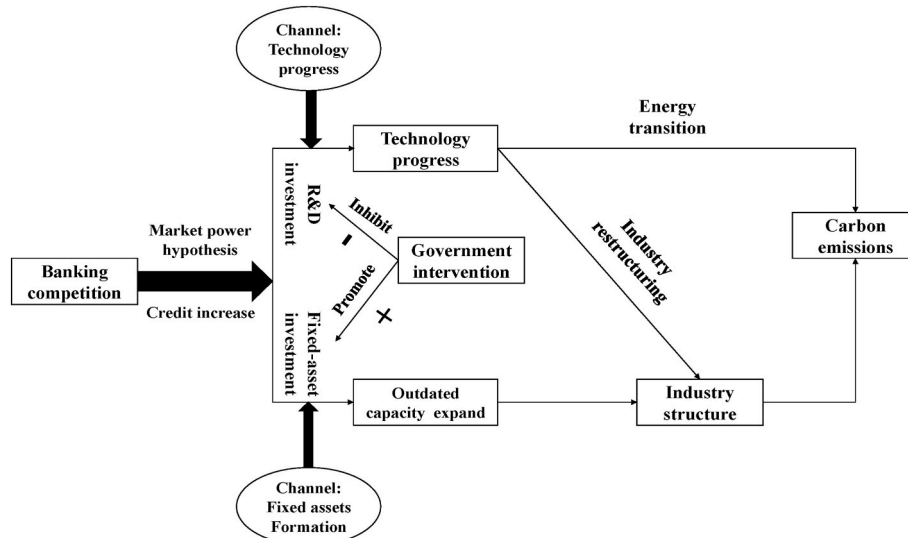


Fig. 2. Road map of banking competition effects. “+” and “-” denote the positive and negative effects, respectively.

intuition.

As Chinese banks must also compete with other kinds of credit-business companies, we add non-bank-credit financial institutions to the sample to obtain *HHI2*, which comprehensively reflects the level of competition with which banks are confronted. Additionally, head offices are included in the sample.

For control variables, we consider the literature and choose energy intensity (*El_{it}*), population size (*Size_{it}*), real GDP per capita (*GDP_{it}*), industrial structure (*IS_{it}*), and urbanization rate (*Urb_{it}*). Detailed information is presented in Table 1.

3.2. Robustness test

3.2.1. Sensitivity test

Furthermore, we perform a sensitivity test and use different proxies for the explanatory variable. We choose *HHI2*, *cr3*, and *cr5* to replace the *HHI* index and test the stability of the benchmark results. Regarding *cr3* and *cr5*, they represent the relative sizes of a city's top three and top five banks, respectively, and are also used to reflect market concentration (Khan et al., 2016). Using *cr3* as an example, the formula is as follows:

$$cr3_{it} = \frac{branch_{it}^3}{\sum_{m=1}^M branch_{m,i,t}} \quad (3)$$

where $branch_{it}^3$ is the sum of the number of branches for the three banks with the largest number of branches in city *i* in year *t*. *cr3* and *cr5* are also inversely proportional to the degree of banking competition.

3.2.2. Mitigating the endogeneity problem

There may be some reverse causality effect that causes an endogeneity problem because high levels of carbon emissions are usually associated with cities with advanced industries, while many banks tend to establish branches in such cities to derive revenues from them. Searching for valid IVs for the *HHI* index and conducting the IV+2SLS method of regression can effectively mitigate the endogeneity problem (Goldberger, 1972). Endogeneity in statistics refers to a situation in which explanatory variables are correlated with regression residuals. IVs are correlated with explanatory variables and independent of residuals. Meanwhile, the 2SLS method is convenient for testing the relationship between explanatory variables and IVs. The method is widely applied in economics, political science, and the sociology field (Acemoglu et al., 2001; Sovey and Green, 2011; Bollen, 2012).

Table 1
Control-variable information.

Symbol	Description	References
<i>El_{it}</i>	<i>El_{it}</i> = <i>energy_{it}</i> / <i>gdp_{it}</i> represents the energy consumption per GDP in units of tons/ten thousand yuan. Similarly, city energy consumption data are calculated using the weight of the night-light intensity and provincial data.	Zhang and Lin (2012)
<i>Size_{it}</i>	<i>Size_{it}</i> = <i>ln(pop_{it})</i> , where <i>pop_{it}</i> represents a city's year-end population in millions.	Zhang and Lin (2012) York et al. (2003)
<i>GDP_{it}</i>	<i>GDP_{it}</i> = <i>ln(realgdp_{it} / pop_{it})</i> , where <i>realgdp_{it}</i> is calculated based on city-level nominal GDP while GDP indexes are measured at constant 1995 RMB in 0.1 billion yuan.	Grossman and Helpman (1991) Heil and Selden (2001)
<i>IS_{it}</i>	<i>IS_{it}</i> = <i>λ_{it}</i> / <i>gdp_{it}</i> , where <i>λ_{it}</i> represents a city's secondary-industry value added in year <i>t</i> , and <i>gdp_{it}</i> is the nominal GDP.	Dong et al. (2022)
<i>Urb_{it}</i>	<i>Urb_{it}</i> = <i>nonagpop_{it}</i> / <i>pop_{it}</i> , where <i>nonagpop_{it}</i> represents city <i>i</i> 's year-end nonagricultural population in year <i>t</i> .	York et al. (2003) Madlener and Sunak (2011)

The average value of the *HHI* index for all cities in a province, except city *i*, is selected as the IV for *HHI_{it}* in city *i* and year *t*:

$$Instru_{it} = 1 - \frac{1}{b-1} \sum_{\substack{a=1 \\ a \neq i}}^{b-1} HHI_{at} \quad (4)$$

where *a* represents city *a* in the province in which city *i* is located, and *b* is the number of cities in the province. In China, urban commercial banks operate mainly in local provinces and are the main competitors against state-owned and joint-stock banks. Their development is usually influenced by common factors such as regulation policies, industrial structure, and a province's financial tradition. Consequently, the *HHI* index for city *i* will correlate with the average level for its province. Meanwhile, the degree of banking competition in other cities cannot affect city *i*'s carbon emissions except through the channel of the endogenous variable, *HHI_{it}*, because companies mainly do business with banks in their local city (Huang et al., 2020).

Another commonly used method to solve endogenous problems is the quasi natural experiment method. We select an exogenous policy shock to conduct a DID estimation that can make quasi-natural experiments. It simulates the experimental methods of natural science and uses exogenous policy shocks as treat variables. It is widely used to evaluate the effects of policies and identify causal relationships (Cornaggia et al., 2015; Hombert and Matray, 2017). Considering that China has repeatedly relaxed the regulatory policy on banks' cross-regional operation, it is appropriate to use a DID method to verify the relationship between banking competition and carbon emissions. The policy shock is "the Adjustment Opinions on Market Access Policies for Branches of Small and Medium-sized Commercial Banks (Trial)" issued by the general office of the former China Banking Regulatory Commission in April 2009 (CBRC Issued (2009) No. 143).

The policy purported to grant some authority of approval for local commercial banks' cross-city operation, especially urban commercial banks, to local regulators, an authority that originally belonged to the central government, with the goal of promoting the development of urban commercial banks. Before 2009, urban commercial banks' cross-city operations were substantially limited. The policy had different effects in various cities. If a city had urban commercial banks before, the local governments' regional protectionism would obviously weaken the effect of the policy. Conversely, the regional protectionism would not come into play and the policy could wholly promote cross-city operation.

Consequently, we regard the cities that had no urban commercial banks before 2009 as the treatment group and the others as the control group. The groups do not reflect the gross effect of the policy because all cities were influenced by the policy. We are only interested in whether the relative increment in banking competition changed the carbon emissions. The equation is as follows:

$$\ln CO_{2it} = \gamma_0 + \gamma_1 D_t + \gamma_2 D_t * T_i + \gamma Control_{it} + \omega_i + \nu_t + \varepsilon_{it} \quad (5)$$

where *D_t* is the treat-time point variable such that *D_t* = 0 if year < 2009 and *D_t* = 1 if year ≥ 2009; *T_i* is the treatment-group dummy variable, where *T_i* = 1 if city *i* had no urban commercial bank before 2009, and otherwise *T_i* = 0. We choose 4 years before and after 2009 as sample periods and dropped the grouping variable, *T_i*, from the formula to avoid multicollinearity.

3.3. Channel effect test

We next determine whether banking competition affects carbon emissions by promoting technological progress and fixed-capital formation. The mediating-effect model is typically used to verify the influence channel (Hill et al., 2020; Bostwick et al., 2022). As it is the most straightforward and widely used, we choose the stepwise regression

method and constructed the following model:

$$\ln CO_{2it} = \beta_0 + \beta_1 BC_{it} + \beta_2 Control_{it} + \omega_i + \nu_t + \mu_{it} \quad (6)$$

$$M_{it} = \alpha_0 + \alpha_1 BC_{it} + \alpha_2 Control_{it} + \omega_i + \nu_t + \mu_{it} \quad (7)$$

$$\ln CO_{2it} = \lambda_0 + \lambda_1 BC_{it} + \lambda_2 M_{it} + \lambda_3 Control_{it} + \omega_i + \nu_t + \mu_{it} \quad (8)$$

where M_{it} represents the channel variables (Mediation) that include technological-progress degree (TP_{it}) and fixed-capital formation (FCF_{it}) in city i in year t ; we then separately regress the two variables.

Obviously, the first equation is our earlier benchmark regression model. Moreover, if $\hat{\beta}_1$ and $\hat{\alpha}_1$ are significant, this demonstrates that banking competition can affect technological progress (or fixed-capital formation) and thus change cities' carbon-emission levels; many studies have demonstrated that technological progress (Chen et al., 2020) and fixed capital (Abbas et al., 2020; Soyatas et al., 2007; Yang et al., 2017) affect carbon emissions. Meanwhile, if $\hat{\lambda}_2$ is significant, this indicates a positive or negative relationship between technological progress (or fixed-capital formation) and cities' carbon emissions in China. However, the result for the last equation may not be robust and will require further precise research. In addition to the HHI index, we use the IV, $Instru_{it}$, to estimate the model.

There are three main types of methods for measuring technological progress: input methods, such as R&D spending, the number of researchers, and amount of relevant funding; output methods, such as the number of invention patents granted and technology contracts awarded; and total-factor productivity methods (TFP). As the data for the TFP and input methods have many missing values at the city level, we adopt output indicators; specifically, we use the number of invention patents granted as the proxy variable (Kwon et al., 2017; Sharifzadeh et al., 2019). The equation is as follows:

$$TP_{it} = \ln(patents_{it}) \quad (9)$$

where $patents_{it}$ represents the number of granted patents out of all the patent applications in city i in year t .

Regarding fixed-capital formation, we follow the OECD (Publishing, 2009) and use the gross fixed-capital formation (GFCF), denoted FCF_{it} . However, due to a severe lack of city-level data in China, FCF_{it} is calculated as follows:

$$FCF_{it} = \ln[(I_{it} + I_{it-1} + I_{it-2}) / 3] \quad (10)$$

where I_{it} denotes city i 's fixed-assets investment in year t , in units of ten thousand yuan. The value of FCF_{it} is the simple mean of the investment data over the previous three years because, theoretically, the weighted average construction period for fixed-asset investment in a city is approximately 3 years in China.

3.4. Moderating-effect test

We must consider the moderating effect of local government intervention in the market (Sadeh et al., 2020; Zhang et al., 2017). The interaction term represents the influence of a change in a variable on the relationship between another explanatory variable and the explained variable; the regression formula is constructed as follows:

$$\ln CO_{2it} = \eta_1 BC_{it} + \eta_2 GI_{it} + \eta_3 BC_{it} * GI_{it} + \eta_4 Control_{it} + \omega_i + \nu_t + \mu_{it} \quad (11)$$

where GI_{it} represents the degree of local government intervention in city i in year t , and $BC_{it} * GI_{it}$ is the interaction term between local government intervention and banking competition. If the estimator, $\hat{\eta}_3$, is positive and significant, this indicates that an increase in local governmental intervention will result in the flow of the additional credit resources generated by banking competition into energy-hogging economic sectors, raising the carbon-emission level. The converse is also true. To improve the robustness and credibility of this result, we change

the variables and used the IV method in the regression.

We use two methods to measure the main explanatory variable, GI_{it} . The first is the ratio of the adjusted local government expenditure (ALGE) to GDP, excluding expenditure on science, education, and health (Deng et al., 2019), because government subsidies to enterprises and the provision of public goods are an important component of fiscal expenditure. Considering the lack of detail on fiscal spending before 2003, we analyze the sample only after that point (2003–2017). The other method is the “index of the relationship between government and market” (IRBGM) (Luo et al., 2021). The 10- IRBGM is used as a proxy variable for GI_{it} because the IRBGM and GI_{it} are negatively correlated. The index only measures provincial conditions, and we regard the province-level index as representing data on every city in the same province.

4. Data preparation

4.1. Data source and pretreatment

Considering the availability of data and the rapid increase in the number of SMBs after 2000, we choose prefecture-level cities in China over the period 2000 to 2017 as the total sample. We treat the sample as follows: (1) we exclude cities that are located in Xizang province because there are many cities with missing data; (2) we regard the four municipalities, Beijing, Shanghai, Tianjin, and Chongqing, as city-level samples, although they are provincial-level administrative regions; (3) we ignore Hong Kong, Macau, and Taiwan; (4) we supplement the missing data using the interpolation method; and (5) we winsorize some key continuous variables up and down by 1%. After the pretreatment, we obtain an unbalanced panel dataset comprising 315 cities, with a total of 5670 observations.

Regarding data on bank branches, we download information on the financial institution licenses from the China Banking and Insurance Regulatory Commission website, and then obtain every institution's parent firm, location, and survival time by manual sorting. We obtain energy-structure data from the Statistical Yearbook of Chinese Cities, night-light data from the DMSP/OLS, and energy-consumption data from the China Energy Statistical Yearbook. The population and economic data are obtained from the China Stock Market & Accounting Research Database (CSMAR), Chinese Research Data Services (CNRDS), and each city's statistical yearbooks. Last, we download and manually filtered the patent information from the China Patent Information Network and derive the “index of the relationship between government and market” from the Wind database.

4.2. Descriptive statistics

As shown in Table S1, the carbon-emission variable has an extremely wide range with a small standard error (0.782); thus, the logarithmic form is suitable. The mean value of $\ln CO_2$ is 1.506, which suggests that the overall level of carbon emissions is relatively high in China. The skewness of carbon emissions per capita is 16.449, and the logarithmic form is reasonable for our model. The proxy variable for banking competition, the HHI index, has a mean value of 0.150, which, compared to the standard for highly concentrated (0.18), indicates that the Chinese banking industry is a medium concentrated market.

Regarding the substitute variables for the HHI index, $cr3$ and $cr5$ have mean values of 0.538 and 0.717, respectively. In other words, the top three banks already own half of the branches, while the top five banks command 70% of the local market in Chinese cities. Compared to the HHI index, the problem is that the variables will be underrepresented if we choose $cr3$, $cr2$, or $cr1$, whereas the value will closely approach 1 if we choose $cr5$ or $cr7$.

The values of the mediating variable, TP , show obvious standard deviation, even if we use the logarithm form. This shows obvious variations in technological progress among cities. The differences in the driving modes of economic development are also nonnegligible in that

many cities are mainly driven by growth in factor-input scale. In contrast, because investment is critical for improving GDP in all cities, the volatility of the variable, FCF , is relatively low.

Regarding the variables for local government intervention in the market, the mean of $ALGE$ is 0.129, which is relatively high considering that it excludes expenditure on science, education, and health. Meanwhile, the maximum value is approximately 6 times the minimum value; in the public sector, it has become an indispensable pillar of local economies in most interventionist cities.

We only regress the sample observations for the period 2005–2013, 4 years before and after the point in the DID model; thus, the mean value of $D_t = 0.5$.

5. Results and discussion

5.1. Benchmark analysis and robustness tests

The estimated results for the benchmark model and its robustness test are presented in Table 2. The F-test for the benchmark model suggests that the FE model outperforms the pooled OLS (POLS) model. The BC coefficients are significant and positive in Models (1), (2), (3), and (5). Here, we show that an intensification of banking competition will promote overall carbon emissions in China, and this relationship remains even when the explanatory variables are changed, and the endogeneity problems are considered. The IV+2SLS model passes the unrecognizable, weak IV, and endogeneity tests, according to the K–P rk LM and K–P rk Wald F statistics and the DWH test. Consequently, the effect of banking competition is more stable in the IV+2SLS model than in the benchmark model, which implies that when the banking competition degree increases by 0.1 units, carbon emissions will rise by 12.9%. Although the coefficient is nonsignificant in Model (4), the value remains positive.

In addition, the DID model results show that the implementation of a promotion-competition policy improves the carbon-emission level, as the coefficient of $D_t * T_i$ is positive and significant. However, a parallel-trend test is essential for the DID model, and the corresponding test result is presented in Fig. 3. The test aims to analyze if the treatment

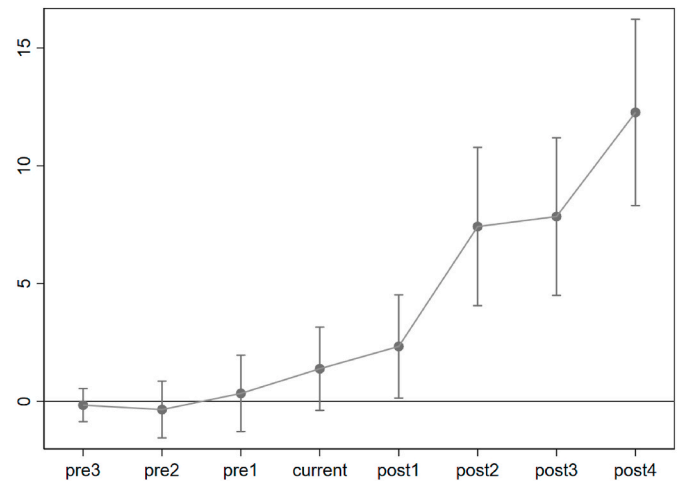


Fig. 3. Parallel-trend test result.

group and control group had similar carbon emissions trend before the policy shock. It constructs the interaction items between each time node and policy processing and put them into regression. We need to observe the corresponding coefficient significance and plot them. We use the first period (2005) as the base period, while the confidence interval was 90%. We use the first period (2005) as the base period, while the confidence interval was 90%. The coefficients in the periods before 2009 are nonsignificant, indicating that there is no significant difference between the treated and control groups before that point. In other words, the sample passes the parallel-trend test. Meanwhile, the value fluctuates around 0 before 2009 but rises sharply and becomes significant thereafter. Intuitively, the policy has a significant impact on the cities' carbon emissions.

Overall, most results suggest a positive causality between banking competition and carbon emissions, which corroborates the conclusion that financial development promotes carbon emissions (Zhang, 2011; Boutabba, 2014; Al-Mulali et al., 2015; Shahbaz et al., 2016). The last

Table 2

Results of the benchmark model and robustness tests.

Models	(1)	(2)	(3)	(4)	(5)	(6)
	1 – HHI	1 – $HHI2$	1 – $cr3$	1 – $cr5$	IV+2SLS	DID
BC	0.313*** (0.112)	0.310** (0.126)	0.114** (0.056)	0.015 (0.055)	1.288*** (0.250)	
$D_t * T_i$						0.062*** (0.013)
D_t						0.476*** (0.118)
EI	0.031** (0.014)	0.031** (0.014)	0.031** (0.014)	0.031** (0.014)	0.031** (0.014)	0.023 (0.017)
$Size$	–0.699*** (0.100)	–0.700*** (0.100)	–0.703*** (0.100)	–0.704*** (0.100)	–0.688*** (0.104)	–0.597*** (0.183)
GDP	0.185** (0.082)	0.184** (0.082)	0.182** (0.082)	0.178** (0.081)	0.204** (0.086)	0.090 (0.122)
IS	0.544*** (0.103)	0.550*** (0.103)	0.560*** (0.103)	0.559*** (0.103)	0.473*** (0.108)	0.457*** (0.106)
Urb	0.014 (0.010)	0.014 (0.010)	0.013 (0.010)	0.014 (0.010)	0.013 (0.011)	–0.131 (0.120)
$Cons$	2.699** (1.192)	2.707** (1.187)	2.949** (1.197)	3.025** (1.193)	1.715 (1.289)	3.728* (1.955)
F-test	197.05***					
K–P rk LM statistic					611.100***	
K–P rk Wald F statistic					866.729	
DWH statistic					21.930***	
Observations	5,467	5,467	5,467	5,467	5,395	2,815
R-squared	0.911	0.911	0.910	0.910	0.902	0.858
Number of groups	314	314	314	314	310	314

Note: Cluster standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Since the four municipalities (Beijing, Tianjin, Shanghai, and Chongqing) are themselves equivalent to provincial units, their observations are excluded from the IV + 2SLS model.

three studies cited above used samples from Europe, India, and Pakistan, including both developed and developing countries. Our study is consistent with Zhang's (2011), only focusing on the most representative countries in emerging markets, which enhances the applicability of the conclusions to developing countries. Comparing their research, we focus on banking competition, which plays an important role in financial development, and not the comprehensive indicators. However, our conclusion is different from that of Kim et al.'s (2020), which may be related to the different samples and China's unique financial system. China is a typical bank-dominated country, while financial sectors in developed countries outperform those in developing countries, as more spontaneous and efficient trading is conducted in the market of the former. Therefore, whether this conclusion is applicable to developed countries remains a question for further study.

The orientation of China's banking-market structure has always been controversial because banking competition also helps accumulate enormous systematic risks (Tan et al., 2021). We believe that an optimal structure for the banking industry should not only consider economic factors; it should also attach importance to environmental responsibility. Especially given the goal of a carbon peak, China should strive for a balance between economic growth and carbon emissions, and should avoid a heavy reliance on bank loans as well as the blind approval of the establishment of SMBs. The government should prudently supervise the expansion of banking scale and accelerate the development of the capital market and direct finance to achieve sustainable development.

Regarding the control variables, the coefficients of *EI*, *GDP*, and *IS* are significant, positive, and stable in all the models. These indicate that energy intensity, real GDP per capita, and the proportion of industry are all proportional to carbon emissions, consistent with the results obtained by others (Zhang and Lin, 2012; Wang and Wang, 2021). Conversely, population size and carbon emissions are negatively correlated, as the coefficient are negative and significant. Concerning the urbanization rate, we regard its effect as uncertain because the significance of the coefficient varies among the models.

5.2. Channel analysis

The main conclusion in the former section is that the gross effect of banking competition is an increase in carbon emissions. Further analysis of the influence channels of banking competition is required. In Table 3, Columns (1)–(4) report the technological-progress channel results. The coefficients of *BC* in Columns (1) and (3) are both significant and positive, which indicates that banking competition can promote technological progress; this finding is supported by Tian and Han (2018) and Xia and Liu (2022); however, it is inconsistent with Cornaggia et al.'s (2015) conclusion. Consistent with the “market-forces hypothesis,” competition in the banking industry will weaken sellers' power, reduce the financing interest rate, and improve the financing efficiency, which is more beneficial to SMBs (York et al., 2003; Lian, 2018). Consequently, banking competition increases financing and improves small enterprises' innovation levels (Tian and Han, 2018).

The technological-progress channel has been demonstrated in Chinese carbon-emission activities. However, the final effect of the channel remains disputed because the coefficient of *TP* in Column (2) is nonsignificant when the corresponding result for the IV+2SLS model equals -0.018 and significant at the 5% level. We argue that technological progress reduces carbon emissions, and that banking competition limits carbon emissions through the technological-progress channel in China. This argument is based on the result that the two coefficients are both negative and the fact that an endogeneity problem has been demonstrated before in the benchmark model. In recent years, there has been a broad consensus that technological change is the way to achieve sustainable development, with corporate R&D spending and patent applications seen as the drivers of low-pollution economic growth. Innovative processes lead to activities and products with higher energy efficiency and less resource consumption (Dong et al., 2022; Liang et al., 2019).

However, previous research also showed that the effect of technological progress is complex, and that technological progress can increase carbon emissions (Chen et al., 2020). The empirical results in this study support the mainstream view, which is of great significance to China's carbon-emission reduction practice. The report of the 20th CPC National

Table 3
Results of Channel analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1 – HHI		IV+2SLS		1 – HHI		IV+2SLS	
	<i>TP</i>	<i>ln CO₂</i>	<i>TP</i>	<i>ln CO₂</i>	<i>FCF</i>	<i>ln CO₂</i>	<i>FCF</i>	<i>ln CO₂</i>
<i>TP</i>		–0.009 (0.008)		–0.018** (0.008)				
<i>FCF</i>						0.118*** (0.019)		0.101*** (0.019)
<i>BC</i>	1.671*** (0.482)	0.328*** (0.108)	5.033*** (1.178)	1.379*** (0.250)	0.358* (0.193)	0.242** (0.108)	1.824*** (0.426)	1.088*** (0.244)
<i>EI</i>	0.088** (0.041)	0.032** (0.014)	0.087* (0.046)	0.033** (0.015)	–0.026* (0.015)	0.033** (0.014)	–0.026 (0.017)	0.033** (0.014)
<i>Size</i>	0.466* (0.272)	–0.695*** (0.100)	0.531* (0.286)	–0.678*** (0.105)	0.649*** (0.226)	–0.769*** (0.090)	0.649*** (0.226)	–0.750*** (0.095)
<i>GDP</i>	0.451** (0.197)	0.190** (0.082)	0.541** (0.214)	0.214** (0.087)	0.592*** (0.187)	0.114 (0.069)	0.610*** (0.191)	0.140* (0.075)
<i>IS</i>	0.371 (0.527)	0.548*** (0.103)	0.151 (0.560)	0.476*** (0.107)	2.107*** (0.187)	0.297*** (0.109)	1.988*** (0.193)	0.273** (0.112)
<i>Urb</i>	0.062* (0.034)	0.014 (0.010)	0.058* (0.034)	0.014 (0.011)	0.031 (0.023)	0.011 (0.010)	0.027 (0.023)	0.011 (0.011)
<i>Cons</i>	–6.901** (3.001)	2.636** (1.196)	–8.438** (3.881)	2.241 (1.457)	2.930 (2.796)	2.372** (1.068)	1.647 (2.847)	1.572 (1.167)
K–P rk LM statistic			70.853***	66.606***			69.834***	67.978***
K–P rk Wald F statistic			104.459	98.297			100.748	97.908
DWH statistic			9.685***	24.752***			16.082***	16.253***
Observations	5,467	5,467	5,395	5,395	5,425	5,425	5,353	5,353
R-squared	0.818	0.911	0.809	0.901	0.961	0.915	0.959	0.908
Number of groups	314	314	310	310	314	314	310	310

Note: Cluster standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Congress emphasizes that modernization should focus on innovation and achieve high-quality development and a harmonious coexistence between people and nature. Therefore, more policies will be issued to support technological progress, especially green technology, and we provide a strong theoretical basis for these policies from the perspective of carbon-emission reduction.

Regarding the fixed-capital formation channel, the results are reported in Columns (5)–(8). The results show that banking competition will cause an obvious increase in the amount of fixed-capital formation, a finding that is similar to those in previous reports (Khan et al., 2016), as the coefficients of *BC* in Columns (5) and (7) are both significant and positive. Meanwhile, both the benchmark and the IV+2SLS models show that fixed-capital formation and carbon emissions are positively correlated. Consequently, we demonstrate that an intensification of banking competition will promote carbon emissions by increasing the amount of fixed-capital formation because banking competition facilitates the issuance of loans in China and some developing countries. Due to a lack of the necessary policy guide, these incremental funds tend to flow into fixed assets (real estate and machinery), various energy-intensive enterprises, and infrastructure construction. Moreover, the coefficient of *BC* in Column (8) equals 1.088 and is significant. This indicates that banking competition can also increase carbon emissions through other channels, and not only through fixed-capital formation.

Given increasing banking competition, China must encourage and guide credit funds to R&D activities and reduce the effect of fixed-asset formation channels. Given the current downward pressure on the internal and external economies, the government should not only pursue growth, but should also attempt to eliminate path dependency and switch from the traditional investment-driven model to an innovation-driven one.

It should be noted that after 2019, with the global Covid-19 pandemic and outbreak of the Russia-Ukraine war, the channel effect of banking competition on carbon emissions will have changed, and China must respond timely to this. In the short term, the spread of Covid-19 has brought recessionary pressure on the economy (Brodeur et al., 2021). The policy support for infrastructure and real-estate investment in China will attract credit funds to the field of high carbon emissions and amplify the effect of fixed-asset formation channels. The outbreak of the Russia-Ukraine war has aggravated the problem of high global inflation, while central banks' monetary policies in major countries have been significantly tightened. By the end of October 2022, the Federal Reserve and European Central Bank have raised interest rates by 300 and 200 basis points, respectively (The Federal Reserve System, 2022; European Central Bank, 2022), leading to a significant decline in commercial banks' and enterprises' risk appetite (Bonfim and Soares, 2018). Even if banking competition is intensified, it will be difficult for credit funds to flow into the real economy, while enterprises will not significantly increase R&D and fixed-asset investment. For the long run, the global spread of Covid-19 and the Russia-Ukraine war have made the global industrial chain more vulnerable (Remko, 2020; Shao et al., 2022), especially increasing the uncertainty in traditional energy prices and supply. For example, according to Wind data, the West Texas Intermediate (WTI) crude oil futures price once fell below \$20/barrel after the outbreak of the epidemic and rose to more than \$110/barrel in 2022. China is a large country of traditional energy consumption; according to China Energy Statistics Yearbook (2021), in 2020, coal consumption alone reached more than 4 billion tons, accounting for 57% of the total energy consumption. To spread risks, China, with the help of structural financial policy tools such as green credit and green bonds, has continuously encouraged credit funds to flow to the green-energy industry to reduce the dependence on traditional energy. Meanwhile, China has implemented the "Made in China 2035) Plan" to eliminate backward production capacity and achieve industrial upgrading. Therefore, as time passes, the technological-progress channel effect of banking competition will become more pronounced, while the fixed-asset formation channel effect will decline. The relationship between banking

competition and carbon emissions may change from that of promotion to one of inhibition.

5.3. Moderating effect

The preceding results show that the promotion effect of banking competition on carbon emissions exceeds the inhibition effect; here, we hope to analyze the role of government intervention in the situation. The coefficients of the interaction term, $GI * BC$, are key results. As shown in Table 4, the coefficients equal 5.047 and 7.710 and are both significant at the 1% level. This suggests that a rise in government expenditure will amplify the promotion effect of banking competition and will not contribute to the inhibitory effect. The relationship is also established when we use *IRBGM* as the government-intervention variable. Both results show that increased government intervention in the market will enhance the positive effect of banking competition on carbon emissions. This implies that the moderating effect of government intervention is positive, while local governments' current intervention activities are not conducive to the planned carbon peak in China. This demonstrates that local government intervention in the market will encourage bank credit resources to flow into economic areas with high carbon emissions by generating factor-market distortions, consistent with results in previous studies (Acharya et al., 2021; Duchin and Sosyura, 2014). It is worth noting that government intervention is usually proportional to fiscal expenditure, and that the pressure of fiscal expenditure will promote a dependence on land finance and the prosperity of the real-estate industry (Qun et al., 2015; Pan et al., 2016). The real-estate industry can obtain more bank loans and expand, thus increasing carbon emissions, which is particularly obvious in China.

Therefore, to pursue the carbon peak, China's most urgent task is to ensure that the credit increment due to banking competition flows more to the R&D field, especially technology related to energy conservation and emission reduction. In this process, the government should continue to promote market-oriented reform, give play to the decisive role of the market in resource allocation, and achieve sustainable development through public policy rather than micro intervention. In addition, the Chinese government should optimize the assessment mechanism for officials, enrich the evaluation dimensions other than economic growth rate, and especially increase the emphasis on the green economy and environmental protection, which strive to reduce the motivation for government intervention at source.

Furthermore, we must calculate the variation in the marginal effect of banking competition on carbon emissions when *GI* has different values in order to intuitively analyze the moderator variables' function. Fig. 4 separately shows the marginal effects for *ALGE* (left) and *IRBGM* (right). We take *ALGE* and *1-IRBGM* at intervals of 0.05 and 1.00 respectively and calculate their effects on carbon emissions by Stata and "margins" command. Both results show that the marginal effect of banking competition on carbon emissions rises and becomes significant as the degree of government intervention increases. Meanwhile, when *GI* has lower values, both the corresponding coefficients are negative and even remain significant in the right (*IRBGM*) figure.

This result, the changing coefficients of *BC*, is interesting for our conclusion. When the interaction term is added to the equation, the coefficient of *BC* becomes negative but remains significant in Columns (2), (6), and (8). Although the value in Column (4) remains positive, it declines by approximately 0.9 and becomes nonsignificant. Noteworthy, the meaning of the coefficient reflects that the average effect of banking competition on carbon emissions with $GI = 0$, when the model includes the interaction term. However, the former coefficient represents the average effect of banking competition on carbon emissions when *GI* assumes the average value for the sample. Based on the marginal-effect figure, we propose that banking competition can decrease carbon emissions in China if the degree of government intervention is at a low level. In other words, additional credit will flow into more innovation activities in a market with little distortion, and thus

Table 4
Results for the moderating effect.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>ALGE</i>				<i>IRBGM</i>			
	1 – <i>HHI</i>		IV+2SLS		1 – <i>HHI</i>		IV+2SLS	
<i>BC</i>	0.335*** (0.091)	–0.219* (0.122)	1.310*** (0.249)	0.435 (0.323)	0.263** (0.113)	–0.333** (0.160)	1.060*** (0.269)	–1.037** (0.512)
<i>GI</i>	0.452*** (0.133)	–4.041*** (0.892)	0.330** (0.144)	–6.535*** (2.155)	0.055*** (0.010)	–0.127*** (0.036)	0.050*** (0.011)	–0.657*** (0.132)
<i>GI + BC</i>		5.047*** (1.010)		7.710*** (2.429)		0.209*** (0.044)		0.809*** (0.157)
<i>EI</i>	0.001 (0.013)	0.012 (0.013)	0.002 (0.013)	0.019 (0.014)	0.034** (0.014)	0.040*** (0.014)	0.034** (0.014)	0.059*** (0.017)
<i>Size</i>	–0.764*** (0.120)	–0.748*** (0.114)	–0.773*** (0.117)	–0.749*** (0.114)	–0.727*** (0.098)	–0.701*** (0.099)	–0.719*** (0.100)	–0.614*** (0.116)
<i>GDP</i>	0.120* (0.068)	0.119* (0.068)	0.118* (0.068)	0.116* (0.068)	0.203** (0.082)	0.216** (0.084)	0.212** (0.085)	0.266*** (0.097)
<i>IS</i>	0.392*** (0.081)	0.399*** (0.081)	0.345*** (0.085)	0.353*** (0.085)	0.449*** (0.102)	0.472*** (0.101)	0.398*** (0.104)	0.484*** (0.114)
<i>Urb</i>	–0.086 (0.081)	–0.062 (0.079)	–0.093 (0.089)	–0.058 (0.088)	0.006 (0.010)	0.011 (0.010)	0.006 (0.010)	0.025** (0.012)
<i>Cons</i>	4.013*** (1.096)	4.375*** (1.078)	3.309*** (1.147)	3.902*** (1.121)	2.565** (1.192)	2.811** (1.202)	1.832 (1.263)	2.576* (1.357)
K–P rk LM statistic			63.300***	62.900***			69.299***	58.045***
K–P rk Wald F statistic			92.608	44.517			100.061	39.953
DWH test			23.376***	11.453***			12.738***	20.957***
Observations	4,157	4,157	4,097	4,097	5,344	5,344	5,273	5,273
R-squared	0.899	0.902	0.886	0.890	0.916	0.918	0.911	0.893
Number of groups	287	287	283	283	314	314	310	310

Note: Cluster standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

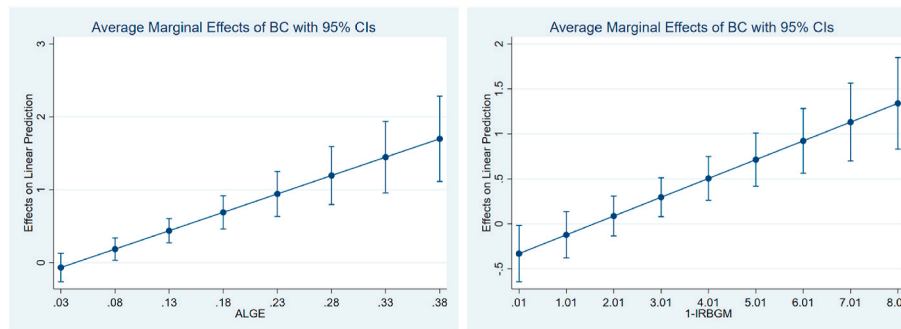


Fig. 4. Marginal effect figure.

government intervention is a crucial reason that banking competition has a positive, total effect on carbon emissions in China.

6. Conclusions and policy implications

We analyze the relationship between banking competition and carbon emissions based on a sample of China's prefecture-level cities for the period 2000–2017. Considering the results of the models in this study, we draw three main conclusions. First, an increase in banking competition promotes carbon emissions in China, a conclusion that is stable in the various models. Second, banking competition inhibits carbon emissions by advancing technological progress and increases emissions by boosting fixed-capital formation. Interestingly, the promotion effect is stronger than the inhibition effect. Last, a rise in government intervention in the market enhances the positive effect of banking competition on carbon emissions in China and plays a crucial role in this effect. The above results suggest the following policy implications.

- (1) The relationship between financial development and carbon emissions is controversial. We demonstrate that the banking competition will increase carbon emissions, which means that the financial regulatory authorities, especially the People's Bank of

China, the Banking and Insurance Regulatory Commission and the National Development and Reform Commission, should prudentially approve the establishment of SMBs, control the expansion rate of banking, and develop capital markets and direct finance.

In addition, government should promote the merger and reorganization of regional SMBs, mainly urban commercial banks, rural commercial banks and credit cooperatives, in order to reduce the competitive strength of the regional banking market. In fact, due to excessive credit expansion and massive accumulation of risks, many regional banks have merged since 2021. For example, in 2022, Luoyang Bank, Pingdingshan Bank and Jiaozuo China Travel Bank had been merged by Central Plains Bank. It alleviates the excessive credit of SMBs to backward production capacity such as real estate, steel and coal.

- (2) Implementation policies to promote technological progress channel and inhibit fixed capital formation channel is essential. It is crucial to guide credit funds to green industries and R&D through financial policies. In terms of monetary policy, the People's Bank of China has guided banks to provide preferential interest rate credit funds to green enterprises and technological

innovation entities through structural tools such as re-lending to support the clean and efficient use of coal, scientific and technological innovation and carbon emission reduction. However, the effectiveness of structural monetary policy is restricted by many factors. Some of the targeted liquidity will be reallocated in the inter-bank market. Therefore, the People's Bank of China should further improve the efficiency of monetary policy transmission and marketization of interest rates, avoid the command control policies, and make the loan market quoted rate (LPR) become the benchmark interest rate formed by market transactions. To avoid the circulation of funds only among financial institutions, the Bank of England's Financing for Lending Scheme (FLS) can be used for reference. After provide credit to green enterprises, commercial banks borrow government bonds from the central bank with credit assets as eligible collateral, and then use government bonds as collateral to acquire funds from the bonds repurchase market. The commission is inversely proportional to the amount of green credit. Innovation activities usually rely on long-term funds, while monetary policy can only indirectly change long-term interest rates by controlling short-term interest rates. The People's Bank of China should further extend the term of the targeted re-lending to more than 4 years (not dependent on rollover). At present, the maximum term of the targeted medium-term lending facility (TMLF) is only 1 year, and the bank can apply for rollover to a maximum of 3 years.

The Chinese government should further encourage the development of green financial securities, including green commercial paper, green credit, green bonds, carbon financial instruments (carbon forward, carbon futures, carbon options), and a series of financial supervision, incentive and assessment systems. At present, the international prevailing rules of green finance are still under construction, lacking unified standards. The current restriction of green finance lies in the high degree of information asymmetry, which is easy to bring moral hazard. Therefore, stakeholders should focus on the disclosure of environmental protection information and improving the information disclosure system. Universities, the central bank, the Ministry of Ecological Environment and private enterprises should cooperate on building post-event monitoring and evaluation mechanism for carbon emissions. It includes carbon emissions database that can be audited by a third party, and high-frequency monitoring method for carbon emissions, which helps to reduce the information asymmetry between commercial banks and green credit enterprises, capital market investors and green securities issuers, central banks and commercial banks.

Besides, government should adopt appropriate fiscal policies (and the corresponding incentive and regulatory measures, such as tax breaks) toward cleaner production enterprises, implementing a carbon-label system, strengthening the carbon audit, etc., to encourage enterprises to pay more attention to R&D, the application of energy conservation and emissions-reduction technology, and the upgrading of production equipment to "green."

- (3) The government intervention in the micro-economy activities should be controlled, as it is an important basis for the market-oriented reform of factors allocation. Government should improve the effectiveness of the central institutions' supervision of regional SMBs. On the one hand, the review and supervision power of local governments on regional SMBs should be reduced. On the other hand, referring to the two peaks regulation model, a special financial behavior supervision department should be set up to supervise and guide the specific market trading activities of banks, while prudently supervising the smaller regional banks. Strengthening bank governance is another necessary way to mitigate the local government intervention. Using digital currency and other financial technology instruments to audit the actual capital contribution of shareholders, and strictly punishing

the acts of false capital contribution and capital flight aim to implement the shareholders' risk responsibility for banks operation (skin in the game). It is also important to promote SMBs to optimize the equity structure. Government and legislature should limit the equity ratio of local state-owned shareholders, especially urban investment platform shareholders, and guide cross-regional investors to participate. In addition, the functions of the board of supervisors should be optimized so that it can cooperate with the central authorities and play certain role in the supervision of bank operations.

It is indispensable to strengthen the government's resources and environment management function. Environmental sustainability and innovative growth rate should be added into the official promotion assessment system to encourage local governments to limit backward production capacity and reduce economic intervention. Besides, we suggest that government should strengthen the construction of energy conservation and environmental protection standard system, formulate emission standards for polluting enterprises, environmental protection enterprises and key regions, and establish appropriate energy conservation and environmental protection standard system.

CRediT authorship contribution statement

Yitian Xiang: Methodology, Software, Validation, Writing – review & editing. **Haotian Cui:** Writing – original draft, Data curation, Software, Validation. **Yunxiao Bi:** Writing – original draft, Revision, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.enpol.2023.113476>.

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