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The impacts of climate change risks on financial performance of mining industry: Evidence from listed companies in China

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ABSTRACT

The mining industry is susceptible to climate change risks since it has the characteristics of high exposure, high sensitivity and high substitution. Firstly, this paper reviews the impact mechanism of climate change risks on corporate financial performance from direct and indirect channels. Secondly, this paper employs the unique data, climate risk indicator with 5 types of climate risks, to analyze the effect of climate change risks on the China's mineral listed companies. The empirical analysis shows that there is a correlation between climate change and financial performance of mining companies. The mining companies with different types of resource have different sensitivities to climate change risks. The climate change risks have both positive and negative effects on the financial performance of mining companies. In respond to the climate change risks, mining companies should actively implement low-carbon strategies and proactively disclose emission information to improve the brand value and create new competitive advantages for long-term development.

1. Introduction

With the rapid development of industrialization and urbanization, the excessive exploitation and utilization of mineral resources have sharpened the concentration of greenhouse gases in the atmosphere, which has led to an increase in the frequency and severity of extreme climate events all over the world (IMF, 2017; IPCC, 2014) and incurred a huge impact on the ecological environment and socio-economic system. According to the 2020 Global Risk Report, the top five risks to occur are extreme weather events, climate action failure, natural disasters, biodiversity loss and human-made environmental disasters. Unless the whole world agrees to take more ambitious action on temperature control and aids poor countries to cope with climate change, the developing countries will lose US$1.7 trillion a year by 2050 (Kong et al., 2018). According to the China Climate Index Report, the direct economic losses caused by climate change risks accounted for 71% of all natural disasters from 1990 to 2015 (National Climate Center of China, 2017).

The impacts of climate change on the mining industry are multi-faceted. The intensity and frequency of extreme climate events can bring damage to the construction of the mining industry (Pearce, 2019) and aggravate tensions between the mining industry and the public (Vigya and Daniel, 2013). The three sectors most at risk, according to Moody's report, were unregulated power generation, coal mining and coal terminals. The climate change policies will also change the demand and supply of mineral resources. Besides, it is worth noting that climate change will accelerate the population migration and undermine the stability of political rights and property rights system. Compared with other industries, the mining industry has three characteristics in climate change risks: high exposure, high sensitivity and high substitution.

The production is high exposure. Since the mining activities are mainly in the form of open-air construction and underground stope construction, the changes in natural conditions caused by climate change will directly affect the working environment and the normal operation. On the other hand, the transport means of supply, production and sale in mining industry mainly depends on automobile and railway at present, which have high exposure in the natural environment. The outlook is highly sensitivity. The mining industry is the key target of the policies for climate change because of its intensive carbon emission and environmental pollution, which force mining companies to launch a

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low-carbon transition. The demand is high substitution. With the rapid development of renewable energy, the importance of coal and oil in the world energy market is declining. The sharp decline in cost has endowed the new energy industry with a greater competitive advantage. Meanwhile, the governments at all levels have issued preferential policies to encourage companies to develop and use clean energy. Therefore, the traditional energy such as coal and oil are very likely to be replaced by new energy.

Some leading mining companies have realized the consequences of climate change risks and that they are in the frontline of the battle to reduce emissions. BHP Billiton and Rio Tinto support emissions trading scheme, develop low carbon energy projects and clean coal technology around the world by creating a low carbon energy business (Pellegrino and Lodhia, 2012). Both Shell and BP announced that they will achieve "Net-zero emissions". Shell plans to reduce the carbon footprint of its products and reach carbon neutrality by 2050. In addition, there are some non-governmental organizations to help mining companies make strategic adjustments to cope with climate change. The World Bank launched its Climate-Smart Mining Facility to address the challenges of scaling up new mining exploration and supply chains and mitigate risk for multinational mining companies (Phadke, 2019). The United Nations Economic Commission for Europe (UNECE) has developed Best Practice Guidance on Effective Methane Drainage and Use in Coal Mines, which presents recommended principles and standards on coal mine methane capture and use in a clear and succinct way, provides decision-makers with a solid base of understanding. However, China's mining enterprises are still behind in dealing with climate change risks, and relevant domestic organizations do not pay enough attention to it.

The factors affecting the financial performance of the mining industry mainly focus on the governance structure, environmental cost and social responsibility performance in the existing researches. The empirical researches on the impacts of climate change risks mostly focus on the city-level and industry-level. Thus, the possible contributions in this article include the following three aspects: Firstly, introducing climate change risk into the analysis of financial performance of the mining industry. Secondly, systematically analyzing the positive and negative impacts of climate change risks on corporate financial performance with the company-level data. Thirdly, employing the unique climate risk indicators that is composed of five types of climate risks.

The rest of the paper is as follows: The next section reviews the literature, Section 3 reports the mechanism, Section 4 describes the methodology and data, Section 5 reports the empirical results and discussions. The final section concludes the paper with policy implications.

2. Literature review

Climate change risks have received widespread attention at the macro-level. As global temperatures are expected to continue to rise, it is increasingly important to understand and anticipate the impact of climate change risks on economic activity (Dell et al., 2014). Economic activities such as agriculture, forestry, fishermen and mining are directly affected by the extreme climate events since these industries are vulnerable to climate change. The industries that are less dependent on the natural environment are also affected by climate change because the market can link all sectors. Thus, climate change risks have a wide-ranging impact on production operations in all kinds of industries, either directly or indirectly. However, climate change risks present both opportunities and challenges for social and economic activities (IPCC, 2014).

The impacts of climate change on certain industries have received widespread attention. Agriculture is widely accepted to be sensitive to the risks of climate change because of its dependence on temperature and seasonal conditions (Gasbarro and Pinkse, 2019). Climate change risks also affect the development of industry and services (Zhang and Miu, 2001). Extreme high-temperatures have large negative impacts on non-agricultural industries, including mining and public utilities (Dell et al., 2012; Hsiang, 2010). Tourism, which is closely related to natural resources, will undergo major changes due to climate change risks. The frequent meteorological disasters will further weaken the affordability of insurance companies and the availability of insurance services.

The occurrence of climate change risks is not easy to be found in the initial stage and its severity is higher in the later stage. As a result, most of companies are often unaware of the severity of climate change risks and hardly take effective countermeasures in time. However, the risks of climate change have become the challenges and opportunities that companies have to consider. According to the McKinsey & Company's survey, 60% of executives believe that climate change risks should be integrated into the company's overall strategy. Nearly half of the respondents indicated that they have considered climate change factors in product development and investment planning (Gordon, 2008). Addressing climate change risks also has become an important indicator of corporate social responsibility. Through questionnaire surveys, companies' awareness of climate change comes later than that of foreign-funded companies in China since a lack of thinking and understanding of climate change risks from a strategic perspective.

Although the production activities of mining industry involve a large number of open-air operations, the infrastructures of most mines are not designed with climate change in mind. The intensity and frequency of extreme climate events can bring damage to the construction of the mining industry (Pearce, 2019). For example, in Queensland, the state lost more than $5 billion in gross domestic product because the floods shut down many mines (Sharma and Franks, 2013). In Australia, the large demand for water in the mining industry during the dry period and the discharge of mine water during floods have bring serious negative reputation, which threaten the company's survival by social activists and consumers. The transition from "carbon economy" to "green economy" is seen as a critical way to mitigate climate change, which means less exploitation of mineral resources. At the same time, the development and utilization of renewable resources will also lead to a decline in the demand for fossil energy resources (Buorgouin, 2014). Climate change also affects the normal operation of mining activities by changing environmental factors (Odell et al., 2018). The rapid expansion in mining activities is deteriorating the water quality in the Chindwin River of Myanmar, which will been aggravated by the climate change in future (Shrestha et al., 2020). Obviously, climate change risks have a wide-ranging impact on the mining industry on a global scale.

Some studies have demonstrated the impact of environmental protection on financial performance. It is necessary for companies to strengthen the cost management, the awareness of environmental protection in order to improve the comprehensive financial capacity. In the long run, companies actively implementing environmental governance and protection measures can achieve a win-win situation between the environment and finance (Yang and Wang, 2016). The active implementation of social responsibility by listed mining companies can also play a significant role in promoting the current financial performance of companies. Researches on the financial performance of the mining industry have mainly focused on financial capability, capital structure, cash flow, solvency ability. However, there are a few studies focusing on the impacts of climate change risks, which is precisely the motivation and logical starting point of this article.

3. Mechanism

The risks of climate change affect the financial performance of the company through both direct and indirect channels. The direct impact of climate change risks on the financial performance is to change the natural conditions of production and operation of companies including assets, raw material, manufacturing technique, support systems and so on. The indirect impact is to change the operating and competitive environment including environmental regulation, climate policy, stakeholders' attitudes, litigation cases and so on. Both direct and indirect channels will change the financial ability and performance of

company.

3.1. Direct impact

It is widely accepted that extreme climate events have a direct impact on the financial performance of companies that operate in climate-scarred areas or rely on natural conditions in their operations. Physical risks and opportunities of climate change can exert significant financial impacts on companies, including revenues, expenditures, assets, liabilities, and capital and financing (Ambrosio et al., 2020).

3.1.1. Core operation

Extreme climate events can damage a company's production materials and infrastructure, then change the production environment and efficiency of a company, causing companies to fail to carry out normal production activities with additional expenses. In the development of offshore oil and natural gas, natural disasters such as storms can easily damage equipment, hinder or interrupt normal development activities. Sea level rise caused by global warming has caused many companies to change the location of production activities and pay for the corresponding migration costs. For companies whose geographical location is closely related to the distribution of production materials, they will face high risk costs. Many companies are often planning infrastructures based on the prevailing climate conditions without considering future climate changes risks. Therefore, for companies whose core operations depend on natural conditions, climate change will bring the loss of material assets and the increase of expenses, which will have a negative impact on the financial performance of the company.

3.1.2. Value chain

For companies that produce goods, a value chain comprises the steps that involve bringing a product from conception to distribution such as procuring raw materials, manufacturing functions, and marketing activities. Climate change will affect the supply of raw materials from accessibility and cost. Climate change will also change the productivity of labor force since high temperatures limit the working hours of outdoor operations. Climate change will change the demand patterns of consumer. The energy demand and temperature changes and found a clear U-shaped relationship between them in U.S.A (Deschênes and Greenstone, 2011). These changes directly affect suppliers, human capital, and market demand in the company's production value chain. Companies need to adjust their business model to cope with the risks brought about by climate change. The companies that don't take proactive measures to deal with climate risks will suffer from negative impacts on the quality of product, staff efficiency and competitiveness.

3.1.3. Support system

Public infrastructures including transportation, communication networks, energy supply and related infrastructure provide the foundation for business operations and production. Climate change has improve the frequency of extreme climate events such as floods, droughts and typhoons, which will lead to the interruption of the water supply, power supply, public infrastructure and local logistics system. These extreme climate events disrupt business operations and affect income derived from business activities.

3.2. Indirect impact

Since the markets are interconnected, when an industry is affected by climate change risks, the upstream and downstream industries associated with it will also be indirectly involved. At the same time, climate change policies also indirectly affect the financial performance of many industries through multiple channels.

3.2.1. Climate policy constrain

The government further limits and reduces the proportion of industries with intensive-energy, which crack down on the market value of related industries. The government needs to use legal means to put pressure on companies to reduce carbon emissions since they tend to input the intensive-carbon energy to create economic benefits while destroying the ecological environment without paying any price (Bondarev and Greiner, 2014). Six years after starting the pilot Emission Trading System (ETS), China launched the national carbon market in 2017. The petroleum, chemical, and non-ferrous industries have been covered in the first phase of China's national ETS. The upstream and downstream of these companies will face considerable environmental pressure to reduce emissions in case of companies that fail to meet their reduction targets will pay high abatement costs. European emission reductions have led to a significant increase in production costs in industries such as electricity and cement (Chan et al., 2013).

There is often an over investment in fossil fuels since the long-term targets of carbon reduction are not included in traditional market valuations in most situations, which could make the associated assets and resources stranded. The stranded assets or resources of an enterprise may be underestimated or even converted into liabilities (Bos and Gupta, 2019). The internalization of environmental costs in the production activities will promote companies to make scientific choices between costs and benefits, thereby enhancing the efficiency of resource conservation and promoting the establishment of environmentally sustainable development models, which will have a positive impact on financial performance.

3.2.2. Market opportunity

The traditional energy consumption represented by coal and oil has the most serious impact on carbon emissions. Therefore, it is necessary to formulate reduction plans according to the demand of energy, and gradually reduce the consumption of coal and oil products (Cheng et al., 2019; Wu et al., 2020). The goal of control temperature within 2 °C will significantly reduce the demand of oil and gas resources, which will affect the development of the oil and gas industry.

According to statistics, the oil and gas industry has lost its place in energy investment and will face pressure from financing. Some financial institutions such as JP Morgan Chase & Co. will end or phase out loans to some fossil-fuel projects including putting restrictions on the financing of new coal-fired power plants, phasing out credit exposure to the mining industry by 2024 and stopping funding new oil and gas drilling projects. The People's Bank of China has launched the initiative of green finance and issued a series of policies including green credit, green investment, green funds, green insurance and so on. All of these information signal that the financing of mining industry is becoming increasingly difficult. If companies do not have sufficient free cash flow, they may miss good market opportunities and fail to realize the long-term development of the company. The implementation of a low-carbon strategy is conducive to the sustainable development of companies, and the transformation of investment fields will become a new opportunity for business development, which will have a positive impact on financial performance of them.

Through direct investment and subsidy policies, the government encourages companies to apply low-carbon technologies and guides companies to carry out low-carbon transformation. By disclosure of environmental information and identification of green product, consumers' preference is turning to more environmentally friendly goods, which creates new opportunities for some companies. If companies comply with this change of market demand, they will actively carry out structure transformation and develop low-carbon technologies. In the short-term, companies have to invest to upgrade equipment and technology and establish low-carbon production models, which have negative impacts on corporate financial performance since these efforts cannot be returned immediately. However, in the long run, the low-carbon technology and updated equipment can improve the efficiency of resource utilization and reduce the compliant cost, which will provide internal driving force for the sustainable development of companies and

have a positive impact on financial performance.

3.2.3. Reputation impact

The extreme climate events exert negative effects on operation and service performance of enterprise, which may lead to the decline in brand value and reduce the attractiveness of consumers and investors. On the other hand, it can be seen that ordinary investors and consumers are paying more and more attention to corporate climate responsibility disclosure. The attitude of companies to climate change risks is becoming one of the standards for stakeholders to measure the risk of corporate brand value. Through fulfilling environmental protection responsibilities, companies can enhance brand value and win social reputation. If companies can actively cope with climate change and take the initiatives to disclose emission information, they will convey to investors the signal that the company will develop well in the future. So, the higher the investor's recognition of the company, the stronger the financing ability of the company. With the growing awareness of climate change, consumers are becoming more environmentally conscious and often willing to pay a green premium above the average market price to support the development of clean products, as a result, green products become more competitive in same markets.

3.2.4. Legal proceeding

The changes in law or regulation related to climate change increase the probability of the occurrence of corporate contingent liability and also bring more risks of the enterprise taking on contract, civil or criminal liabilities, resulting in negative effects on cash flow or market value. The litigation may occur in corporate climate risk mainly for three reasons: Firstly, in areas where environmental regulation is already in place, companies face fines and lawsuits for failing to meet their obligations to reduce emissions. Secondly, with the understanding of climate change and the improvement of living environment requirements, the carbon emissions of companies may seriously damage the health and life safety of residents in the region, which will lead to lawsuits for local residents. Thirdly, if managers fail to consider the risks of climate change and cause financial losses, shareholders may sue executives for failing to perform their fiduciary duties. Lawsuits will increase the contingent liabilities of the company and affect the solvency of the company.

To sum up, the impact mechanism of climate change risks on corporate financial performance is shown in Fig. 1. The climate change risks can directly affect the core operations, value chain and support system of listed mining companies, resulting in the changes of financial performance. Climate change risks can also affect the financial performance of listed mining companies through climate policy constrains, market opportunity, reputation impact and legal proceeding. Actively coping with climate change risks can promote the improvement of production efficiency and the enhancement of competitiveness, while negative response to climate change risks may bring huge abatement costs and weaken development capabilities.

4. Methodology and data

4.1. Model setting

The independent variable of this paper is the financial performance of the company that is measured by the Return on total assets (Roa) since it plays a guiding role in evaluating the financial performance of companies (Peters and Mullen, 2009). The higher the return on total assets of the company, the higher the efficiency of the company's assets, the stronger the profitability, the better the financial performance of the company, and vice versa. In order to test the impacts of climate change risks on the financial performance of China's listed mining companies, in this paper, the comprehensive climate risk index (CRI) is selected as independent variable. This paper establishes the basic model as follows:

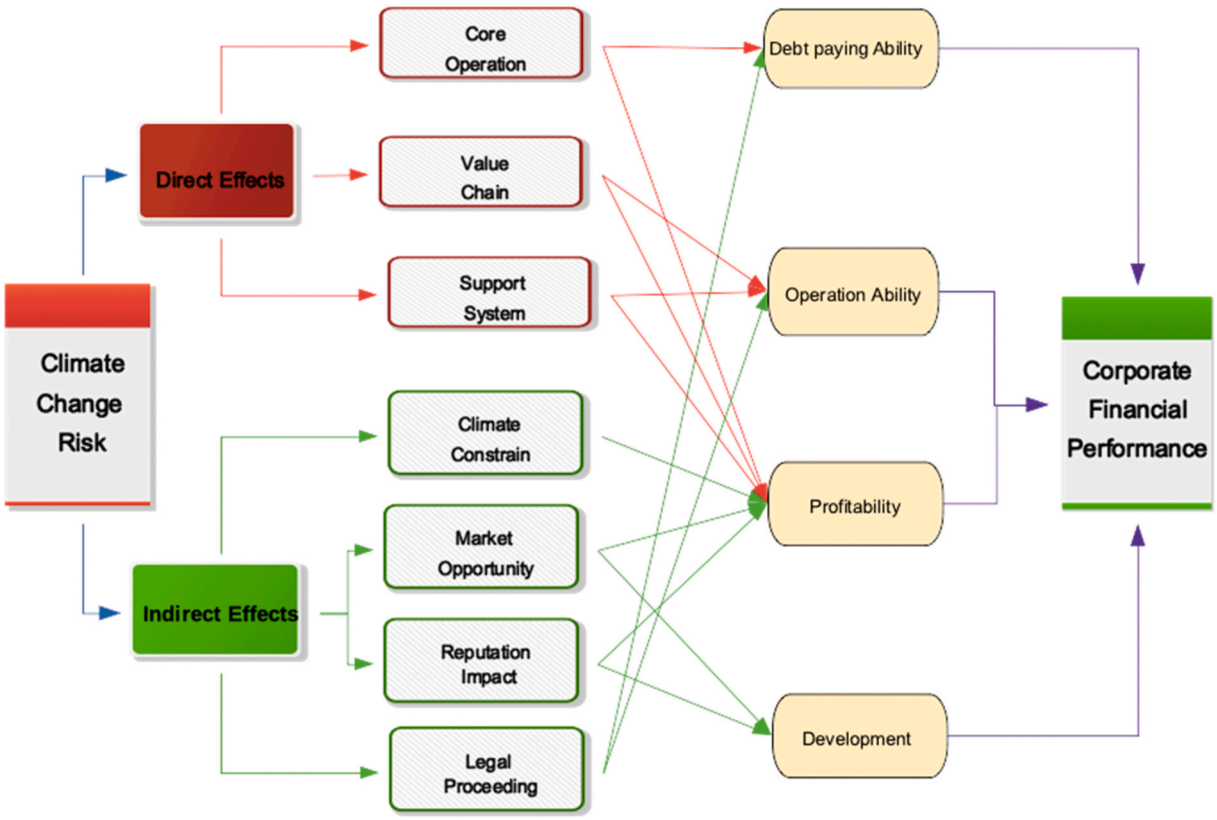

Fig. 1. Impact of climate change risk on corporate financial performance.

$$Roa_{it} = \alpha_0 + \alpha_1 CRI_t + \alpha_2 Debtas_{it} + \alpha_3 \ln Totalin_{it} + \alpha_4 \ln Size_{it} + \alpha_5 Holder_t + \alpha_6 Ownership_t + \alpha_7 PGDP_t + \alpha_8 Finance_t + \alpha_9 Humanresource_t + e_{it} \quad (1)$$

The Integrated Climate Risk Index (CRI) is a composite index based on five climate risk indicators. However, since some sectors in the mining industry may only be sensitive to certain climate risks and there may be offsetting effects among different climate risks, it is failure to identify the impact of climate risks on listed mining companies. Therefore, subdivided climate change risk indicators are necessary for regression, including Rain-waterlogging Index (CYRI), Drought Index (CYDI), Typhoon Index (CYTI), High Temperature Index (CYHI) and Cryogenic Freezing Index (CYFI). These five risk indices are independent of each other. The extended model is established as follows:

$$Roa_{it} = \beta_0 + \beta_1 CYRI_t + \beta_2 CYDI_t + \beta_3 CYTI_t + \beta_4 CYHI_t + \beta_5 CYFI_t + \beta_6 Debtas_{it} + \beta_7 Totalin_{it} + \beta_8 \ln Size_{it} + \beta_9 Holder_t + \beta_{10} Ownership_t + \beta_{11} PGDP_t + \beta_{12} Finance_t + \beta_{13} Humanresource + e_{it} \quad (2)$$

In order to testify the robustness of the empirical results, this paper selects the meteorological indicators from China Meteorological Data Network as another set of independent variables including the maximum temperature (Temmax), the minimum temperature (Temmin), the average temperature (Temave) and the total duration of the annual sunshine (Sunday).

According to existing research, this paper selects two sets of variables as control variable. The first set of control variables is the micro level of corporate financial indicators including the company's capital structure (Debtas), the development ability of the company (Totalin), the company size (Lnsize), the controlling shareholder (Holder), the company ownership (Ownership) and so on. The second set of macro-level control variables including economic development (PGDP), the human capital (human capital), and financial development (Finance) at city level where the listed company is located.

4.2. Data

4.2.1. Corporate financial data

This paper collects and sorts the financial data of China's 75 mining listed companies from 1995 to 2017 through GTA Database and Wind Database. The return on total assets defined as the ratio of the net profit in the current year to the average total assets is used to measure the corporate financial performance. We employ the asset-liability ratio to measure the company's capital structure, the total asset growth rate to measure the company's growth, and the company's total assets to measure the company's size. In this paper, the company's assets at end of the year are treated logarithmically to better reflect the scale of the company. The share proportion of the largest holder is used to measure the shareholding ratio of the controlling shareholder. The nature of company ownership is divided into state-owned companies and private companies.

4.2.2. Climate change risk data

The index of climate change risks between 1995 and 2017 were published by the National Climate Center of China and the prefecture-level meteorological data were provided by China Meteorological Data Network. The climate risk index is based on the meteorological disaster loss data of China in the last ten years, which is processed by nonlinear function and normalized to obtain the weight of the index. The climate risk index includes five types: Drought index, Rain-waterlogging Index, High-temperature Index, Typhoon Index and Cryogenic Freezing Index. The comprehensive climate risk index is obtained by weighting five meteorological disasters with the average annual loss as the weight.

The maximum (minimum) temperature is calculated by averaging the monthly maximum (minimum) temperature at the location of main mine areas of the listed mining company. The average temperature is calculated by averaging the temperature over several months in the main mining areas of listed mining companies. The total annual sunshine duration is the cumulative value when the direct solar irradiance of a listed mining company reaches or exceeds 120 W/m^2 in a year.

4.2.3. City-level economic data

This paper collects and sorts out the economic data of the prefecture-level cities where the listed mining companies are registered from 1995 to 2017 by consulting China City Statistical Yearbook. Per capita GDP is used as an indicator to measure the level of economic development. The proportion of college students is used as an indicator to measure human capital. The development level of financial institutions is used as an indicator to measure regional financial development which is equal to the ratio of the loan balance of the financial institution to the city' GDP. A description of all variables is shown in Table 1 as below.

5. Empirical results and discussions

5.1. Basic regression

Table 2 reports the regression results of climate change risks on the financial performance of China's listed mining companies. The impact of the comprehensive climate risk index (CRI) on the financial performance of listed mining companies is not significant. The possible reason is that the effects of different climate change risks offset each other since some climate change risk types may be positive, others may be negative.

The impact of rain-waterlogging risk (CYRI) on the financial performance of listed mining companies is not significant since there are only a few mining companies that are sensitive to rain-waterlogging. The drought risk (CYDI) is significantly and positively correlated with the financial performance of listed mining companies. The impact of typhoon risk (CYTI) on the financial performance of listed mining companies is not significant. The typhoon-affected areas in China are mainly located in southeast coastal, while most of mining industry listed companies are concentrated in north and northwest China. The high temperature risk (CYHI) is negatively correlated with the financial performance of listed mining companies since high temperature will affect the working environment of the mining industry and reduce labor productivity (Su et al., 2018). The risk of cryogenic freezing (CYFI) is negatively correlated with the financial performance of listed mining companies since cryogenic freezing poses a serious threat to the supply system (An, 2008).

The capital structure (Debtas) is positively correlated with the financial performance of listed mining companies. The higher the asset-liability ratio, the better the company's financial performance since the mining industry requires a large amount of capital investment and a long occupation period. The growth of the company (Totalin) is positively related to the financial performance of listed mining companies. In general, the faster the company grows, the bigger the market share, the greater the competitiveness of the company, and the higher the financial performance of the company. The scale of the company (Lnsize) is negatively correlated with the financial performance of listed mining companies. This may be due to the large scale of listed mining companies, the expansion of the scale led to a significant increase in the difficulty of internal management, resulting the increase in costs and the decline in profits. The shareholding ratio of the controlling shareholder (Holder) and the ownership structure (Ownership) have no significant impact on the financial performance of listed mining companies. This may be contributed to the fact that China's mining listed companies are mainly state-owned, and there is little difference between the corporate governance structure and ownership.

Besides, the impact of macroeconomic variables on the financial performance of listed mining companies is not significant. This may be because the location distribution of listed mining companies in China is relatively concentrated on some cities and their differences of economic

Table 1
The variable's definitions.

Variable Type	Variable Name	Variable Code	Variable Description
Dependent variable	financial performance	Roa	Return on Assets
Independent variable 1	Comprehensive climate risk index	CRI	The monthly indices of five meteorological disasters are weighted averaged and normalized
	Rain waterlogging index	CYRI	The monthly rainfall index is arithmetically averaged and normalized
	Drought index	CYDI	Monthly drought index arithmetic average and normalized
	Typhoon index	CYTI	The weighted average and normalized treatment were carried out with the coverage area of each grade of wind and rain as the base
	High temperature index	CYHI	Monthly high temperature index is arithmetically averaged and normalized
	Cryogenic freezing index	CYFI	Weighted average of monthly Cryogenic freezing index and normalized
Independent variable 2	Minimum temperature	Temmin	Annual minimum temperature
	Maximum temperature	Temmax	Annual maximum temperature
	Average temperature	Temave	Annual average temperature
	Sunshine hours	Sunday	Total annual sunshine duration
Control variables 1	Capital Structure	Debtas	Asset-liability ratio
	Growth	Totalin	Asset growth rate
	Company Size	Lnsize	Natural logarithm of total assets at the end of the year
	Shareholding ratio of controlling shareholders	Holder	Number of shares held by the largest shareholder/ total number of shares
	Ownership structure	Ownership	Virtual variables, 1 for state-owned companies and 0 for private companies
Control variables 2	Economic development	PGDP	Per capita GDP
	Financial development	Finance	The proportion of financial institutions' loan balance to the regional GDP
	human capital	Human capital	The proportion of college students to the total population

development are small. The mining industry has low requirements for the level of labor education, and the improvement of human capital quality has no obvious promoting effect on listed mining companies.

5.2. Heterogeneity of climate change risks

Since different types of mineral resources have different sensitivities to climate change risks, it is very necessary to divide the mining industry into sub-industries to examine the impact of climate change. In this paper, we divide the mining industry into the following sectors: coal mining and washing (Sector 1), oil and gas extraction (Sector 2), common non-ferrous metal mining (Sector 3), precious metal mining (Sector 4), non-metallic mining and other mining (Sector 5).

Table 3 reports the regression results of the impact of comprehensive climate risk index on the listed mining companies in different sector. The

Table 2
Regression results of climate change risk.

Variables	Roa	Roa
CRI	0.0133	
	(0.0381)	
CYRI		0.124
		(0.0759)
CYDI		0.159**
		(0.0689)
CYTI		0.0543
		(0.0547)
CYHI		−0.0768*
		(0.0461)
CYFI		−0.246***
		(0.0659)
Debtas	0.00534**	0.00493*
	(0.00259)	(0.00257)
Totalin	1.720***	1.750***
	(0.134)	(0.134)
Lnsize	−0.166***	−0.167***
	(0.0555)	(0.0552)
Holder	0.00626	0.00741
	(0.00673)	(0.00669)
Ownership	0.295	0.283
	(0.237)	(0.235)
PGDP	0.0131	0.00670
	(0.0261)	(0.0260)
Finance	−1.17e-07	−2.94e-07
	(1.85e-06)	(1.84e-06)
Humancapital	0.000453	0.000417
	(0.000305)	(0.000304)
Constant	2.771**	2.287*
	(1.086)	(1.179)
Observations	705	705
Number	69	69

Notes: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively, and () is the estimated standard error.

comprehensive climate risk index is positively correlated with the financial performance of the oil and gas extraction sector (Sector 2) since extreme climate events affect energy demand. For example, the increase in the frequency of extreme cold or hot weather both will lead to an increase in the demand of energy. The other sectors are not significantly affected by the comprehensive climate risk index. Because the impacts of various climate change risks on a company's financial performance offset each other. The impact of corporate financial variables and macroeconomic variable on the financial performance of listed mining companies is basically consistent with the results of the previous analysis.

5.3. Impacts of subdivided climate change risks

Table 4 reports the regression results of impacts of subdivided climate change risks on the financial performance of mining companies in different sectors. The coal mining and washing sector (Sector 1) is sensitive to cryogenic freezing risks. Due to geothermal temperature and water damage, there is a high temperature hazard in mine operation. With the increase of mining depth and daily output, mine heat damage becomes more serious. The lowering of the ambient temperature can alleviate the heat damage of the mine to some extent, and improve the production of the mine. On the other hand, cryogenic freezing causes people to need heating for longer and consuming more coal since China's energy mix is still dominated by coal.

The precious metal mining sector (Sector 4) is sensitive to drought risk and cryogenic freezing risk. The dry weather is conducive to the development of mining activities, thus promoting the growth of company income. The financial performance of precious metal mining companies is negatively correlated with the cryogenic freezing risk. The cryogenic freezing will make the mine operating environment deteriorate and reduce the productivity of the company. Cryogenic freezing will

Table 3
Regression results of different sectors.

Variables	Sector1	Sector 2	Sector 3	Sector 4	Sector 5
	Roa	Roa	Roa	Roa	Roa
CRI	0.00108	0.00510**	−0.000760	0.0239	−0.00333
	(0.00155)	(0.00250)	(0.00545)	(0.112)	(0.00263)
Debtas	−0.216***	−0.311***	−0.189**	0.000836	−0.0933*
	(0.0254)	(0.0471)	(0.0804)	(0.00472)	(0.0539)
Totalin	0.0873***	0.0932**	0.0795	1.849***	0.0679***
	(0.0133)	(0.0369)	(0.0592)	(0.243)	(0.0192)
Lnsize	0.00550*	0.00128	−0.0413	−0.429***	−0.00390
	(0.00319)	(0.00492)	(0.0491)	(0.165)	(0.0147)
Holder	0.00104***	1.36e-05	0.00258***	−0.0265	0.000815
	(0.000387)	(0.000665)	(0.000823)	(0.0229)	(0.00089)
Ownership	0.0288*	−0.0188	0.0116	1.229*	0.0204
	(0.0170)	(0.0147)	(0.0336)	(0.747)	(0.0365)
Observations	273	61	48	240	83
Number	26	5	4	22	12

Notes: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively, and () is the estimated standard error.

Table 4
Regression results of different climate risks and different sectors.

VARIABLES	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
	Roa	Roa	Roa	Roa	Roa
CYRI	0.00219	0.00644	0.00842	0.320	−0.0215***
	(0.00292)	(0.00486)	(0.0103)	(0.219)	(0.00643)
CYDI	0.00275	0.00409	0.0103	0.437**	−0.0142**
	(0.00263)	(0.00422)	(0.00901)	(0.198)	(0.00663)
CYTI	−0.00147	−0.000602	−0.000368	0.137	7.42e-05
	(0.00211)	(0.00329)	(0.00778)	(0.156)	(0.00518)
CYHI	−0.000747	0.00366	−0.00431	−0.212	0.00824*
	(0.00177)	(0.00284)	(0.00629)	(0.133)	(0.00430)
CYFI	0.00879***	0.00198	0.000826	−0.625***	0.00217
	(0.00254)	(0.00425)	(0.00828)	(0.191)	(0.00656)
Debtas	−0.202***	−0.288***	−0.190**	−6.80e-05	−0.0665
	(0.0231)	(0.0495)	(0.0830)	(0.00467)	(0.0475)
Totalin	0.0766***	0.0861**	0.0554	1.868***	0.112***
	(0.0130)	(0.0405)	(0.0692)	(0.243)	(0.0222)
Lnsize	0.00584**	0.00167	−0.0193	−0.407**	−0.00436
	(0.00273)	(0.00496)	(0.0541)	(0.163)	(0.0108)
Holder	0.000904**	8.71e-05	0.00290***	−0.0223	0.000643
	(0.000359)	(0.000670)	(0.000880)	(0.0225)	(0.000702)
Ownership	0.0280*	−0.0209	0.0121	1.138	0.0228
	(0.0154)	(0.0149)	(0.0357)	(0.735)	(0.0263)
Observations	273	61	48	240	83
Number	26	5	4	22	12

Notes: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively, and () is the estimated standard error.

also cause damage to production materials resulting in more maintenance costs for production equipment.

The other mining sector (Sector 5) is sensitive to rain-waterlogging risk and drought risk since flooding and drying up will make their work more difficult. As a result, they have to pay more efforts to provide the same business services in bad weather, so their financial performance declines.

Besides, the oil and gas extraction sector (Sector 2) and common nonferrous metal mining and dressing sector (Sector 3) are not sensitive to a single category of climate change risk. The impacts of corporate financial variables and macroeconomic variables on the financial performance of listed mining companies are basically consistent with the results of the previous analysis.

5.4. Robustness test

In order to test the rationality of the model setting and the robustness of result, another set of independent variables was selected for empirical analysis. Changes in meteorological conditions are manifestations of climate change risks since meteorological indicators such as temperature and sunshine can reflect the current climate change risk to a certain extent. Therefore, this paper selects the meteorological indexes of the main mining areas of listed mining companies as another set of independent variables to verify the correlation between climate change risks and the financial performance of China's listed mining companies, including the highest temperature (Temmax), the lowest temperature (Temmin), average temperature (Temave) and total sunshine duration (Sunday). Table 5 reports the regression results.

The impacts of temperature changes on the financial performance of listed mining companies are not significant since the impact of temperature changes may been offset each other resulting in the insignificant. The total duration of sunshine is negatively correlated with the financial performance of listed mining companies. Mining companies involve a large amount of outdoor operations, production activities and infrastructure exposed to the natural environment for a long time. The increase of sunshine time will accelerate the damage of mechanical equipment, companies need to pay more maintenance costs. At the same time, long hours of sunshine can lead to a decline in workers' labor force.

The financial performance of the coal mining and washing sector (Sector1) is positively correlated with the maximum temperature. The rise of summer temperature will lead to a significant increase in the use

Table 5
Regression results of robustness test.

Variables	Roa	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
		Roa	Roa	Roa	Roa	Roa
Temmin	0.00971	−0.00216	−0.00226	−0.00801*	0.0941	0.000454
	(0.0405)	(0.00185)	(0.00268)	(0.00421)	(0.122)	(0.00408)
Temmax	0.00865	0.00506**	−0.00704**	−0.00108	0.0545	0.00428
	(0.0447)	(0.00210)	(0.00329)	(0.00591)	(0.136)	(0.00436)
Temave	−0.0434	−0.00118	0.00577	0.00796	−0.223	−0.0140
	(0.0835)	(0.00383)	(0.00743)	(0.0149)	(0.236)	(0.00861)
Sunday	−9.026***	−0.427**	−0.285	−0.893	−18.33**	−0.529
	(3.192)	(0.179)	(0.401)	(0.703)	(8.632)	(0.374)
Debtas	0.00369	−0.199***	−0.413***	−0.153**	−0.00302	0.0122
	(0.00278)	(0.0282)	(0.0439)	(0.0769)	(0.00513)	(0.0615)
Totalin	1.749***	0.0922***	0.116***	0.0880	1.841***	0.0858***
	(0.143)	(0.0137)	(0.0326)	(0.0568)	(0.259)	(0.0215)
Lnsize	−0.232***	0.00290	0.00489	−0.0602	−0.603***	−0.0179
	(0.0658)	(0.00387)	(0.00816)	(0.0484)	(0.195)	(0.0130)
Holder	0.00598	0.000793*	−0.000890	0.00287***	−0.0202	0.000393
	(0.00818)	(0.000414)	(0.00108)	(0.000913)	(0.0268)	(0.000816)
Ownership	0.192	0.0510***	−0.0524**	0.0266	0.889	0.0634*
	(0.280)	(0.0184)	(0.0237)	(0.0299)	(0.873)	(0.0372)
Observations	617	236	56	44	210	71
Number	65	24	5	4	21	11

Notes: *, **, *** indicate significant at the 10%, 5%, and 1% levels, respectively, and () is the estimated standard error.

of air conditioners, increasing the demand for coal-based energy. The financial performance of the oil and gas extraction sector (Sector 2) is negatively correlated with the maximum temperature. Climate change risks have an impact on oil and gas extraction sector from two aspects, namely the pull effect of energy demand and the destruction effect of energy output. As temperatures rise, the production materials become more volatile, potentially increasing the risk of ignition. Therefore, companies need to pay extra costs to take the corresponding security measures. Although the increase in temperature will increase in the consumption of energy, China's energy mix is still dominated by coal at present. Thus, the pulling effect of demand is less than the destructive effect of output, resulting in the negative impact on financial performance. The common non-ferrous metal mining and dressing sector (Sector 3) has a negative correlation with the minimum temperature. The decline of temperature will damage the production materials and affect the production environment and make it more difficult for companies to operate. The precious metal mining sector (Sector 4) has a negative correlation with the sunshine hours since long-term sun exposure will accelerate the destruction of machinery and equipment.

Through regression analysis of the meteorological conditions and the financial performance of China's listed mining companies, it is verified that the empirical results are robust.

6. Conclusions and policy implications

Climate change risks affect a company's financial performance through both direct and indirect channels. This paper verifies the correlation and mechanism by establishing a panel data model based on China's listed mining companies. The comprehensive climate change risk has a positive impact on the financial performance of listed mining companies. Due to the mutual offsetting of risks, the comprehensive climate change risk is only significantly related to the oil and gas exploration sector.

The risk of rain waterlogging has a negative impact on the financial performance of listed mining companies. Flooding can impede mining and transportation activities in the mining industry, leading to a decline in financial performance. The risk of drought has a positive impact on the financial performance of listed mining companies, mainly because mining activities prefer dry to wet, dry weather is more suitable for the mining activity. The impact of typhoon risk on the financial performance of the mining industry is not obvious. This is mainly because listed Chinese mining companies have little overlap with typhoon-affected areas, making them less vulnerable to typhoon. High temperature risks and cryogenic freezing risks have a negative impact on the financial performance of China's listed mining companies. However, the risk of cryogenic freezing has a positive impact on the financial performance of coal mining and washing sector since the pulling effect of cryogenic freezing on coal energy consumption is greater than the destructive effect on coal energy output.

Different sectors have different sensitivity to different types of climate change risks, so climate change risks have a positive or negative impact on the financial performance of China's mining industry, thus bringing both opportunities and challenges to the future development of companies. Therefore, companies can actively contain climate change risks through the following ways, and thereby improve their financial performance.

(1) It's important for listed mining companies to change their traditional concepts and realize the importance of climate change risks to the future development. When planning infrastructure construction and future production activities, companies should give full consideration to the trend of climate change risks. At the same time, it is necessary to establish functional departments to deal with climate change and integrate climate change risks into the company risk management system.
(2) Listed mining companies should actively fulfill their emission reduction responsibilities to avoid high fines from the competent authorities. Companies should also make full use of the preferential policies that government encourages the development of low-carbon economy to obtain financial support and cultivate the new business growth points and core competitiveness in the future.
(3) With consumers and investors concerned more about climate change, the listed mining companies should actively disclosure the climate change information in order to signal the true management situation of climate change risks to stakeholders, which can create a good reputation for the company and improve the brand value in the market.

Since most of China's mining companies are non-listed companies, the number of samples selected in this paper is limited and need to be expanded. This is the direction of future efforts.

CRediT authorship contribution statement

Yongping Sun: Conceptualization, Validation, Formal analysis, Writing - original draft. **Ying Yang:** Writing - review & editing. **Nan Huang:** Writing - review & editing, Data curation. **Xin Zou:** Methodology, Data curation, Formal analysis.

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