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Resource curse on innovation: A perspective on local mining industry monopolies in resource-based cities in China

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A B S T R A C T

This study investigates the effects of monopolies in the local mining industry on the innovation activities of non-mining enterprises in Chinese resource-rich cities. Using data from the Annual Survey of Industrial Firms and firm-level patent data in China from 1999 to 2007, we find that the high monopoly degree of local mining industry is related to the significant decline of innovation activities of non-mining enterprises in the resource-rich cities. Moreover, the negative effects are larger in cities with larger mining industry, greater fiscal pressure, closer collusion between government and enterprises, officials with lower education levels and older age, as well as lower degree of marketization. In addition, the monopoly degree of local non-state-owned enterprises has a larger inhibitory effect on cross-industry innovation than state-owned enterprises. Furthermore, monopoly in the local mining industry has no significant effects on innovation behavior of mining enterprises, but it significantly increases the effective tax rate, reduces government subsidies for non-mining enterprises; and industries with stronger input-output relationships to the mining industry are more significantly affected, confirming the key role of local governments as "middlemen" in the innovation behavior of local enterprises across industry.

1. Introduction

The *Resource Curse* refers to a paradoxical situation in which some countries with abundant natural resources remains developing countries in the long term, whereas some other countries with scarce natural resources grows into developed countries. The above phenomenon is counterintuitive and has aroused wide attention of scholars (Auty, 1993; Leite & Weidmann, 1999; Papyrakis & Gerlagh, 2007; Sachs & Warne, 2001; Sachs & Warner, 1995, 1999).

The main explanations for the resource curse in existing studies can be summarized into two perspectives. The first is the "Dutch Disease" effect: industries raise the costs of input factors according to the growth of the natural resources, thus leading to the failure of other industries (e.g., the manufacturing industry), which can result in reducing the spillover effects on the development of local productivity and hinder the economic growth (Corden & Neary, 1982; Krugman, 1987; Matsuyama, 1992; Van Wijnbergen, 1984). The crowding-out effect of resource industry caused by "Dutch Disease" can clarify the resource curse in comparative static analyses. In the long run, however, with the increase of investment in the resource industry, its marginal revenue decreases, while the marginal

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revenue of other industries increases. For this reason, the factors of production should flow into other industries. In accordance with the above theory, there is no long-term economic stagnation in resource-rich countries and regions. Thus, the long-term stagnation should be correlated with some secular factors hindering the operation of the market mechanism.

Some scholars have given another explanation from the institutional perspective that natural resources are the “natural rent” of a country, which can result in rent-seeking corruption (Leite & Weidmann, 1999). Furthermore, Acemoglu and Robinson (2006) prove that abundant resources can lead to the emergence of interest groups representing the elite. When the political advantages and future economic rents of interest groups are threatened, interest groups will hinder economic and political changes, thus resulting in a resource curse. The above theory explains the phenomenon why resource-rich countries or regions cannot sustain long-term development. However, in current literature, few empirical studies try to explain the resource curse from the above angle.

In this paper, the emergence of interest groups in resource-rich industries and their influence on the government are explained in accordance with the collective action theory of Olson (1965), which deepens and supplements the institutional explanation of the resource curse. As indicated by Olson's logic of collective action, the cost of organizing collective action will be reduced when the number of interest groups members decreases, which is conducive to form interest groups and influence the formulation and implementation of government policies beneficial to the interest groups. Local government leaders may be likely to make some short-sighted decisions for political promotion, which will lead to collusion between government and enterprises and help some industries or enterprise interest groups, and then inhibit the development of non-interest group enterprises. Assuming that monopolies of local mining enterprises affect the local governments' decision-making,[1] we investigate the effect of market monopolies in the local mining industry on non-mining enterprises' innovation behavior. Given that the mining industry cannot directly influence the innovation activities of non-mining enterprises, we highlight the role of local governments as “middlemen” in cross-industry innovation. Here, local governments are responsible for the resource (including financial subsidies, tax incentives, etc.) allocation in mining industries and non-mining industries, and collective action taken by mining enterprises to lobby local governments will affect the innovation activities of non-mining enterprises.

The *Annual Survey of Industrial Production* conducted by the National Bureau of Statistics of China (1999–2007) and the *China Patent Database Digest* 1985–2012 are primarily used for empirical analysis. The main analysis exploits an enterprise-level panel data model that investigates the effect of monopolies in the local mining industry measured with the Herfindahl-Hirschman Index on non-mining enterprises' R&D investment and patent applications. Although we control for multiple variables to reduce the bias of missing variables, there are still some unobservable factors that may correlate with the innovation and local market structure of the mining sector at the same time, such as local culture and its changes. To address the potential endogeneity problem caused by omitted variable bias and measurement errors, a new instrumental variable is constructed based on the spatial distribution of mineral resources. The empirical studies reveal three main findings. First, mining industry monopolies have negative effects on the innovation of non-mining enterprises. The increase of the standard deviation of monopoly can lead to a decrease of R&D investment of non-mining enterprises by 13.5%–15.7%, the proportion of enterprises with R&D activities by 8.60%, and the number of patent applications will also decrease significantly.

Second, we find considerably heterogeneous crowding-out effects across different cities, industries, and enterprises. Specifically, the effects are larger in cities with larger mining scale, greater fiscal pressure, more serious collusion between government and enterprises, lower education level, older local leaders, and lower degree of marketization. In comparison with state-owned enterprises (SOEs), non-SOEs are more motivated to form interest groups to influence the policies and behaviors of local governments. The resulting heterogeneity proves the hypothesis that the mining industry affects the innovation activities of non-mining industry enterprises by forming interest groups to “regulation capture”[2] the local governments and affect its decision-making and policies.

Third, we find that the monopoly degree of the mining market has no significant impact on the innovation behavior of mining enterprises, but it significantly increases the effective tax rate and reduces government subsidies for non-mining enterprises, thus confirming the “middlemen” role of local governments in the innovation behavior of local firms across industries. Besides, it is found that industries with stronger input-output linkage with the mining industry are more significantly affected.

This study may contribute to literature in three aspects. First, our findings help to understand the crowding-out effect of innovation characterized by over-reliance on natural resources. Existing literatures mainly focus on the innovation crowding-out effect of the resource curse in accordance with enterprises' behavior and the market competition behavior between enterprises (e.g. Auty, 2001; Papyrakis & Gerlagh, 2004, 2007; Sachs & Warne, 2001; Shao & Yang, 2010). Few studies examine the government as “middlemen” in discussing cross-industry impact.

Second, the study of the cross-industry innovation effect enriches the literature on the logic of collective action. Although many

[1] In general, a higher degree of market monopolies reveals that the number of enterprises in interest groups is smaller; thus, the lower the cost in organizing the enterprises to reach consensus and take actions, the easier it will be to develop political cooperation and form interest groups (Schuler et al., 2002). Although the above index doesn't indicate the strength of a particular company in its industry, existing research has demonstrated a significant positive correlation between the degree of market monopoly/concentration of industry and enterprises' political behavior (Pittman, 1977; Schuler, 1996; Schuler et al., 2002). It is evident that higher market concentration is associated with deeper familiarity between enterprises, and more cooperation between enterprises is associated with stronger motivation for enterprises to gain benefits through concerted actions (Bernheim & Whiston, 1990; Li & Greenwood, 2004).

[2] Regulation capture refers to the government's short-term policy decisions that violate the public interest due to significant influence from practitioners in a certain industry. In pursuit of higher taxes, more employment and other public interests, regulatory agencies (e.g. local government) can be captured by regulatees (e.g. powerful enterprises) and provide them with favorable policies (Laffont & Tirole, 1991).

studies emphasize “disinterested government” (Liang & Gao, 2017) or “encompassing organization” (Olson, 1982), evidence based on the logic of collective action, especially that related to the effect of enterprise interest groups on enterprise innovation in other industries remains insufficient.

Third, this research is also related to studies on the impact of industry market structure on enterprise innovation. Most previous studies focus on the impact of market structure on the innovation of enterprises in the same industry (Arrow, 1962; Frenkel, Shefer, Koschatzky, & Walter, 2001). We are among the first studies investigating the impact of interest groups in the mining industry in hindering the innovation activities of non-mining enterprises from the perspective of interest groups' regulation capture to local governments, which provides a unique and new explanation for the effect of cross-industry innovation behavior.

The rest of this paper is organized as follows. In Section 2, the related literature is reviewed, and the theoretical framework is expounded. In Section 3, the data and empirical methods are introduced. In Section 4, the main empirical results and robustness tests are presented. Section 5 presents the heterogeneity analysis. Section 6 presents a further discussion. In Section 7, the conclusions and policy implications are presented.

2. Literature review and theoretical framework

2.1. Literature review

There are four branches of the literature related to this paper. The first is the discussion of “resource curse”. At the end of the last century, the hypothesis of resource curse triggered extensive discussions among development economists about the effect of natural resources on the economic growth of a country or region. A large number of researches investigate the crowding-out effect of over-reliance on natural resources on savings investment (Papyrakis & Gerlagh, 2006) and human capital (Sachs & Warne, 2001), and put forward various mechanisms. To be specific, some studies suggest that a higher profit rent of natural resources can attract more entrepreneurs to participate in the production activities of primary industry sectors, thus exerting a crowding-out effect on the development of the innovation sector (Sachs & Warne, 2001; Shao & Yang, 2010). Other scholars suggest that over-reliance on natural resources may lead to rent-seeking and corruption (Auty, 2001; Papyrakis & Gerlagh, 2004, 2007). Enterprises “crafty” consciously or unconsciously, which can concentrate their efforts on rent-seeking activities, abandoning R&D as well as technological innovation (Papyrakis & Gerlagh, 2007; Sachs & Warne, 2001). And, some studies propose that a growth in the natural resources industry can hinder the development of the manufacturing industry through transfer effect, relative price effect and expenditure effect (Corden & Neary, 1982; Sachs & Warner, 1995).

Chinese scholars also involved the discussion on the existence and mechanism of resource curse. For example, Xu and Wang (2006), Shao and Yang (2010) find that the phenomenon of “resource curse” does exist in regional level in China. In terms of the mechanisms of China's resource curse, Shao and Yang (2010) point out that dependence on resource may lead to the resource curse by crowding out foreign investment and private economy, weakening the development of manufacturing industry, and strengthening government economic intervention. Li and Xu (2018) find that resource-rich cities tend to form path dependence on natural resource endowment, increasing the proportion of secondary industry in the economy by crowding out investment in scientific research and development and foreign trade, thus causing a “curse” to the growth of urban green economy.

The second literature is on the logic of collective action, especially the influence of market structure on corporate behavior. Olson (1965) highlights that in the case of smaller groups, the cost of organizing collective action is lower, which is conducive to the formation of interest groups and influence the policy making of local government. According to most existing studies emphasizing “disinterested government” (Liang & Gao, 2017) or “encompassing organization” (Olson, 1982), it has been assumed that the actions taken by the government are not profit-oriented. In other words, the governments' policies are beneficial to the interests of whole society rather than the interests of individual groups. In fact, however, government behaviors are usually affected by the regulation capture caused by the actual power or policy burden of interest groups (Liang & Gao, 2017). Over the past few years, some studies have verified the collective action of Olson (1965) from the perspective of corporate interest groups. For instance, Wei et al.(2013) theoretically propose that interest groups will hinder the introduction of new technologies by lobbying the government for their own interests, and local governments have the motivation to block industrial upgrading and technological progress under the fiscal decentralization system. Acemoglu (2010)'s theoretical model suggesting that local governments' fiscal policies will be affected by social elites, which will result in a decline in resource allocation efficiency.

The third literature focuses on the collusion between local governments and enterprises. China evaluates government officials based on GDP, which exacerbates competition among local governments. And, GDP evaluation is prone to trigger opportunistic behaviors of local governments, thus prompting short-term economic growth through government-enterprise collusion (Nie, 2013). Since China is a developing country with imperfect institutions, government-enterprise collusion can explain many negative phenomena in the process of China's rapid economic growth, such as corruption (Dutta, 2009), inefficient allocation of credit resources (Wang & Song, 2010), coal mine accidents and high mortality (Nie & Jiang, 2011), land violations (Zhang, Gao, & Xu, 2013), and corporate tax evasion (Fan & Tian, 2016).

The fourth literature studies on enterprise innovation behavior. In general, competitive industries will have more R&D incentives than monopoly industries (Arrow, 1962), and high-tech industries have stronger R&D investment intensity and willingness than traditional industries or non-high-tech industries (Frenkel et al., 2001). Given the broad input-output relationships shared among industries, this difference in innovation demand may affect innovation behavior among industries. For instance, Wang et al. (2018) find that zombie enterprises damage patent applications and total factor productivity of normal enterprises by intensifying resource constraints, distorting credit allocation, and damaging fair competition in the industry.

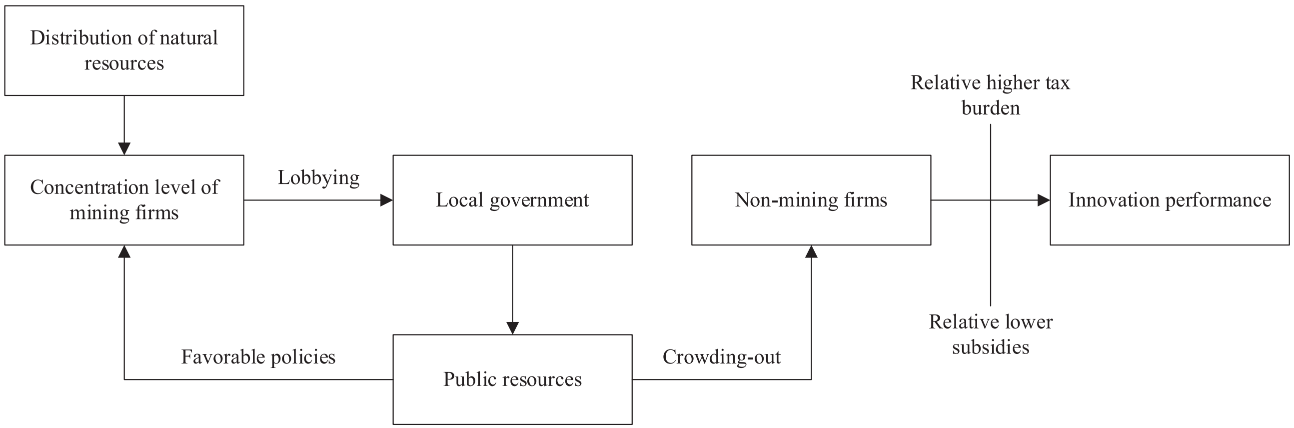

Fig. 1. Conceptual Framework.

2.2. Theoretical framework

This paper attempts to provide a supplement for the logical chain on the systematic interpretation of "resource curse" by focusing on the influence of mining industries on other industries in resource-rich cities. In this section, the theoretical framework of the paper is elaborated, and the corresponding conceptual framework diagram is shown in Fig. 1.

According to Olson's logic of collective action, interest groups with fewer members have lower cost to organize collective action and have higher motivation to lobby local governments to make policies in favor of the interest groups (Olson, 1965). Existing studies have discussed the reasons why interest groups can capture local governments in the following aspects. First, mining enterprises can make illegal payments or transactions to government officials privately. Second, powerful enterprises rely on their market status to capture local governments (Grossman & Helpman, 2001; Hellman, Jone, & Kaufmann, 2003; Kale, Dyer, & Singh, 2001). Notably, they can influence government's behavior and decision-making based on their own sizes, origins (state-owned or privatization), relationship with officials, as well as contribution to local economy, tax revenue and employment (policy burden) (Hellman et al., 2003). Third, regulation capture arises from information asymmetry or collective action (Hellman et al., 2003). This paper focuses on the third reason, i.e., collective action taken by mining enterprises to lobby local governments to formulate favorable policies toward mining industries and inhibit the innovation activities of non-mining enterprises.

As it has been highlighted in existing literature that when the market concentration is high, the transaction costs among enterprises in the industry would be low, thus it is easier to form "cooperative collusion" instead of competition, as well as to lobby local governments by adopting consistency/collective action regulation (Mason, Phillips, & Nowell, 1992). Local governments have been found to play a vital role in the economic development of cities in China through the allocation of public resources. Particularly, local governments in China can influence the behavior of enterprises through both tax preference and subsidies. Howell (2016) takes the VAT reform implemented by the Chinese government in 2004 as a policy shock and concludes that increasing tax burden would reduce enterprises' innovation activities. Mukherjee, Singh, and Žaldokas (2017) exploit the staggered changes in state-level corporate tax rates to show that an increase in taxes reduces future innovation. It is also found that government subsidies on innovation can promote the development of enterprises' innovation activities (Kleer, 2010; Lee & Cin, 2010). In brief, the highly concentrated distribution of natural resources encourages the collusion of mining enterprises. The rent-seeking behavior of the mining enterprises captures local governments, and local governments will formulate policies in favor of mining enterprises by allocating more public resources. Such crowding-out of public resources has a negative impact on the innovation activities of non-mining enterprises.

Due to the particularity of the mining industry, most countries usually implement strict licensing systems for the entry of mining industry, leaving room for rent-seeking and even corruption for government officials in the approval process (Shleifer & Vishny, 1993). In particular, some rent-seeking phenomena exist in the process of license approval (e.g., legal or illegal, collusion between government and businesses). Taking the coal industry as an example, coal production and operation enterprises must obtain a coal operation license in order to produce and carry out normal coal operation. Therefore, in order to obtain the right to produce and operate, coal enterprises will obtain the licenses through rent-seeking behavior. So the entry threshold for the mining industry determines that it needs to maintain close contact with local governments compared to other industries, and the likelihood of local governments being captured by interest groups is also higher.

Mining enterprises are more motivated to form interest groups to capture local governments and protect their interests. As argued by the new political economy, increased capital and technological progress (generally, improved conditions for economic development) may decrease the probability that incumbent governments and interest groups will hold political power (Acemoglu & Robinson, 2000). Thus, mining enterprises, from the dominant industry in resource-rich areas, are more motivated to form interest groups to prevent technological progress to maintain their market position and obtain more "natural rents". The mining industry, as the pillar industry in most resource-rich cities, has contributed considerable tax revenue and job opportunities to local governments, and has a critical economic and political position, rendering it sufficient capacity to impact the decision-making of local governments. To prevent technological progress from reducing the probability of their own political rights, local governments are more likely to accept the regulatory capture by the interest groups of the mining industry.

Given the limitation of factor endowment at the early stage, the mining industry is more labor-intensive in production. Innovation and technological progress also imply that more machines and equipment are going to be used which reduce the demand for low-skill labor. The reduction of labor demand will inevitably lead to a large number of workers being laid off and unemployed. Accordingly, mining enterprises have gained support from their workers to form interest groups to hinder the above-mentioned technological progress.

In view of the above discussion, we put forward the main hypothesis, that is, in resource-rich cities, the higher market concentration of the mining industry makes the mining industry more motivated to form interest groups to lobby local governments, and influence the allocation of public resources (e.g., tax preference and subsidies by local governments).

3. Methodology and data

3.1. Empirical model

This empirical study aims to verify the hypothesis that the mining industry indirectly influences the innovation behavior of non-mining enterprises by affecting local government behavior. In this section, we focus on the level of the market monopolies in the mining industry. According to the logic of collective action of Olson (1965), a higher level of market monopolies is associated with a smaller number of enterprises and more market share for the respective enterprises in the market, which can lead to stronger motivation for enterprises' collusion to obtain benefits by taking consistent actions (Bernheim & Whiston, 1990; Li & Greenwood, 2004). In addition, for the analysis of this paper, the mining industry has two advantages. First, compared with other industries, the mining industry generally presents higher degree of market monopolies, and enterprises in the mining industry show higher similarities in factor input, labor demand and production technology, thus it is more likely to form interest groups. Second, since the development of the mining industry depends on external mineral resources, the industry's capacity in market monopoly is more exogenous, which is conducive to resolving endogeneity problems.

To be specific, the following enterprise-level panel data model is employed for empirical analysis:

$$Innovation_{ijct} = \beta_0 + \beta_1 \cdot HHI_{ct} + \beta_2 \cdot X_{it} + \beta_3 \cdot Z_{ct} + \rho_i + \delta_{st} + \theta_{jt} + \varepsilon_{ijct} \tag{1}$$

where subscripts *i*, *j*, *c*, *s* and *t* denote enterprise, industry, city, province and year, respectively. The explanatory variable *Innovation* represents the innovation output of non-mining enterprises. *HHI* expresses the degree of market monopolies in the mining industry in the city where the enterprise is located, i.e., the core independent variable of this paper. *X* denotes a vector of enterprise-level variables. *Z* represents a vector of city-level variables. ρ_i is firm fixed effects. δ_{st} denotes the province × year fixed effects. θ_{jt} expresses the industry × year fixed effects. ε represents the error term. The standard error is clustered at the city level to solve potential heteroskedasticity and serial correlation. Since innovation needs long-term accumulation, all explanatory variables and control variables in the model (except for age and ownership of enterprises[3]) are both lagged for one period to alleviate the endogeneity problems. β_1 is the coefficient of interest. In accordance with the previous discussion in this paper, β_1 is expected to be negative, which suggests that a higher degree of market monopolies in the mining industry may result in less innovation of non-mining enterprises.

3.2. Data

To ensure that there are sufficient mining enterprises to calculate the degree of market monopolies and to match the patent data of enterprises, the cities chosen are resource-rich cities[4] with mining as the leading industry.[5] Finally, 143 prefecture-level cities are kept for empirical analysis (Appendix Table 1).

The patent data used in this paper originate from the *China Patent Database Digest* 1985–2012 (CD-ROM Edition), which is issued by the Security Press of the State Intellectual Property Office. The enterprise characteristics and financial data are from the *Annual Survey of Industrial Production* carried out by the National Bureau of Statistics of China (1999–2007). The analysis of R&D investment is limited to 2001–2007 (excluding 2004) since the information regarding R&D expenditures in the database only provides information between 2001 and 2007, and R&D expenditures' information in 2004 is missing. On the whole, there are 493,653 firms with 1,450,426 observations of R&D expenditures from 2001 to 2007 (excluding 2004), and a total of 581,705 firms with 2,054,308 observations of patents from 1999 to 2007. For the 143 resource-rich cities, there are 97,402 firms with 241,718 observations of R&D expenditures, 103,756 firms with 345,300 observations of patents from 1999 to 2007.[6] The financial indicators at the city level primarily originate from the *County and Prefecture Public Finance Statistics Yearbook of China* (1999–2007). The industrial enterprise data are further managed using the conventional method in the literature. First, the observations with total assets less than fixed assets, fixed assets less than RMB 1 million yuan, and <10 employees are dropped. Second, the observations whose total assets, total employees, taxable income are missing or non-positive are dropped. Third, since the classification standard of the Chinese economies' national industry has been revised in 2002, the classification of two-digit industry codes is unified to the 2002 standard. Fourth, we drop enterprises in the production and supply industry of electricity, gas, as well as water, which are recognized as highly monopolistic industries in China. Fifth, since we do not know whether a missing R&D expenditure arises from the absence of R&D activities or the unwillingness to report R&D expenditure, we drop the observations that didn't report R&D expenditure following the methods of Li and Song (2010), Adam (1988), and Koh and Reeb (2015). Lastly, the enterprise observations with some variables missing are deleted. Besides, to avoid the effect of extreme values on the regression results, the top and bottom 1% samples of variables at the enterprise level are winsorized. After the above data management is conducted, a sample of 50,441 firms with 106,848 observations for R&D expenditures is obtained, and a sample of 55,427 firms with 139,000 observations for patents is acquired for the empirical analysis in this paper.[7]

3.3. Variables

3.3.1. Enterprise innovation

We consider four variables that have been extensively used in the literature to measure enterprise innovation, including the

[3] During the research period of this paper, the forms of ownership of some enterprises have changed, so this control variable is added into the regression model.

[4] In accordance with the national sustainable development plan for resource-based cities (2013−2020) promulgated by the State Council, there are 262 resource-based cities in China, including prefecture-level administrative regions. For prefecture-level cities, there are 126 regions, autonomous states, leagues, etc., 62 county-level cities, 58 counties (e.g., autonomous counties and forest areas), and 16 municipal districts (e.g., development zones and management zones). 126 prefecture-level administrative regions are selected.

[5] If the mining industry has the largest average output in a city, it is considered as leading industry.

[6] Among the innovation indicators, R&D investment ranges from 2001 to 2007, and the data of 2004 are missing. The patent application data cover the period between 1999 and 2007.

[7] We list the detailed number of observations in each sample selection step in Appendix Table 2.

percentage of R&D expenditure to total assets (*Inno1*), the percentage of R&D expenditure to sales (*Inno2*), whether the enterprise's R&D expenditure in the current year is higher than zero (*Inno3*), and the number of patents (*Inno4*).

3.3.2. Market monopolies

We follow Grullon, Larkin, and Michael (2019) and use the Herfindahl-Hirschman Index (*HHI*) to measure the degree of market monopolies. The specific calculation formula is as follows:

$$HHI_{ct} = \sum_{i=1}^{N} \left(I_{ict}/I_{ct}\right)^2 \quad (2)$$

where I_{ict} denotes the total income of mining industry enterprise *i* in city *c* in year *t*; I_{ct} represents the total income of mining industry enterprise *i* in city *c* in year *t*. A higher *HHI* indicates that the concentration of mining enterprises and the degree of market monopolies are higher.

3.3.3. Control variables

A set of enterprise-level and city-level characteristic variables that may affect enterprises' innovation are controlled in accordance with the studies by Gu, Chen, and Pan (2018), Hirshleifer, Low, and Teoh (2012), Hall, Moncada-Paternò-Castello, Montresor, and Vezzani (2016), Li and Yu (2015), Li and Zheng (2016), Pang and Wang (2020), Zhou and Luo (2005). To be specific, the enterprise-level control variables consist of (i) The size of enterprise measured by total assets (*asset*) and total employees (*emp*), which is positively correlated with enterprises' innovation (Li & Yu, 2015). (ii) Proportion of mining industry employees (*size*). As indicated by a large proportion of labor force in the mining industry, the city is highly dependent on the resource industry, and therefore the development of innovative sector will be crowded out (Shao & Yang, 2010). Thus, we expect that the proportion of mining industry employees is negatively correlated with innovation in non-mining enterprises. (iii) Ownership of enterprises (*SOE*). As explained by Li and Yu (2015), SOEs generally have lower degree of innovation compared with non-SOEs in China. (iv) Financial leverage (*leverage*). Higher financial leverage means greater financial risk, which is not conducive to enterprise innovation. Accordingly, financial leverage is negatively correlated with enterprises' innovation (Pang & Wang, 2020). (v) Capital intensity (*capital*). As expounded by Zhou, Cheng, and Wang (2012), capital intensive is negatively correlated with enterprise' innovation. (vi) Intangible assets ratio (*intangibility*). As intangible assets can represent a company's research and development expenses to a certain extent, intangible assets ratio is expected to be positively correlated with enterprises' innovation. (vii) Return on capital (*ROA*). As pointed out by Gu et al. (2018), return on capital is positively associated with enterprise's innovation. (viii) Liquidity ratio (*liquidity*). Liquidity ratio represents the proportion of current assets in an enterprise. Generally speaking, the enterprise with a higher proportion of current assets has a better cash status, therefore their innovation capabilities are stronger (Gu et al., 2018; Hall et al., 2016). (ix) Firm's age (*age*). As studied by Gu et al. (2018) and Hall et al. (2016), young firms are more innovative than mature ones. Therefore, firm's age is negatively correlated with enterprise' innovation. (x) Government subsidy (*subsidy*) is positively correlated with enterprises' innovation (Li & Zheng, 2016).

We also control for variables related to regional economic development for: (i) Fiscal deficit (*deficit*). Higher fiscal deficit means greater financial pressure and poor economic development, which is detrimental to enterprise innovation. Therefore, fiscal deficit is documented to be negatively correlated with enterprises' innovation. (ii) Budget expenditure ratio (*budget*). Higher regional budget expenditure indicates that the region is facing greater financial pressure and lacks funds to create a favorable market environment for local enterprises, which is not conducive to innovation activities for enterprises. (iii) Fiscal population burden ratio (*population*). Larger financial population burden ratio implies greater financial pressure of the city, who lacks funds to create a favorable market environment to promote enterprise innovation. (iv) Fiscal surplus (*surplus*). Lower surplus represents greater fiscal stress in the region. The lack of financial funds is not favorable to enterprise innovation. (v) Financially supported population (*finpop*). Larger financially dependent population suggests greater financial pressure, which is not beneficial to enterprises' innovation.

3.3.4. Endogeneity and instrumental variable

As we are examining the effect of city-level mining monopolies on non-mining enterprises' innovation activities, there is no serious reverse causality problem. Moreover, all explanatory variables and control variables are lagged for one period, which can alleviate possible reverse causality. The major endogeneity problems in this paper include the missing variables bias and measurement errors. Although we have added adequate control variables and fixed effects (e.g., the cross dimensions of enterprise, industry, province and year), other unobservable factors that simultaneously affect local mining monopolies and enterprises' innovation are likely to remain. To solve the potential endogeneity problems, a spatial concentration index of mineral resources is constructed based on the spatial distribution of mineral resources in cities:

$$R_c = \frac{\overline{D}(m)}{0.5\sqrt{\frac{a}{n}}} \tag{3}$$

where R_c denotes the nearest neighbor index[8] of city c; $\overline{D}(m)$ represents the average value of the straight-line distance between each mine and its nearest mine in city c; a expresses the land area of city c; n represents the total number of mines in city c.[9] The value of R_c ranges from 0 to 2.15. A lower R_c indicates a more concentrated distribution of mineral resources, while a higher R_c indicates a more uniform distribution. Since the production activities of mining enterprises are largely dependent on the spatial distribution of mineral resources, we assume that the probability of forming large-size mining enterprises will be higher if the distribution of mines is more spatially-concentrated, which is more conducive to the formation of interest groups and higher market monopolies according to the above discussions.

Using Eq. (3), we can obtain the instrumental variable of market monopolies in the mining industry from a cross-city dimension. Subsequently, we follow the methods of Chaney, Sraer, and Thesmar (2012) to use the interaction terms between the average value of the world price of mineral resources in the respective city and the nearest distance index and use their reciprocal values as the instrumental variable of city-year market monopolies in the mining industry.

$$IV_{ct} = \frac{1}{log(price_t)\cdot R_c} \tag{4}$$

Here the average value of the world price of mineral resources is recognized as exogenous shocks to the development of the mining industry. The average value of the world price of mineral resources indicates the macroeconomic or policy factors for the development of national mineral resources market, which is exogenous for a specific city. Based on the positive shock, more enterprises will enter the mining industry, probably alleviating the industry's market monopolies, so the impact is negatively correlated with the degree of market monopolies of the mining industry. In brief, there is a positive correlation between the instrumental variables calculated by Eq. (4) and the market monopolies of cities' mining industry.

3.4. Descriptive statistics

The definitions and summary statistics of the main variables employed for empirical analysis are listed in Table 1.

3.4.1. Enterprise innovation and market concentration

During the research period, the average value of enterprises' R&D investment (*Inno1* and *Inno2*) is 0.089–0.093, and the maximum value is nearly 4.3, which indicates that enterprises' R&D expenditures are leaning in to the left, and there is a large difference among enterprises' R&D investments. The average value of *Inno3* is 0.115, that is 11.5% of enterprises' R&D investment, which suggests that the enterprises' R&D expenditures are insufficient. The average number of patent applications is 0.081, which suggests that the innovation capacity of Chinese enterprises is inadequate and should be improved in the future. The average value of *HHI* in the mining industry is 0.242 with the minimum and maximum value standing at 0.013 and 1, respectively.

The evolution of *HHI* in the resource-rich cities is shown in Fig. 2. Geographically, *HHIs* in northeast and northwest regions in China are the highest, followed by the central region, and *HHIs* in southwest region stand at the lowest. For the time variation, *HHI* in China presents a polarization pattern. To be specific, the *HHIs* in the southwestern region increase from 1999 to 2007 while the *HHIs* in northern, central, and southeastern regions reduced. The *HHI* in northeast region has not changed significantly and remains high. The above phenomenon is related with the regional development strategy.[10]

3.4.2. Control variables

On the management characteristics of the enterprise, the average value of total assets of the enterprises is RMB 62.8 million yuan with a standard deviation of RMB 164.8 million yuan. The average number of employees is 262, and a standard deviation is 449. The average proportion of employees in the mining industry in the total number of employees in the city reaches 0.217, with the maximum value of 0.781, indicating that the mining industry has made a significant contribution to the employment in resource-rich cities. The average value of ownership of enterprises reaches 0.085, which indicates that 8.5% of enterprises are state-owned enterprises. The financial leverage ratio, capital intensity, intangible assets ratio, return on capital and liquidity ratio average are 0.587, 0.391, 0.015, 0.113 and 1.897, respectively. The average age of firms is 10.13 with a standard deviation of 10.9. The average subsidies of enterprises are RMB 167,100 yuan with a standard deviation of RMB 775,500 yuan.

At the city level, the average fiscal deficit, budget expenditure ratio, fiscal population burden ratio and fiscal surplus reach 0.054,

[8] For a description of the nearest distance index, see https://www.geoib.com/nearest-neighbor-index.html.

[9] The mine data used in this study are from http://www.resdc.cn/data.aspx?DATAID=292. Using ArcGIS software, we spatialize all 76,184 mines on the electronic map according to their longitude and latitude information and identify the location of mines in each city by matching them with city boundary information. The number of mines and the distance between each mine and its nearest mine are then calculated according to the formula of the nearest distance index.

[10] In short, our empirical results rely on both regional and time variation. We also notice that the new change of government policy toward mining industry after 2010, but unfortunately, we do not secure comparable firm-level data after that, so we cannot discuss the new change with empirical support.

Table 1
Summary statistics.

Variable Name	Definitions	Obs.	Mean	Std. Dev.	Min	Max
Inno1	(R&D expenditure /total assets) × 100	106,848	0.089	0.456	0	4.362
Inno2	(R&D expenditure /sales) × 100	106,848	0.093	0.469	0	4.323
Inno3	Dummy variable, which is 1 if R&D expenditure is greater than zero, and 0 otherwise.	106,848	0.115	0.333	0	1
Inno4	The number of patents applied by each enterprise	139,000	0.081	1.577	0	93
Inno5	The ratio of net intangible assets to value-added	139,000	0.089	0.331	0	2.251
Inno6	The logarithm of the number of patent applications plus one	139,000	0.016	0.187	0	4.543
Inno7	The number of patents for invention	139,000	0.031	0.587	0	40
HHI	Herfindahl-Hirschman Index of local mining industries which is calculated based on the total assets of the enterprise	139,000	0.242	0.224	0.013	1
asset	The total assets (million RMB)	139,000	62.798	164.793	1.230	1247.213
emp	Employees of non-mining enterprises	139,000	262.041	449.486	15	3107
size	The mining industry employees / the total number of employees in the city	139,000	0.217	0.178	0.007	0.781
SOE	Dummy variable, which is 1 if it is a state-owned firm, and 0 otherwise	139,000	0.085	0.279	0	1
leverage	Total liabilities / total assets	139,000	0.587	0.298	0.012	1.451
capital	The net value of fixed assets / total assets	139,000	0.391	0.206	0.015	0.864
intangibility	The net value of intangible assets / total assets	139,000	0.015	0.046	0	0.280
ROA	The net value of profit / total assets	139,000	0.113	0.218	−0.210	0.966
liquidity	The current assets / current liabilities	139,000	1.897	3.079	0.177	22.333
age	The number of years of establishment of the enterprise	139,000	10.126	10.897	0	50
subsidy	The annual subsidy (thousand RMB)	139,000	167.087	775.546	0	5984
deficit	(General budget expenditure – general budget revenue) / GDP	139,000	0.054	0.054	−0.001	0.595
budget	General budget expenditure /GDP	139,000	0.105	0.061	0.038	0.687
population	The financial supported population / general budget revenue	139,000	0.159	0.193	−0.444	1.351
surplus	(General budget revenue – general budget expenditure) / general budget revenue	139,000	0.689	0.541	0.068	5.335
finpop	The financial supported population (thousand)	139,000	140.299	68.053	22.947	293.609
IV	The reciprocal of the world price of a certain mine in each city × the reciprocal of the nearest distance index of the mine	112,731	0.410	0.267	0.121	2.177

0.105, 0.159 and 0.689, respectively. The average financially-supported population is 140,000 with a standard deviation of 68,000.

4. Results

4.1. Benchmark results

Table 2 lists the regression results of Eq. (1). Columns (1)–(6) report the regression results with R&D investment of non-mining enterprises as dependent variables. Columns (7) and (8) report the regression results with the number of patent applications as the dependent variable. In general, using either OLS or two-stage least squares (2SLS) estimations, we find the coefficient of *HHI* is significantly negative at the statistical level of at least 10%, which suggests that market monopolies in the mining industry significantly decrease the innovation activities of non-mining enterprises.

As revealed by the first-stage results of the 2SLS regressions, the *IV* shows a positive correlation with the *HHI* of the mining industry, consistent with our expectations. The Durbin-Wu-Hausman test rejects the null hypothesis that "all explanatory variables are exogenous", suggesting there exists endogeneity problem. Therefore, we rely more on the 2SLS estimations for conclusion. The Anderson-Rubin Wald test further demonstrates that there is a strong correlation between *IV* and endogenous variables. Moreover, the Kleibergen-Paap F-statistic of first-stage regression is significantly higher than the corresponding Stock-Yogo critical value, which indicates that there exists no weak instrumental variable problem. The *p*-value of the Kleibergen-Paap rk LM statistic is 0.00, indicating that the null hypothesis is rejected, and the instrumental variable passes the unrecognizable test. In Appendix Table 3, we perform an exclusive assumption test by adding IV into the baseline Equation (1). The results show that the IVs in all models are not statistically significant, which excludes the possibility that *IV* could influence the dependent variable by any omitted variables. The second-stage regression results show that the coefficient of *HHI* is significantly higher than the OLS estimation, which suggests that there are unobservable factors resulting in the low estimated results of OLS. For instance, if the degree of marketization of a city is improved or the government adopts policies to reduce the power of industrial monopolies, market monopolies in the mining industry will decrease, and the enhanced market competition will promote innovation (Arrow, 1962). In another example, when the local economy goes down, small-size mining enterprises will close or merge with large-size mining enterprises, which will lead to an increase in the mining industry market concentration. At the same time, enterprises will appropriately reduce investment in R&D efforts to cope with the market downturn (Barlevy, 2007).

The 2SLS estimation results indicate that if the *HHI* of the local mining industry increases by a standard deviation (0.224), the proportion of R&D expenditure of non-mining industry enterprises in total assets will decline by 13.5% (= 0.224 × 0.604), that of R&D expenditure in sales will be reduced by 15.7% (= 0.224 × 0.703), the proportion of enterprises with R&D activities decreased by 8.60%, and the average number of patent applications of non-mining enterprises will be down-regulated by 0.45 (= 0.224 × 2.010, nearly 0.285 standard deviation).

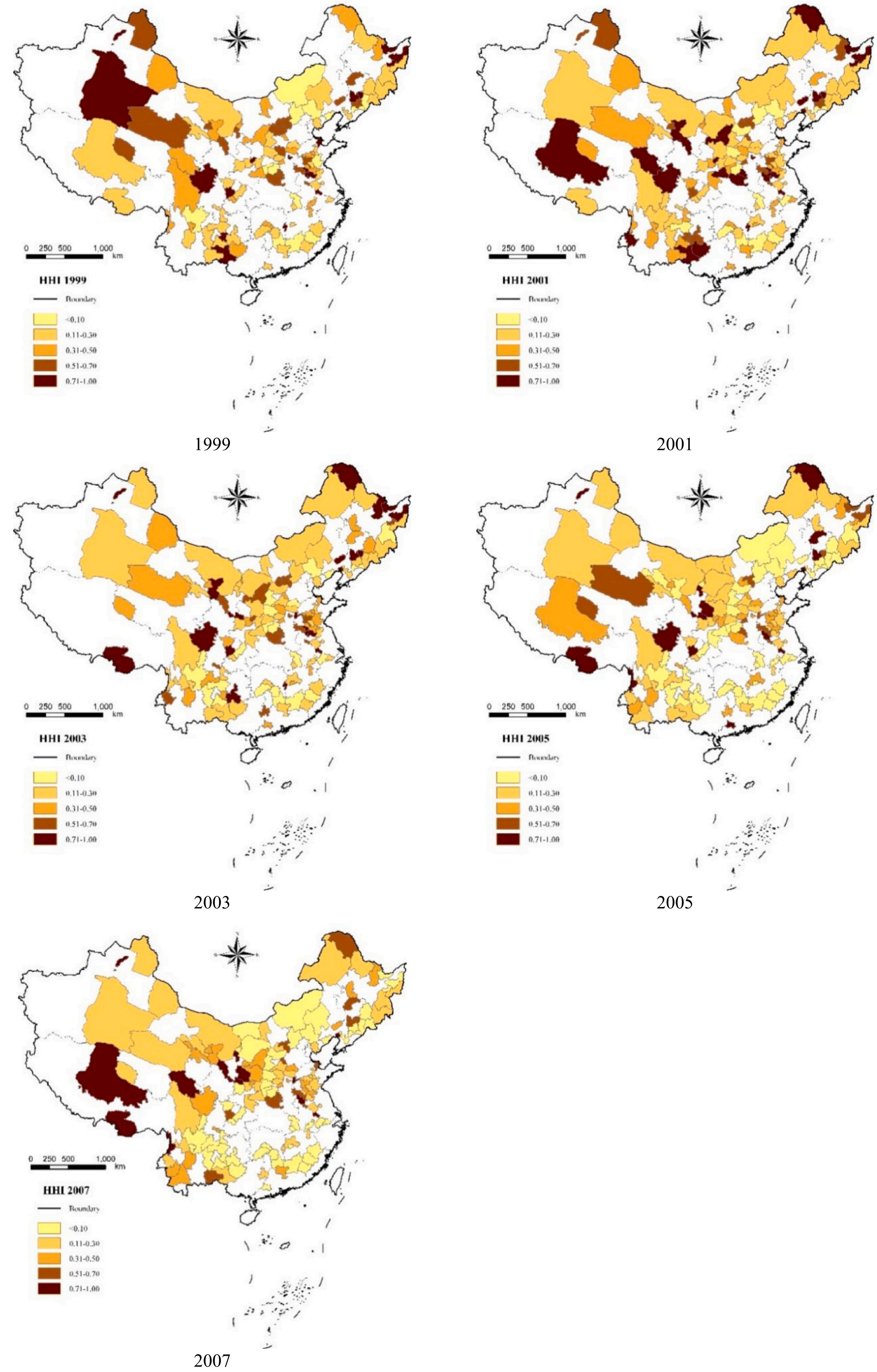

Fig. 2. The evolution of HHI.

The signs of control variables are basically consistent with the previous studies. For enterprise-level variables, we find the enterprise size (*lnasset* and *lnemp*) to be positively correlated with innovation, consistent with the findings of Li and Yu (2015). The coefficient of enterprise ownership (*SOE*) is negative, suggesting that private enterprises have more innovation output compared to

Table 2
Benchmark results.

Dependent Variables:	*Inno1*		*Inno2*		*Inno3*		*Inno4*	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HHI_{t-1}	−0.043**	−0.604**	−0.052**	−0.703**	−0.040**	−0.384*	−0.170***	−2.010**
	(0.021)	(0.302)	(0.022)	(0.348)	(0.019)	(0.220)	(0.064)	(0.979)
$lnasset_{t-1}$	−0.006	−0.003	0.001	0.007	0.016***	0.015***	−0.004	−0.036
	(0.008)	(0.004)	(0.006)	(0.004)	(0.004)	(0.003)	(0.014)	(0.025)
$lnemp_{t-1}$	0.018***	0.019***	0.014**	0.017***	0.017***	0.016***	0.017*	0.057**
	(0.006)	(0.005)	(0.006)	(0.005)	(0.005)	(0.003)	(0.010)	(0.024)
$size_{t-1}$	0.052	0.278	0.047	0.319	0.052	0.210	0.069	0.815
	(0.065)	(0.433)	(0.062)	(0.351)	(0.034)	(0.297)	(0.105)	(0.945)
SOE	−0.057**	−0.049***	−0.061**	−0.046**	−0.023	−0.013	−0.094	−0.311
	(0.023)	(0.016)	(0.025)	(0.022)	(0.017)	(0.013)	(0.101)	(0.223)
$leverage_{t-1}$	0.004	−0.003	−0.014	−0.014	0.002	−0.002	0.024	0.036
	(0.015)	(0.011)	(0.013)	(0.010)	(0.009)	(0.007)	(0.021)	(0.029)
$capital_{t-1}$	−0.001	−0.005	−0.016	−0.018	0.007	0.006	0.023	0.024
	(0.018)	(0.013)	(0.014)	(0.012)	(0.011)	(0.009)	(0.036)	(0.044)
$intangibility_{t-1}$	0.066	0.038	0.066	0.044	0.005	−0.001	−0.136	0.166
	(0.072)	(0.054)	(0.091)	(0.060)	(0.046)	(0.035)	(0.115)	(0.284)
ROA_{t-1}	−0.004	−0.001	−0.005	−0.001	0.015	0.017**	0.075**	−0.051
	(0.025)	(0.014)	(0.013)	(0.010)	(0.018)	(0.008)	(0.034)	(0.049)
$liquidity_{t-1}$	−0.001	−0.002	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
lnage	−0.004	−0.004	−0.001	−0.001	0.001	0.001	−0.005	−0.022
	(0.007)	(0.005)	(0.008)	(0.006)	(0.005)	(0.004)	(0.011)	(0.023)
lnsubsidy	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.010
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.003)	(0.007)
$deficit_{t-1}$	0.496	−0.778	0.594	−1.057	0.138	−0.787	−1.840	−4.319***
	(0.438)	(0.913)	(0.538)	(1.077)	(0.368)	(0.665)	(2.545)	(1.626)
$budget_{t-1}$	−0.280	0.387	−0.379	0.473	−0.169	0.299	1.102	2.163
	(0.202)	(0.478)	(0.268)	(0.549)	(0.184)	(0.333)	(1.803)	(1.941)
$population_{t-1}$	−0.003	−0.007	0.002	−0.005	0.010	0.006	0.158	−0.045
	(0.025)	(0.020)	(0.022)	(0.022)	(0.019)	(0.015)	(0.108)	(0.087)
$surplus_{t-1}$	0.025**	0.032***	0.028**	0.034**	0.009	0.008	0.041	0.653**
	(0.011)	(0.011)	(0.012)	(0.013)	(0.007)	(0.008)	(0.039)	(0.317)
$lnfinpop_{t-1}$	0.023	0.008	0.003	0.032	0.048	0.013	0.404	0.407
	(0.065)	(0.058)	(0.072)	(0.064)	(0.050)	(0.045)	(0.328)	(0.269)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indurtry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.066	N/A	0.125	N/A	−0.670	N/A	−4.610*	N/A
	(0.765)	N/A	(0.845)	N/A	(0.592)	N/A	(2.639)	N/A
N	106,848	93,891	106,848	93,891	106,848	93,891	139,000	112,731
R^2	0.592	N/A	0.642	N/A	0.644	N/A	0.465	N/A
First-stage results								
IV		0.166***		0.166***		0.166***		0.047***
		(0.018)		(0.018)		(0.018)		(0.003)
Durbin-Wu-Hausman		31.92		46.59		24.51		80.07
		[0.004]		[0.000]		[0.040]		[0.000]
Kleibergen-Paap rk Wald F		85.60		85.60		85.60		39.53
Kleibergen-Paap rk LM		88.83		88.83		88.83		39.84
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.17		4.20		3.17		4.58
		[0.041]		[0.040]		[0.074]		[0.032]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses; *p*-values are presented in the square brackets. (2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

state-owned enterprises (Li & Yu, 2015). The return on capital (*ROA*) shows a positive correlation with innovation activities, revealing that better profitability of the enterprise is associated with stronger innovation ability (Fang, Lerner, & Wu, 2017; Hall et al., 2016).

At a city level, as indicated by the results of municipal control variables, fiscal deficit (*deficit*) is negatively correlated with innovation activities. Fiscal surplus (*surplus*) shows a positive correlation with innovation activities. This is because the more perfect the market environment in the economically developed regions, the richer the capital and other resources will be, and the more active the innovation activities will be (Zhou & Luo, 2005).

4.2. Robustness checks

Table 3 lists the results of some robustness tests, consisting of modifying the calculation methods of independent and dependent variables, regulating the estimation model, as well as coding the missing R&D expenditure as 0.

4.2.1. Alternative measures of HHI

We modify the calculation methods of the independent variables to test the robustness of our results. In baseline regression, the total income is taken as a measure of an enterprise to construct the core explanatory variable (Grullon et al., 2019). However, some inaccuracies may exist in the measurement of total income. Accordingly, following Autor, Dorn, Katz, Patterson, and Reenen (2020) and Yang and Chen (2016), main business revenue, number of employees, total output, and total assets are adopted to calculate the *HHI* of the mining industry. The estimated results are listed in panel A in Table 3. A significantly negative effect of different *HHI* measures on the innovation activities of non-mining enterprises is found, further verifying the inhibition effect of the level of market monopolies in the mining industry on the innovation activities of non-mining enterprises.

4.2.2. Alternative measures of innovation

First, the ratio of net intangible assets to value-added developed by Akcigit, Baslandze, and Lotti (2023) is adopted to measure enterprise innovation (*Inno5*). Columns (1) and (2) of panel B in Table 3 list the OLS and 2SLS regression results using *Inno5* as the dependent variable. As indicated by the results, the coefficient of *HHI* regression is still significantly negative.

For the patent application index, impacted by the existence of numerous zero values, the processing in the benchmark regression will cause a large standard error, and the estimated results are more likely to be affected by singular values. For this reason, in the Columns (3) and (4) of panel B, we use the logarithm of the number of patent applications plus one (*Inno6*) for analysis. In addition, China's patents fall into three types, including patents for invention, patents for utility models and design patents. The application of patents for utility models and design patents is relatively easy, whereas the application of patents for invention is difficult. It is generally considered that patents for invention are the patents that best reflect the technical level in practice. Therefore, we use the number of patents for invention to measure the innovation of enterprises (*Inno7*). The estimated results are listed in Columns (5) and (6) of panel B in Table 3. According to the last four columns of panel B in Table 3, the coefficients of *HHI* are still significantly negative, thus verifying the robustness of the empirical conclusions.

4.2.3. Alternative estimation methods

Since there are only 11% of firms that show positive values of R&D, *Inno3* is re-estimated using Tobit regression as robustness tests.[11] The estimate coefficients are listed in Columns (1)–(2) of panel C of Table 3. For the counted patent data, negative binomial regression is adopted to estimate the model.[12] The regression results are listed in Columns (3)–(4) of panel C of Table 3. The coefficients of *HHI* are still significantly negative in all regressions, consistent with the results achieved through linear regressions.

4.2.4. Coding the missing values as zero

In the benchmark regression, we drop all firms with missing R&D. For robustness test, we make two works to assess whether this data processing will cause significant sample selection bias. First, we compare the average values of patent application numbers between firms with and without missing R&D. Not surprisingly, we find the average number of patent applications of firms with missing R&D (0.076) is smaller than that of firms reporting R&D (0.093) with p-value of two-sample mean t-test to be 0.00. This result leads us to do further test for the selection bias. Second, we follow the methods of Koh and Reeb (2015) and code the missing R&D expenditure as 0. The regression results with new samples are shown in panel D of Table 3, where we still find a significantly negative effect of *HHI* of the mining industry on the innovation activities of non-mining enterprises.

5. Heterogeneity analysis

We have documented that market monopolies in the mining industry significantly inhibit the innovation activities of non-mining enterprises. Notably, the mining industry forms interest groups to influence the decision-making process of local governments. Since these interest groups may have different decisions and policies, the influence on non-mining industries' innovation will vary as well. Thus, we focus on the heterogeneous effects of market monopolies in the mining industry on the innovation activities of non-mining enterprises from multiple perspectives.

[11] Honore (1992) proposes a method to estimate the fixed effect of truncated data, and we use the commands pantob in STATA to do the Tobit regression of the fixed effect. Since there is no corresponding IV regression command, we separately use the command cmp and two-stage method to conduct the IV regressions. The estimated coefficients and standard errors are nearly the same.

[12] The variance of *Inno4* is 30 times of the average value. We use the command nbreg to do the mixing negative binomial regression and clustering robust standard error. The results of negative binomial regression show that the 95% confidence interval of over-dispersion parameter α is [100.9, 139.8], rejecting the original hypothesis of "$H0$: $\alpha = 0$" and indicating excessive dispersion exists. Therefore, we use negative binomial regression other than Poisson regression. For regressions, we use the command xtnbreg to do the negative binomial regressions. Since there is no corresponding IV regression command, we separately use the command cmp and two-stage method to conduct the IV regressions. The estimated coefficients and standard errors are nearly the same.

Table 3
Robustness checks.

Dependent Variables:	*Inno1*		*Inno2*		*Inno3*		*Inno4*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A. Alternative measures of *HHI*								
HHI	−0.042**	−0.424**	−0.053***	−0.576**	−0.037**	−0.401**	−0.138**	−1.723**
(main business revenue)	(0.019)	(0.188)	(0.020)	(0.285)	(0.017)	(0.193)	(0.063)	(0.691)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	139,000	112,731
R^2	0.592	N/A	0.624	N/A	0.644	N/A	0.465	N/A
First-stage results								
IV		0.150***		0.150***		0.150***		0.040***
		(0.017)		(0.017)		(0.017)		(0.005)
Durbin-Wu-Hausman		35.94		43.73		31.08		77.51
		[0.001]		[0.000]		[0.042]		[0.000]
Kleibergen-Paap rk Wald F		80.623		80.623		80.623		38.169
Kleibergen-Paap rk LM		81.21		81.21		81.21		38.52
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.53		4.67		3.64		4.82
		[0.026]		[0.031]		[0.053]		[0.038]
HHI	−0.013	−0.373**	−0.021	−0.428**	−0.019*	−0.205**	−0.141*	−2.209**
(number of employees)	(0.022)	(0.165)	(0.023)	(0.206)	(0.011)	(0.099)	(0.073)	(1.109)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	139,000	112,731
R^2	0.592	N/A	0.624	N/A	0.644	N/A	0.465	N/A
First-stage results								
IV		0.103***		0.103***		0.103***		0.036***
		(0.018)		(0.018)		(0.018)		(0.008)
Durbin-Wu-Hausman		30.18		45.82		24.74		82.75
		[0.011]		[0.003]		[0.035]		[0.022]
Kleibergen-Paap rk Wald F		81.235		81.235		81.235		39.786
Kleibergen-Paap rk LM		82.39		82.39		82.39		41.26
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.92		4.14		3.61		4.45
		[0.048]		[0.012]		[0.038]		[0.017]
HHI	−0.039**	−0.487**	−0.049**	−0.643**	−0.034**	−0.315**	−0.138**	−1.562*
(total output)	(0.019)	(0.217)	(0.021)	(0.319)	(0.017)	(0.150)	(0.063)	(0.825)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	139,000	112,731
R^2	0.593	N/A	0.625	N/A	0.644	N/A	0.465	N/A
First-stage results								
IV		0.054***		0.054***		0.054***		0.012***
		(0.009)		(0.009)		(0.009)		(0.004)
Durbin-Wu-Hausman		83.89		86.84		79.12		182.74
		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		79.011		79.011		79.011		40.370
Kleibergen-Paap rk LM		80.157		80.157		80.157		42.084
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.91		5.21		4.54		5.63
		[0.027]		[0.027]		[0.018]		[0.010]
HHI	−0.028	−0.397**	−0.043**	−0.432**	−0.032**	−0.319**	−0.118*	−1.398**
(total assets)	(0.020)	(0.177)	(0.020)	(0.213)	(0.014)	(0.151)	(0.063)	(0.698)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	139,000	112,731
R^2	0.592	N/A	0.624	N/A	0.644	N/A	0.465	N/A
First-stage results								
IV		0.153***		0.153***		0.153***		0.043***
		(0.020)		(0.020)		(0.020)		(0.009)
Durbin-Wu-Hausman		32.23		47.13		24.87		91.56
		[0.004]		[0.000]		[0.036]		[0.004]
Kleibergen-Paap rk Wald F		79.154		79.154		79.154		41.329
Kleibergen-Paap rk LM		79.23		79.23		79.23		43.124
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.26		4.25		3.24		4.87
		[0.039]		[0.039]		[0.078]		[0.024]

(*continued on next page*)

Table 4
Heterogeneity: Size of mining industries.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*										
HHI	−0.034*	−0.437**	−0.037*	0.310	−0.039**	−0.410*	−0.039**	−0.616**	−0.042**	−0.610*
	(0.019)	(0.186)	(0.019)	(0.398)	(0.019)	(0.218)	(0.019)	(0.296)	(0.019)	(0.357)
HHI × *lnemp*	−0.004**	−0.051*								
	(0.002)	(0.030)								
HHI × *lnasset*			−0.003**	−0.034*						
			(0.001)	(0.018)						
HHI × *output_prop*					−0.168**	−1.133*				
					(0.076)	(0.664)				
HHI × *emp_prop*							−0.116*	−1.176*		
							(0.060)	(0.637)		
HHI × *asset_prop*									−0.120**	−1.591
									(0.057)	(1.118)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.592	N/A	0.592	N/A	0.592	N/A	0.592	N/A	0.592	N/A
First-stage results										
IV		0.111***		0.102***		0.096***		0.078***		0.097***
		(0.008)		(0.014)		(0.004)		(0.002)		(0.002)
IV × *size of mining industries*		0.053***		0.044***		0.031***		0.022***		0.027***
		(0.006)		(0.005)		(0.003)		(0.002)		(0.002)
Durbin-Wu-Hausman		71.98		72.31		88.37		90.67		121.94
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		50.971		61.108		17.109		18.971		15.093
Kleibergen-Paap rk LM		51.769		62.536		19.651		20.297		16.613
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.15		2.97		5.49		5.62		6.57
		[0.076]		[0.084]		[0.076]		[0.038]		[0.011]
Panel B: *Inno2*										
HHI	−0.023	−0.225**	−0.023	−0.214	−0.033*	−0.220	−0.028	−0.110	−0.034*	−0.170
	(0.022)	(0.096)	(0.022)	(0.240)	(0.020)	(0.234)	(0.022)	(0.465)	(0.020)	(0.161)
HHI × *lnemp*	−0.006***	−0.054*								
	(0.002)	(0.030)								
HHI × *lnasset*			−0.004***	−0.024**						
			(0.002)	(0.011)						
HHI × *output_prop*					−0.232***	−0.310**				
					(0.069)	(0.125)				
HHI × *emp_prop*							−0.156**	−0.637		
							(0.068)	(0.630)		
HHI × *asset_prop*									−0.133**	−0.308
									(0.051)	(0.249)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.626	N/A	0.626	N/A	0.626	N/A	0.626	N/A	0.626	N/A

(*continued on next page*)

Table 4 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
First-stage results										
IV		0.111***		0.102***		0.096***		0.078***		0.097***
		(0.008)		(0.014)		(0.004)		(0.002)		(0.002)
IV × *size of mining industries*		0.053***		0.044***		0.031***		0.022***		0.027***
		(0.006)		(0.005)		(0.003)		(0.002)		(0.002)
Durbin-Wu-Hausman		118.84		92.66		112.96		98.73		109.86
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		50.971		61.108		17.109		18.971		15.093
Kleibergen-Paap rk LM		51.769		62.536		19.651		20.297		16.613
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.09		2.63		5.30		5.43		3.22
		[0.026]		[0.055]		[0.041]		[0.024]		[0.010]
Panel C: *Inno3*										
HHI	−0.001	−0.397	−0.001	−0.007	−0.005	−0.410*	−0.004	−0.451*	−0.006	−1.133*
	(0.015)	(0.279)	(0.015)	(0.391)	(0.014)	(0.248)	(0.014)	(0.251)	(0.015)	(0.654)
HHI × *lnemp*	−0.003**	−0.024**								
	(0.001)	(0.011)								
HHI × *lnasset*			−0.002***	−0.018**						
			(0.001)	(0.007)						
HHI × *output_prop*					0.126***	−1.183				
					(0.048)	(1.170)				
HHI × *emp_prop*							−0.081**	−0.848**		
							(0.037)	(0.345)		
HHI×*asset_prop*									−0.082**	−1.612
									(0.036)	(2.070)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.645	N/A	0.645	N/A	0.645	N/A	0.645	N/A	0.645	N/A
First-stage results										
IV		0.111***		0.102***		0.096***		0.078***		0.097***
		(0.008)		(0.014)		(0.004)		(0.002)		(0.002)
IV × *size of mining industries*		0.053***		0.044***		0.031***		0.022***		0.027***
		(0.006)		(0.005)		(0.003)		(0.002)		(0.002)
Durbin-Wu-Hausman		181.77		144.78		169.94		133.84		166.04
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		50.971		61.108		17.109		18.971		15.093
Kleibergen-Paap rk LM		51.769		62.536		19.651		20.297		16.613
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.45		3.12		5.45		5.37		7.97
		[0.041]		[0.005]		[0.039]		[0.008]		[0.019]
Panel D: *Inno4*										
HHI	0.036	−0.743**	0.040	−0.092	0.030	−1.967**	0.031	−1.190**	0.028	−1.203**
	(0.043)	(0.335)	(0.068)	(0.185)	(0.044)	(0.821)	(0.044)	(0.512)	(0.043)	(0.540)
HHI × *lnemp*	−0.012**	−0.074**								

(*continued on next page*)

Table 4 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(0.006)	(0.029)								
HHI × lnasset			−0.011*	−0.121*						
			(0.006)	(0.069)						
HHI × output_prop					−0.138	−1.128				
					(0.147)	(2.531)				
HHI × emp_prop							−0.065	−0.918		
							(0.119)	(1.959)		
HHI × asset_prop									−0.227*	−0.917
									(0.130)	(1.035)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731	139,000	112,731	139,000	112,731	139,000	112,731
R^2	0.464	N/A	0.464	N/A	0.464	N/A	0.464	N/A	0.464	N/A
First-stage results										
IV		0.057***		0.056***		0.057***		0.047***		0.053***
		(0.009)		(0.008)		(0.009)		(0.013)		(0.008)
IV × size of mining industries		0.035***		0.028***		0.035***		0.031***		0.033**
		(0.007)		(0.006)		(0.007)		(0.010)		(0.014)
Durbin-Wu-Hausman		90.81		89.23		86.86		84.61		26.19
		[0.000]		[0.000]		[0.000]		[0.000]		[0.051]
Kleibergen-Paap rk Wald F		56.219		46.871		45.221		39.102		39.201
Kleibergen-Paap rk LM		57.027		47.902		46.187		40.187		40.187
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.41		3.91		5.25		5.11		5.12
		[0.003]		[0.001]		[0.026]		[0.008]		[0.011]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Size of mining industries represents indicators such as *lnemp*, *lnasset*, *output_prop*, *emp_prop* and *asset_prop*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 (*continued*)

Dependent Variables:	*Inno1*		*Inno2*		*Inno3*		*Inno4*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS

Panel B. Alternative measures of innovation

Dependent Variables:	*Inno5*		*Inno6*		*Inno7*	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HHI	−0.028**	−0.315**	−0.012*	−0.156*	−0.042**	−0.392*
(total income)	(0.014)	(0.142)	(0.007)	(0.084)	(0.018)	(0.208)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	139,000	112,731	139,000	112,731
R^2	0.549	N/A	0.506	N/A	0.452	N/A
First-stage results						
IV		0.051***		0.054***		0.058***
		(0.006)		(0.008)		(0.008)
Durbin-Wu-Hausman		120.36		33.33		24.47
		[0.000]		[0.000]		[0.011]
Kleibergen-Paap rk Wald F		70.870		50.363		48.884
Kleibergen-Paap rk LM		108.047		127.582		124.408
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		3.97		3.52		3.11
		[0.046]		[0.061]		[0.028]

Panel C. Alternative estimation methods

Dependent variable:	*Inno3*		*Inno4*	
	(1)	(2)	(3)	(4)
	Tobit	IV Tobit	Negative binomial	IV Negative binomial
HHI	−0.081**	−5.205***	−0.440**	−4.548***
(total income)	(0.022)	(0.804)	(0.214)	(0.879)
Marginal effects			−0.440**	−4.548***
			(0.214)	(0.879)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	106,848	93,891	139,000	112,731
First-stage results				
IV		0.166***		0.047***
		(0.018)		(0.003)
Durbin-Wu-Hausman		24.51		80.07
		[0.040]		[0.000]
Kleibergen-Paap rk Wald F		85.60		39.53
Kleibergen-Paap rk LM		88.83		39.84
		[0.000]		[0.000]
Anderson-Rubin Wald		3.17		4.58
		[0.074]		[0.032]

Panel D. Coding the missing values as zero

Dependent variable:	*Inno1*		*Inno2*		*Inno3*	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
HHI	−0.034**	−0.450*	−0.047***	−0.505*	−0.035**	−0.168*
(total income)	(0.014)	(0.268)	(0.014)	(0.259)	(0.015)	(0.100)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	117,376	109,695	117,376	109,695	117,376	109,695
R^2	0.519	N/A	0.531	N/A	0.548	N/A
First-stage results						
IV		0.112***		0.117***		0.113***

(*continued on next page*)

Table 3 (*continued*)

Panel D. Coding the missing values as zero

Dependent variable:	*Inno1*		*Inno2*		*Inno3*	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
		(0.008)		(0.008)		(0.014)
Durbin-Wu-Hausman		45.55		49.64		44.70
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		69.379		69.379		69.379
Kleibergen-Paap rk LM		70.321		70.321		70.321
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		2.90		3.62		2.89
		[0.089]		[0.057]		[0.085]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.1. Size of mining industries

In general, companies of larger sizes will have more complex demands regarding public policy. For this reason, they have more incentives to form interest groups for capturing local governments to formulate policies beneficial to them (Schuler, Rehbein, & Cramer, 2002). Moreover, companies of larger sizes are generally better to assume the organizational costs and rent-seeking funds and contribute to taxation and employment more significantly. They generally have a greater ability to participate and discourse power in political decision-making, thus showing their greater ability to impact the decision-making of the local governments. Thus, if the size of local mining enterprises is larger, when the level of the market monopolies in the mining industry increases, there will be more motivation and capability to capture local governments and impact innovation subsidies or incentives for non-mining enterprises, which has an effect on the innovation activities of non-mining enterprises.

We test the hypothesis by introducing the interaction terms between *HHI* and the size of the mining industry in Eq. (1). The model is listed as follows:

$$\text{Innovation}_{ijct} = \beta_0 + \beta_1 \cdot \text{HHI}_{ct} + \beta_2 \cdot \text{HHI}_{ct} \cdot \text{T} + \beta_3 \cdot \text{T} + \beta_4 \cdot \text{X}_{it} + \beta_5 \cdot \text{Z}_{ct} + \rho_i + \delta_{st} + \theta_{jt} + \varepsilon_{ijct} \quad (5)$$

where *T* represents the size of the mining industry. To be specific, we construct five indicators to measure the size of the mining industry to ensure the robustness of the empirical results. The above indicators consist of the logarithm of the total number of employees in the mining industry (*lnemp*), the logarithm of the total assets of the mining industry (*lnasset*), the proportion of the total output of the mining industry to the total industrial output of the whole city (*output_prop*), the proportion of mining industry employees in the whole city (*emp_prop*), and the proportion of the total assets of the mining industry to the total assets of the whole city (*asset_prop*). To avoid interaction effects between the size of the mining industry and the level of market monopolies, the mentioned indicators are calculated using the numerical value at the beginning of the study period.

Table 4 lists the estimated results on the heterogeneity of enterprise size in the mining industry. The coefficients of the interaction terms between *HHI* and the size of the mining industry are found to be negative. These results reveal that in cities with a large size of the mining industry, the increase of market monopolies will lead to a greater decline in innovation in non-mining industry enterprises. To be specific, we take the second column of *Inno1* in Table 4, the negative effect of *HHI* on innovation would increase by 7.5% for an enterprise in the 75th percentile of the size distribution (= 0.437 + 0.051 × 5.561 = 0.721) compared to an enterprise in the 25th percentile (= 0.437 + 0.051 × 4.094 = 0.646).

5.2. Local fiscal pressure

From the perspective of local governments, local fiscal pressure will affect the possibility of being captured by the local monopolists. When faced with fiscal pressure, local governments will rely on the financial contributions of local monopoly industries and large enterprises to alleviate the economic pressure, so they are more likely to be captured by monopoly industries and large enterprises. Therefore, it is expected that when the fiscal pressure of the local government is stronger, the negative effect arising from the level of market monopolies in the mining industry on the innovation of non-mining enterprises is more significant.

We use fiscal deficit (*deficit*), rate of fiscal self-sufficiency (*self-support*) and fiscal population burden ratio (*population*) to measure the fiscal pressure of cities.[13] We test the heterogeneous effects by estimating Eq. (5) but replacing *T* with the three fiscal pressure

[13] In general, greater fiscal deficit indicates lower fiscal surplus, and higher burden rate of fiscal population indicates greater fiscal pressure.

measures. As revealed by the regression results in Table 5, the coefficients of *HHI* and fiscal pressure interaction terms are congruent with our expectations. Accordingly, it suggests that the greater the local fiscal pressure, the greater the negative effect the market monopolies in the mining industry will have on the innovation activities of non-mining enterprises. Take the second column of *Inno1* in Table 5, the negative effect of *HHI* on enterprise's innovation would increase by 21% in the city in the 75th percentile of the fiscal deficit distribution ($= 0.451 + 5.108 \times 0.062 = 0.768$) compared to the city in the 25th percentile ($= 0.451 + 5.108 \times 0.021 = 0.558$).

5.3. Collusion between the government and enterprises

Our main explanation of the main results is the middleman role of the local governments, so the relationship between enterprises and local governments, or the degree of collusion between the government and enterprises, is another possible factor for the ability of the interest groups of the mining industry to impact local governments.

Collusion is recognized as a connection for mutual benefit between the government and local political and economic elites. In comparison with foreign leaders, locally promoted leaders are more likely to engage in collusion with local elites (Nie & Jiang, 2011; Zhang et al., 2013). We explore whether market monopolies in the mining industry have a more significantly negative effect on the innovation of non-mining enterprises in cities in which government-enterprise collusion is higher or easier to achieve. For this end, the resumes of mayors and secretaries of municipal party committees in the respective city are collected in the study period, and the method proposed by Persson and Zhuravskaya (2012) and Zhang et al. (2013) is adopted to construct the collusion measure—whether the mayors and secretaries of municipal party committees had worked locally in his political career before their promotion. To be specific, we set up dummy variables for local promotion of mayor (*mayor_promotion*), local promotion of secretaries of municipal party committees (*SC_promotion*), and local promotion of mayor or municipal party committees (*official_promotion*) to measure the collusion between the government and enterprises.

We replace variable *T* with the collusion measure in Eq. (5) to estimate the heterogeneous results of collusion between the government and enterprises. The regression results are listed in Table 6, indicating that collusion between the government and enterprises can aggravate the negative effect of market monopolies in the mining industry on the innovation activities of non-mining enterprises. According to the second column of *Inno1* in Table 6, the negative effect of *HHI* on enterprise's innovation would increase by 45.2% (=0.213/0.471) in cities with government-enterprises collusion compared to cities without. This finding further confirms the collective action logic.

5.4. Personal characteristics of officials

Since the mayors/party secretaries of Chinese municipalities play central roles in the local governments' decision, the value orientation of local government officials can influence whether they accept lobbying from mining industry interest groups. And their value orientation is closely related to their personal preferences and experiences. Therefore, we consider the impact of different value orientations of different officials on the market concentration of mining industries and the innovation ability of non-mining industries.

Officials with higher educational backgrounds recognize the idea that "science and technology are the primary productive force," and pay more attention to the role of innovation in economic growth (Gu & Shen, 2012). In contrast, for municipal party secretaries and mayors at the bureau level, the chances of promotion are very small after they are aged about 54–55 years, and the promotion incentive will be significantly reduced (Yu, Zhou, & Zhu, 2016). For this reason, they will pay more attention to personal benefit rather than enacting public policies to advance professional promotion. Thus, it is expected that in cities with younger, more highly educated officials, local governments are less likely to be captured by mining interest groups.

In this regard, the individual characteristic variables of educational background and age of municipal party secretaries and mayors have been collected during the study period. We set up a dummy variable of official education (*mayor's degree*, *SC's degree*), with a value of 1 representing a graduate degree or above and a value 0 otherwise. Likewise, a dummy variable is set for officials' age (*mayor's age*, *SC's age*). The value is 1 if the official is over 55 years of age, otherwise, it is 0. We rely on Eq. (5) to estimate the heterogeneous effects from officials' characteristics. Table 7 lists the regression results with interaction terms between *HHI* and officials' characteristics, which confirms a smaller effect of market monopolies in the mining industry on non-mining enterprises' innovation activities in cities with more highly educated and younger officials. According to the second column of *Inno1* in Table 7, the negative effect of *HHI* on enterprise's innovation would decrease by 24.7% (=0.143/0.578) in cities with highly educated mayors compared to cities without. According to the eighth column of *Inno1* in Table 7, the negative effect of *HHI* on enterprise's innovation would decrease by 12.3% (=0.049/0.397) in cities with younger official mayors compared to cities without.

5.5. Marketization

The degree of regional marketization will affect local governments' intervention in the economy, and then affect local governments'

Table 5
Heterogeneity: Local fiscal pressure.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*						
HHI	−0.042**	−0.451*	−0.043**	−0.391*	−0.039*	−0.114
	(0.019)	(0.260)	(0.021)	(0.221)	(0.021)	(0.401)
HHI × deficit	−0.656**	−5.108*				
	(0.266)	(3.002)				
HHI × surplus			0.030**	0.381*		
			(0.013)	(0.210)		
HHI × population					−0.028**	−0.413**
					(0.014)	(0.205)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.592	N/A	0.592	N/A	0.592	N/A
First-stage results						
IV		0.016***		0.107***		0.121***
		(0.006)		(0.020)		(0.023)
IV × fiscal pressure		0.276***		0.264***		0.277***
		(0.017)		(0.095)		(0.018)
Durbin-Wu-Hausman		79.41		86.77		87.21
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		87.761		55.734		50.817
Kleibergen-Paap rk LM		101.747		67.747		81.659
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		7.61		3.19		3.46
		[0.012]		[0.020]		[0.021]
Panel B: *Inno2*						
HHI	−0.035	−0.351	−0.037*	−0.319	−0.027	−0.591*
	(0.026)	(0.518)	(0.022)	(0.346)	(0.024)	(0.305)
HHI × deficit	−0.611***	−3.719				
	(0.192)	(4.541)				
HHI × surplus			0.030***	0.315**		
			(0.010)	(0.147)		
HHI × population					−0.055***	−0.481*
					(0.015)	(0.269)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.625	N/A	0.625	N/A	0.625	N/A
First-stage results						
IV		0.016***		0.107***		0.121***
		(0.006)		(0.020)		(0.023)
IV × fiscal pressure		0.276***		0.264***		0.277***
		(0.017)		(0.095)		(0.018)
Durbin-Wu-Hausman		85.76		88.95		90.09
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		87.761		55.734		50.817
Kleibergen-Paap rk LM		101.747		67.747		81.659
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		6.09		3.42		3.57
		[0.019]		[0.018]		[0.040]
Panel C: *Inno3*						
HHI	−0.007	−0.816***	−0.010	−0.231**	−0.002	−0.191*
	(0.014)	(0.261)	(0.014)	(0.103)	(0.017)	(0.104)
HHI × deficit	−0.311**	−3.171*				
	(0.131)	(1.670)				
HHI × surplus			0.018***	0.319***		
			(0.006)	(0.096)		
HHI × population					−0.038**	−0.510***
					(0.016)	(0.156)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.645	N/A	0.645	N/A	0.645	N/A
First-stage results						

(*continued on next page*)

Table 5 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
IV		0.016*** (0.006)		0.107*** (0.020)		0.121*** (0.023)
IV × *fiscal pressure*		0.276*** (0.017)		0.264*** (0.095)		0.277*** (0.018)
Durbin-Wu-Hausman		150.98 [0.000]		165.99 [0.000]		168.86 [0.000]
Kleibergen-Paap rk Wald F		87.761		55.734		50.817
Kleibergen-Paap rk LM		101.747 [0.000]		67.747 [0.000]		81.659 [0.000]
Anderson-Rubin Wald		6.26 [0.028]		3.45 [0.013]		4.02 [0.008]
Panel D: *Inno4*						
HHI	0.029 (0.051)	−1.613* (0.886)	−0.431*** (0.160)	−2.518* (1.433)	−0.136* (0.078)	−1.360 (1.160)
HHI × *deficit*	−0.535* (0.305)	−4.763** (2.296)				
HHI × *surplus*			0.275** (0.124)	0.176 (0.170)		
HHI × *population*					−0.095** (0.038)	−0.848 (0.860)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731	139,000	112,731
R^2	0.464	N/A	0.464	N/A	0.464	N/A
First-stage results						
IV		0.023*** (0.001)		0.020*** (0.002)		0.029*** (0.008)
IV × *fiscal pressure*		0.069*** (0.010)		0.071*** (0.015)		0.069*** (0.003)
Durbin-Wu-Hausman		87.95 [0.000]		87.72 [0.000]		95.21 [0.000]
Kleibergen-Paap rk Wald F		41.971		42.864		41.624
Kleibergen-Paap rk LM		50.445 [0.000]		51.264 [0.000]		50.109 [0.000]
Anderson-Rubin Wald		7.04 [0.010]		3.19 [0.036]		4.75 [0.071]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Fiscal pressure represents indicators such as *deficit*, *surplus* and *population*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

acceptance of lobbying by interest groups. Many studies have confirmed that regional marketization is negatively related with government's intervention on the economy (Shleifer & Vishny, 1993). Conversely, in regions with lower marketization, local governments are more likely to intervene the economy, which is more likely to breed corruption. Consequently, it is expected that the effect of market monopolies in the mining industry on non-mining enterprises' innovation activities should be smaller in cities with higher marketization.

We then use Eq. (5) to examine the heterogeneous effects across cities with different degrees of marketization. The marketization index[14] of cities of China follows Fan, Wang, and Ma (2011). We select two representative indicators, the total score of marketization (*total_score*) and the score of the relationship between government and the market (*relation_ score*). The regression results shown in Table 8 indicate that the negative effect of market monopolies in the mining industry on non-mining enterprises' innovation activities is smaller in cities with a higher marketization index, which indicates that the degree of marketization has a significant inhibitory effect on the non-market behavior of interest groups. Take the second column of *Inno1* in Table 8, the negative effect of *HHI* on firm's

[14] Marketization index refers to the level and degree of regional marketization development, which is composed of five indexes including the relationship between government and market, the development of non-state-owned economy, the development degree of product market, the development degree of factor market, the development of market intermediary organization and legal system environment. Based on the research objective, we select the total score of marketization and the score of the relationship between government and the market to measure the degree of marketization.

Table 6
Heterogeneity: Collusion between the government and enterprises.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*						
HHI	−0.036*	−0.471**	−0.043**	−0.398**	−0.036*	−0.493**
	(0.021)	(0.242)	(0.021)	(0.183)	(0.021)	(0.211)
HHI × mayor_promotion	−0.034*	−0.213*				
	(0.020)	(0.129)				
HHI × SC_promotion			−0.031**	−0.096*		
			(0.015)	(0.057)		
HHI × official_promotion					−0.034*	−0.085*
					(0.019)	(0.050)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.591	N/A	0.591	N/A	0.591	N/A
First-stage results						
IV		0.117***		0.068***		0.060***
		(0.006)		(0.007)		(0.006)
IV × Collusion		0.284***		0.220***		0.168***
		(0.015)		(0.010)		(0.009)
Durbin-Wu-Hausman		87.24		87.11		87.35
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		41.971		84.961		83.197
Kleibergen-Paap rk LM		38.600		87.609		91.056
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.94		3.25		3.16
		[0.084]		[0.072]		[0.050]
Panel B: *Inno2*						
HHI	−0.014	−0.205**	−0.024	−0.351**	−0.020	−0.427**
	(0.021)	(0.094)	(0.021)	(0.162)	(0.021)	(0.186)
HHI × mayor_promotion	−0.035*	−0.191*				
	(0.020)	(0.105)				
HHI × SC_promotion			−0.019	−0.173*		
			(0.015)	(0.094)		
HHI × official_promotion					−0.030*	−0.171*
					(0.017)	(0.097)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.626	N/A	0.626	N/A	0.626	N/A
First-stage results						
IV		0.117***		0.068***		0.060***
		(0.006)		(0.007)		(0.006)
IV × Collusion		0.284***		0.220***		0.168***
		(0.015)		(0.010)		(0.009)
Durbin-Wu-Hausman		93.24		98.95		93.92
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		41.971		84.961		83.197
Kleibergen-Paap rk LM		38.600		87.609		91.056
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		2.21		2.19		3.61
		[0.052]		[0.038]		[0.025]
Panel C: *Inno3*						
HHI	−0.004	−0.364*	−0.008	−0.296**	−0.007	−0.299**
	(0.014)	(0.199)	(0.006)	(0.122)	(0.014)	(0.144)
HHI × mayor_promotion	−0.013	−0.065*				
	(0.013)	(0.039)				
HHI × SC_promotion			−0.007	−0.008		
			(0.009)	(0.060)		
HHI × official_promotion					−0.002	−0.013
					(0.011)	(0.041)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.644	N/A	0.644	N/A	0.644	N/A
First-stage results						

(*continued on next page*)

Table 6 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
IV		0.117***		0.068***		0.060***
		(0.006)		(0.007)		(0.006)
IV × Collusion		0.284***		0.220***		0.168***
		(0.015)		(0.010)		(0.009)
Durbin-Wu-Hausman		179.31		148.94		152.86
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		41.971		84.961		83.197
Kleibergen-Paap rk LM		38.600		87.609		91.056
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		2.18		1.87		1.90
		[0.075]		[0.033]		[0.066]
Panel D: *Inno4*						
HHI	−0.078*	−0.791*	−0.161**	−1.230*	−0.035	−0.921*
	(0.040)	(0.462)	(0.071)	(0.717)	(0.084)	(0.484)
HHI × mayor_promotion	−0.007	−0.264*				
	(0.039)	(0.153)				
HHI × SC_promotion			−0.001	−0.351***		
			(0.047)	(0.117)		
HHI × official_promotion					0.013	−0.273***
					(0.051)	(0.096)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731	139,000	112,731
R^2	0.463	N/A	0.463	N/A	0.463	N/A
First-stage results						
IV		0.037***		0.022***		0.018***
		(0.005)		(0.003)		(0.001)
IV × Collusion		0.041***		0.050***		0.063***
		(0.005)		(0.009)		(0.011)
Durbin-Wu-Hausman		88.01		88.31		88.20
		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		40.641		41.248		42.081
Kleibergen-Paap rk LM		93.945		95.417		98.476
		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		2.38		3.18		3.09
		[0.015]		[0.027]		[0.018]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Collusion represents indicators such as *mayor_promotion*, *SC_promotion_promotion* and *official_promotion*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

innovation would decrease by 23.8% in the city in the 75th percentile of the marketization distribution (= 1.034–0.085 × 7.92 = 0.361) compared to the city in the 25th percentile (= 1.034–0.085 × 5.12 = 0.599).

5.6. Ownership of mining firms

In general, mining firms with different ownership have different political connections with local governments, and their degree of regulatory capture of local governments is also different. On the one hand, the ultimate control of SOEs belongs to the government, so SOEs have a natural political connection with the government in terms of property rights. SOEs have more discourse power in local political participation, particularly in the monopoly industries represented by the mining industry. When making decisions, the local governments will take the initiative to prioritize SOEs' interests. As a result, SOEs can generally benefit without capturing and regulating local governments. On the other hand, SOEs also account for meeting economic and social goals (e.g., economic growth, employment promotion, tax creation, as well as social stability). They assume more diversified goals and social responsibilities, whereas the ultimate goal of private enterprises is profit maximization. Thus, compared with SOEs, private enterprises are more motivated to form interest groups and influence local governments behavior. Hellman et al. (2003) investigate the effect of interest groups on local government behavior from the perspective of market structure and enterprise attributes, demonstrating that SOEs will influence local government through property rights, whereas private enterprises will form interest groups to capture and regulate the government.

To test the above hypothesis, we calculate the *HHIs* of state-owned (*HHI_SOE*) and non-state-owned (*HHI_NSOE*) mining industry

Table 7
Heterogeneity: Personal characteristics of officials.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*								
HHI	−0.045** (0.023)	−0.578*** (0.171)	−0.079** (0.033)	−0.254 (0.380)	−0.042* (0.022)	−0.433** (0.191)	−0.043** (0.021)	−0.397* (0.233)
HHI × mayor's degree	0.007 (0.018)	0.143* (0.079)						
HHI × mayor's age			−0.013 (0.035)	−0.010 (0.600)				
HHI × SC's degree					0.003 (0.018)	0.084* (0.046)		
HHI × SC's age							−0.002 (0.014)	−0.049** (0.025)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.591	N/A	0.591	N/A	0.591	N/A	0.591	N/A
First-stage results								
IV		0.063*** (0.006)		0.058*** (0.007)		0.059*** (0.006)		0.232*** (0.026)
IV×Personal characteristics		0.017*** (0.001)		0.049*** (0.007)		0.032*** (0.008)		0.024*** (0.001)
Durbin-Wu-Hausman		94.66 [0.000]		88.29 [0.000]		90.89 [0.000]		93.82 [0.000]
Kleibergen-Paap rk Wald F		86.872		70.520		85.371		88.901
Kleibergen-Paap rk LM		100.617 [0.000]		89.979 [0.000]		86.449 [0.000]		99.762 [0.000]
Anderson-Rubin Wald		13.66 [0.001]		5.09 [0.024]		5.83 [0.054]		3.28 [0.017]
Panel B: *Inno2*								
HHI	−0.058** (0.028)	−0.615*** (0.195)	−0.068 (0.047)	−1.152* (0.691)	−0.187*** (0.046)	−0.724* (0.388)	0.025 (0.021)	−0.345 (0.451)
HHI × mayor's degree	0.016 (0.021)	0.152* (0.079)						
HHI × mayor's age			−0.074** (0.037)	−0.833* (0.446)				
HHI × SC's degree					0.146** (0.061)	0.602* (0.308)		
HHI × SC's age							−0.002 (0.014)	−0.043 (0.042)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.625	N/A	0.626	N/A	0.625	N/A	0.626	N/A
First-stage results								
IV		0.063*** (0.006)		0.058*** (0.007)		0.059*** (0.006)		0.232*** (0.026)
IV×Personal characteristics		0.017*** (0.001)		0.049*** (0.007)		0.032*** (0.008)		0.024*** (0.001)
Durbin-Wu-Hausman		97.10 [0.000]		85.35 [0.000]		90.47 [0.000]		91.82 [0.000]
Kleibergen-Paap rk Wald F		86.872		70.520		85.371		88.901
Kleibergen-Paap rk LM		100.617 [0.000]		89.979 [0.000]		86.449 [0.000]		99.762 [0.000]
Anderson-Rubin Wald		14.02 [0.003]		9.89 [0.007]		10.67 [0.036]		3.13 [0.171]
Panel C: *Inno3*								
HHI	−0.048** (0.018)	−0.523** (0.221)	−0.026** (0.011)	−0.288** (0.143)	−0.029*** (0.010)	−0.319* (0.169)	−0.010 (0.014)	−0.640*** (0.101)
HHI × mayor's degree	0.023* (0.012)	0.249** (0.106)						
HHI × mayor's age			−0.014* (0.008)	−0.134*** (0.050)				
HHI × SC's degree					0.021** (0.010)	0.209* (0.122)		
HHI × SC's age							−0.015*	−0.088*

(*continued on next page*)

Table 7 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
							(0.009)	(0.053)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,488	93,891	106,488	93,891	106,488	93,891	106,488	93,891
R^2	0.643	N/A	0.642	N/A	0.643	N/A	0.644	N/A
First-stage results								
IV		0.063***		0.058***		0.059***		0.232***
		(0.006)		(0.007)		(0.006)		(0.026)
IV×Personal characteristics		0.017***		0.049***		0.032***		0.024***
		(0.001)		(0.007)		(0.008)		(0.001)
Durbin-Wu-Hausman		153.45		148.70		133.89		113.09
		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		86.872		70.520		85.371		88.901
Kleibergen-Paap rk LM		100.617		89.979		86.449		99.762
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		15.08		7.11		7.90		3.59
		[0.011]		[0.004]		[0.055]		[0.031]
Panel D: *Inno4*								
HHI	−0.047	−1.635**	−0.163**	−1.862**	−0.185*	−2.732***	−0.127*	−1.411**
	(0.058)	(0.747)	(0.070)	(0.780)	(0.108)	(0.918)	(0.072)	(0.657)
HHI × mayor's degree	0.121**	0.689						
	(0.051)	(0.605)						
HHI × mayor's age			−0.056*	−0.414***				
			(0.029)	(0.125)				
HHI × SC's degree					−0.048	0.580*		
					(0.061)	(0.302)		
HHI × SC's age							−0.112*	−0.820**
							(0.064)	(0.380)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731	139,000	112,731	139,000	112,731
R^2	0.467	N/A	0.467	N/A	0.467	N/A	0.467	N/A
First-stage results								
IV		0.067***		0.067***		0.067***		0.070***
		(0.009)		(0.009)		(0.009)		(0.010)
IV×Personal characteristics		0.049***		0.041***		0.049***		0.049***
		(0.010)		(0.011)		(0.010)		(0.009)
Durbin-Wu-Hausman		91.80		87.30		87.72		95.71
		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		38.183		40.974		42.871		47.563
Kleibergen-Paap rk LM		168.476		159.735		125.260		167.234
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		4.48		7.17		7.67		8.12
		[0.005]		[0.028]		[0.082]		[0.021]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Personal characteristics represent indicators such as *mayor's degree*, *mayor's age*, *SC's degree* and *SC's age*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

enterprises for each city and re-estimate Eq. (1) but replacing *HHI* with *HHI_SOE* and *HHI_NSOE* to investigate their effects on the innovation activities of non-mining enterprises.[15] At the same time, under the contemporary tax system, those central managed SOEs have very little tax contribution to the local government, making them less likely to collude with local governments. Accordingly, we drop 4179 observations from centrally managed SOEs in total. Table 9 lists the regression results. The coefficient of *HHI_SOE* is found to

[15] To construct two instrumental variables (*IV_SOE and IV_NSOE*) for the two explanatory variables (*HHI_SOE and HHI_NSOE*) in the regression of Table 9, we use the total output of the national mining industry instead of the average value of the world price of mineral resources as an exogenous shock of the development of the mining industry. Specifically, we interact the annual total output of the national state-owned (non-state-owned) mining enterprises and the nearest distance index and use their reciprocal value as the instrumental variable of state-owned (non-state-owned) enterprises' city-year market monopolies in the mining industry.

Table 8
Heterogeneity: Marketization.

	(1)	(2)	(3)	(4)
	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*				
HHI	−0.054	−1.034**	−0.042	−0.861**
	(0.050)	(0.427)	(0.059)	(0.398)
HHI × *total_score*	0.003	0.085*		
	(0.009)	(0.047)		
HHI × *relation_score*			0.001	0.059*
			(0.008)	(0.031)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891
R^2	0.591	N/A	0.591	N/A
First-stage results				
IV		0.004***		0.008**
		(0.001)		(0.004)
IV × *Marketization*		0.023***		0.017***
		(0.001)		(0.003)
Durbin-Wu-Hausman		96.50		96.68
		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		76.781		98.425
Kleibergen-Paap rk LM		82.833		122.473
		[0.000]		[0.000]
Anderson-Rubin Wald		4.48		3.64
		[0.007]		[0.068]
Panel B: *Inno2*				
HHI	−0.082*	−0.498	−0.280**	−0.435**
	(0.045)	(0.594)	(0.130)	(0.199)
HHI × *total_score*	0.005	0.057		
	(0.008)	(0.116)		
HHI × *relation_score*			0.028*	0.133**
			(0.017)	(0.060)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891
R^2	0.624	N/A	0.624	N/A
First-stage results				
IV		0.004***		0.008**
		(0.001)		(0.004)
IV × *Marketization*		0.028***		0.017***
		(0.001)		(0.003)
Durbin-Wu-Hausman		85.19		89.52
		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		76.781		98.425
Kleibergen-Paap rk LM		82.833		122.473
		[0.000]		[0.000]
Anderson-Rubin Wald		4.41		5.37
		[0.011]		[0.016]
Panel C: *Inno3*				
HHI	−0.122***	−0.618*	−0.116**	−0.672**
	(0.042)	(0.359)	(0.046)	(0.323)
HHI × *total_score*	0.016**	0.087*		
	(0.007)	(0.042)		
HHI × *relation_score*			0.011*	0.062***
			(0.006)	(0.022)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891
R^2	0.644	N/A	0.644	N/A
First-stage results				
IV		0.004***		0.008**
		(0.001)		(0.004)
IV × *Marketization*		0.028***		0.017***
		(0.001)		(0.003)
Durbin-Wu-Hausman		162.73		161.46
		[0.000]		[0.000]

(*continued on next page*)

Table 8 (*continued*)

	(1)	(2)	(3)	(4)
	OLS	2SLS	OLS	2SLS
Kleibergen-Paap rk Wald F		76.781		98.425
Kleibergen-Paap rk LM		82.833		122.473
		[0.000]		[0.000]
Anderson-Rubin Wald		4.69		4.58
		[0.009]		[0.008]
Panel D: *Inno4*				
HHI	−0.098	−0.351	−0.049	−0.528
	(0.231)	(0.702)	(0.293)	(0.679)
HHI × *total_score*	0.016	0.325**		
	(0.035)	(0.155)		
HHI × *relation_score*			0.005	0.201**
			(0.037)	(0.093)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731
R^2	0.464	N/A	0.464	N/A
First-stage results				
IV		0.425***		0.004***
		(0.131)		(0.001)
IV × *Marketization*		0.202**		0.028***
		(0.080)		(0.001)
Durbin-Wu-Hausman		31.47		90.35
		[0.018]		[0.000]
Kleibergen-Paap rk Wald F		48.672		89.652
Kleibergen-Paap rk LM		80.831		149.545
		[0.000]		[0.000]
Anderson-Rubin Wald		6.06		5.64
		[0.048]		[0.060]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Marketization represents indicators such as *total_score* and *relation_score*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

be remarkably small and insignificant. In contrast, an improvement in the market monopolies of non-state-owned mining enterprises significantly reduces the innovation of non-mining enterprises. According to fourth column of the *Inno1* in Table 9, if the *HHI* of non-state-owned mining enterprises increases by one standard deviation (0.23), the proportion of R&D expenditure in sales of non-state-owned mining enterprises will decrease by 12.4% (=0.23*0.541). The *p*-value of *t*-test on the difference in the coefficients associated with *HHI_SOE* and *HHI_NSOE* is 0.053, indicating that the two coefficients are statistically different. The above results verify the hypothesis proposed in this paper that private enterprises are more motivated to form interest groups to affect local governments, and the results further confirm the logic of collective action behind the cross-industry negative externality of innovation.

6. Further discussion

The above analyses have demonstrated that mining industry monopolies exert significant and stable negative effects on the innovation activities of non-mining enterprises by capturing and regulating the behavior and decision-making of local governments. In the following, three further questions around this logic will be answered. First, how will the innovation activities of the mining industry change with its own market monopolies? Second, what are the mechanisms that the mining industry interest groups capture and regulate the behavior of local governments to reduce the innovation of non-mining industry enterprises? Third, if mining industry interests hope to benefit from capturing local governments that impede innovation in other industries, which related industries should be optimally suppressed?

6.1. Innovation of mining enterprises

To answer the first question, the sample is changed to mining enterprises and Eq. (1) is re-estimated. As is shown in Table 10, the average values of mining enterprises' R&D investment (*Inno1 and Inno2*) during the study period are 0.01, which are much smaller than those of the non-mining enterprises (4.3). The average value of *Inno3* is 0.04, indicating that only 4% of enterprises have R&D investment. What's more, the average number of patent applications is only 0.06 for mining enterprises is weaker.

The regression results are listed in Table 11, the coefficients of *HHI* are all negative but statistically insignificant, which suggests

Table 9
Heterogeneity: Ownership of mining firms.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*						
HHI_SOE	−0.046 (0.028)	−0.525 (0.532)			−0.065 (0.042)	−0.163 (0.572)
HHI_NSOE			−0.044** (0.020)	−0.541** (0.259)	−0.231 (0.167)	−0.472*** (0.020)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	97,540	73,103	105,334	79,962	92,354	72,257
R^2	0.596	N/A	0.593	N/A	0.590	N/A
P value of t-test					0.058	
First-stage results						
IV_ SOE		0.049*** (0.010)				0.021** (0.008)
IV_NSOE				0.043*** (0.007)		0.047*** (0.005)
Durbin-Wu-Hausman		85.08 [0.000]		87.52 [0.000]		86.24 [0.000]
Kleibergen-Paap rk Wald F		23.755		39.404		18.630
Kleibergen-Paap rk LM		95.07 [0.000]		41.03 [0.000]		43.253 [0.000]
Anderson-Rubin Wald		4.97 [0.026]		4.36 [0.037]		5.22 [0.074]
Panel B: *Inno2*						
HHI_SOE	−0.111 (0.087)	−0.752 (0.515)			−0.032 (0.027)	−0.086 (0.105)
HHI_NSOE			−0.060*** (0.022)	−0.647* (0.345)	−0.054*** (0.020)	−0.185*** (0.033)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	97,540	73,070	105,334	79,923	92,354	72,257
R^2	0.632	N/A	0.627	N/A	0.590	N/A
P value of t-test					0.053	
First-stage results						
IV_ SOE		0.049*** (0.010)				0.021** (0.008)
IV_NSOE				0.043*** (0.007)		0.047*** (0.005)
Durbin-Wu-Hausman		79.46 [0.000]		82.94 [0.000]		82.84 [0.000]
Kleibergen-Paap rk Wald F		23.755		39.404		18.630
Kleibergen-Paap rk LM		95.07 [0.000]		41.03 [0.000]		43.253 [0.000]
Anderson-Rubin Wald		4.97 [0.026]		4.36 [0.037]		3.91 [0.038]
Panel C: *Inno3*						
HHI_SOE	−0.034 (0.021)	−0.596 (0.377)			−0.008 (0.028)	−0.020 (0.015)
HHI_NSOE			−0.031* (0.018)	−0.492** (0.245)	−0.042*** (0.015)	−0.129*** (0.016)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	97,540	73,103	105,334	79,962	92,354	72,257
R^2	0.674	N/A	0.645	N/A	0.590	N/A
P value of t-test					0.005	
First-stage results						
IV_ SOE		0.049*** (0.010)				0.021** (0.008)
IV_NSOE				0.043*** (0.007)		0.047*** (0.005)
Durbin-Wu-Hausman		152.24 [0.000]		147.91 [0.000]		148.98 [0.000]
Kleibergen-Paap rk Wald F		23.755		39.404		18.630
Kleibergen-Paap rk LM		95.07 [0.000]		41.03 [0.000]		43.253 [0.000]

(*continued on next page*)

Table 9 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Anderson-Rubin Wald		4.97 [0.026]		4.36 [0.037]		6.14 [0.046]
Panel D: *Inno4*						
HHI_SOE	−0.159 (0.117)	−2.071 (1.579)			−0.042 (0.062)	−0.208 (0.422)
HHI_NSOE			−0.073 (0.059)	−2.455* (2.361)	−0.003 (0.041)	−0.083*** (0.025)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	129,967	102,580	136,619	106,991	118,745	101,735
R^2	0.465	N/A	0.469	N/A	0.529	N/A
P value of t-test					0.618	
First-stage results						
IV_ SOE		0.047*** (0.009)				0.023*** (0.004)
IV_NSOE				0.028*** (0.005)		0.040*** (0.004)
Durbin-Wu-Hausman		92.00 [0.000]		84.87 [0.000]		85.21 [0.000]
Kleibergen-Paap rk Wald F		35.719		35.170		28.152
Kleibergen-Paap rk LM		99.083 [0.000]		42.404 [0.000]		96.319 [0.000]
Anderson-Rubin Wald		3.33 [0.068]		4.62 [0.032]		5.97 [0.051]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10
Descriptive statistics of mining enterprises' innovation.

Variable Name	Obs.	Mean	Std. Dev.	Min	Max
Inno1	12,766	0.01	0.05	0	0.42
Inno2	12,766	0.01	0.05	0	0.44
Inno3	12,766	0.04	0.19	0	1
Inno4	21,291	0.06	1.55	0	96

that with the increase of market monopolies in the mining industry, its own innovation activities will not change. This may be because the mining industry belongs to an industry with low technology content and technological progress rate, and its demand for technological innovation is relatively minor. Accordingly, no matter whether there is motivation to capture and regulate the decisions of local governments, it will not exert a significant effect on its own innovation activities.

6.2. Mechanism discussion

To answer the second question, we test two possible approaches that the local government could apply to reduce the innovation output of non-mining enterprises. The first is that the interest groups of the mining industry increase the tax burden of non-mining enterprises by regulating the behavior and decision-making of local governments, thus increasing the production cost of non-mining enterprises and reducing their innovation ability. The second is that the interest groups of the mining industry squeeze out government subsidies for non-mining industry enterprises by capturing and regulating local governments.

In accordance with the definition of Li and Zheng (2016), an effective corporate tax rate is equal to the ratio of the corporate income tax payable to the reported profit. As is shown in Table 12, the average value of non-mining enterprise effective corporate tax rate (*Tax*) is 0.13 with a standard deviation of 0.16 and the maximum value of 0.75. The government subsidies (*Subsidy1*) are measured by multiplying the ratio of government subsidy to total assets, the average of which is 0.29. To ensure the robustness of the results, other two measurements are performed for government subsidies, the logarithm of government subsidies (*Subsidy2*) and whether the enterprise receives government subsidies (*Subsidy3*). According to the statistics, the average non-mining enterprises' subsidies is RMB 309,750 yuan with a standard deviation of RMB 4,491,950 yuan. The average value of *Subsidy3* is 0.13, that is 13% of non-mining

Table 11
Further discussion: innovation of mining enterprises.

Dependent Variables:	*Inno1*		*Inno2*		*Inno3*		*Inno4*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
HHI	−0.011	−0.418	−0.015*	−0.313	−0.030	−0.598	−0.023	−0.361
	(0.009)	(0.460)	(0.009)	(0.365)	(0.029)	(0.678)	(0.182)	(0.998)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12,766	10,867	12,766	10,867	12,766	10,867	21,291	20,861
R^2	0.636	N/A	0.680	N/A	0.699	N/A	0.657	N/A
First-stage results								
IV		0.012***		0.012***		0.012***		0.004**
		(0.003)		(0.003)		(0.003)		(0.002)
Durbin-Wu-Hausman		19.01		20.88		28.79		10.
		[0.276]		[0.380]		[0.076]		[0.369]
Kleibergen-Paap rk Wald F		30.117		30.117		30.117		31.491
Kleibergen-Paap rk LM		8.125		8.125		8.125		10.382
		[0.000]		[0.000]		[0.000]		[0.001]
Anderson-Rubin Wald		2.17		0.80		2.05		0.13
		[0.141]		[0.371]		[0.662]		[0.714]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

enterprises receive subsidies from the government.

Table 13 lists the results of the mentioned two impact pathways.[16] Specifically, we regress the effective corporate tax rate (*Tax*) and government subsidies (*Subsidy1, Subsidy2, Subsidy3*) to *HHI* using Eq. (1). As indicated by Columns (1) and (2), with the increase in market monopolies in the mining industry, the effective tax rate (*Tax*) of non-mining enterprises increases significantly. The regression results of the enterprise subsidy are listed in Columns (3)–(8) of Table 13. The effect of the mining industry *HHI* on the subsidies of the non-mining industry is significantly negative, which indicates that with the increase of the mining industry *HHI*, the subsidies of non-mining industry enterprises that are received from the local government significantly decrease. Overall, the results listed in Tables 11 and 13 confirm the role of local governments as "middlemen" in the cross-industry innovation behavior.

6.3. Input-output linkage

To answer the third question, we investigate whether the negative impact of mining industry market concentration on innovation output in non-mining industries will change with input-output relationship. If the technology in the upstream and downstream industries of the mining industry increases, as the center of the input-output chain, the mining industry has to improve its technology to meet the market demand. Accordingly, the interest groups of the mining industry should have more incentive to hinder the innovation of industries closely correlated with their production activities. If the collective action theory of Olson (1965) holds, improvement in market monopolies in the mining industry will have a greater effect on the industries directly correlated with the mining industry, but a smaller effect on industries not directly correlated with the mining industry.

The national input-output table in 2002 is adopted to determine the input-output linkage between each two-digit industry code and the mining industry.[17] Subsequently, the industries significantly correlated with the input and output of the mining industry are employed as upstream-related industries (*upstream*) and downstream-related industries (*downstream*).[18] Table 14 lists the regression

[16] For the regressions on the effective tax rate, we control for a set of enterprise-level characteristic variables that may impact enterprises' effective tax rate following Chen (2017): (i) Size of enterprise is measured as total assets (*asset*) and total employees (*emp*). (ii)Ownership of enterprise (*SOE*). (iii) Financial leverage (*leverage*). (iv) Capital intensive (*capital*). (v)Return on capital (*ROA*). (vi) Firm's age (*age*). For the subsidy model, we control for a set of enterprise-level characteristic variables that may impact government subsidies: (i) The size of enterprise, which is measured as total assets (*asset*) and total employees (*emp*). (ii)Ownership of enterprise (*SOE*). (iii) Financial leverage (*leverage*). (iv) Return on capital (*ROA*).

[17] The input relationship between industry *j* and the mining industry represents the proportion of mining industry inputs coming from industry *j*. The output relationship between industry *j* and the mining industry represents the amount of products produced by the mining industry used in the production of industry *j*.

[18] We use two methods to measure upstream-related industries (*upstream*) and downstream-related industries (*downstream*). Specifically, *upstream_1* (*downstream_1*) is a dummy variable. If the input (output) ratio of mining industry in industry *j* is greater than or equal to the average input (output) ratio of industry *j*, the value is 1; otherwise, it is 0. *upstream_2* (*downstream_2*) is a dummy variable. If the input (output) ratio of mining industry in *j* industry is greater than or equal to the median input (output) ratio of *j* industry, the value is 1; otherwise, it is 0.

Table 12
Descriptive statistics of mechanism variables.

Variable Name	Definitions	Obs.	Mean	Std. Dev.	Min	Max
Tax	The corporate income tax payable /the reported profit	101,288	0.13	0.16	0	0.75
Subsidy1	(Government subsidy /total assets) × 100	106,768	0.29	1.18	0	7.45
Subsidy2	The logarithm of government subsidies	106,768	−3.22	3.64	−4.61	13.34
Subsidy3	Dummy variable, which is 1 if the enterprise received government subsidies, and 0 otherwise.	106,768	0.13	0.34	0	1

Table 13
Mechanisms.

Dependent Variables:	*Tax*		*Subsidy1*		*Subsidy2*		*Subsidy3*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
HHI	0.015*	0.132**	−0.050*	−0.674**	−0.226*	−1.793**	−0.024**	−0.215**
	(0.009)	(0.061)	(0.028)	(0.327)	(0.119)	(0.799)	(0.011)	(0.107)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	101,288	83,652	106,768	90,361	106,768	90,361	106,768	90,361
R^2	0.381	N/A	0.666	N/A	0.656	N/A	0.626	N/A
First-stage results								
IV		0.378***		0.046***		0.046***		0.046***
		(0.054)		(0.006)		(0.006)		(0.006)
Durbin-Wu-Hausman		355.00		134.11		134.15		160.25
		[0.000]		[0.000]		[0.000]		[0.000]
Kleibergen-Paap rk Wald F		78.115		82.469		82.469		82.469
Kleibergen-Paap rk LM		90.692		110.870		110.870		110.870
		[0.000]		[0.000]		[0.000]		[0.000]
Anderson-Rubin Wald		6.77		4.02		5.13		4.10
		[0.009]		[0.045]		[0.024]		[0.043]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) For the regressions on the effective tax rate, the control variables include total assets (*asset*), total employees (*emp*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensive (*capital*), return on capital (*ROA*), firm's age (*age*). For the subsidy model, the control variables include total assets (*asset*), total employees (*emp*), ownership of enterprise (*SOE*), financial leverage (*leverage*), return on capital (*ROA*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

estimation results of the interaction terms between *HHI* and input-output relationship from Eq. (5). The coefficients of the interaction terms are most significantly negative, which indicates that compared with enterprises in other industries, enterprises in upstream and downstream related industries of the mining industry are more affected by market monopolies in the mining industry. To be specific, we take the second and fourth columns of *Inno1* in Table 14, the negative effect of *HHI* on innovation would increase by 63.1% (=0.406/0.643) and 78.8% (=0.431/0.547) for enterprises in upstream and downstream industries of the mining industry, respectively.

7. Conclusion

We empirically investigated the effect of local mining monopolies on the innovation activities of non-mining enterprises in 143 resource-rich Chinese cities in accordance with the collective action theory of Olson (1965). The benchmark results reveal that with higher degree of local mining market's concentration, the innovation activities of local non-mining enterprises are reduced significantly. In particular, for each standard deviation increase in the degree of local monopolies in the mining industry, the proportion of R&D expenditures of non-mining enterprises decreases by 13.5%–15.7%, the proportion of enterprises with R&D activities declines by 8.60%, and the number of non-mining enterprises' patent applications is also reduced significantly. The heterogeneity analysis shows that the negative effects are more significant in cities with larger market in the mining industry, a greater fiscal pressure, more intense collusion between government and enterprises, officials with lower education level and older age, as well as a lower degree of marketization. In addition, compared with SOEs, the inhibition effect on the cross-industry innovation that arises from the increase in the degree of local monopolies of non-SOEs is more significant. The above results of the heterogeneity analysis confirm the logic that interest groups of the mining industry impact non-mining enterprises' innovation activities by capturing local governments. Further, we find that the local mining monopoly has no significant impact on the innovation behavior of mining enterprises themselves but significantly increases effective tax rate and reduces government subsidies for non-mining enterprises. And industries with stronger input-output relationships to the mining industry are more significantly affected.

From the perspective of a theoretical analysis on the resource curse, the findings of this paper link the logical chain of institutional

Table 14
Input-output linkage.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Panel A: *Inno1*								
HHI	−0.072* (0.041)	−0.643* (0.369)	−0.063** (0.025)	−0.547* (0.313)	−0.077* (0.041)	−0.716* (0.387)	−0.060** (0.026)	−1.001** (0.423)
HHI × upstream_1	−0.085* (0.050)	−0.406** (0.196)						
HHI × downstream_1			−0.065* (0.035)	−0.431** (0.207)				
HHI × upstream_2					−0.043 (0.046)	−0.542*** (0.172)		
HHI × downstream_2							−0.072** (0.034)	−0.708*** (0.247)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.639	N/A	0.639	N/A	0.639	N/A	0.639	N/A
First-stage results								
IV		0.027*** (0.008)		0.019** (0.008)		0.015** (0.006)		0.013* (0.008)
IV×Input-output linkage		0.378*** (0.054)		0.328*** (0.006)		0.218*** (0.009)		0.314*** (0.006)
Durbin-Wu-Hausman		128.85 [0.000]		98.41 [0.000]		182.61 [0.000]		182.61 [0.000]
Kleibergen-Paap rk Wald F		70.672		60.987		79.912		76.290
Kleibergen-Paap rk LM		84.028 [0.000]		76.104 [0.000]		99.535 [0.000]		97.552 [0.000]
Anderson-Rubin Wald		6.42 [0.040]		8.04 [0.018]		7.47 [0.024]		7.94 [0.019]
Panel B: *Inno2*								
HHI	−0.020 (0.016)	−0.672** (0.329)	−0.011 (0.030)	−1.052** (0.493)	−0.033* (0.020)	−0.370** (0.177)	−0.007 (0.030)	−1.386*** (0.511)
HHI × upstream_1	−0.040* (0.024)	−0.591** (0.245)						
HHI × downstream_1			−0.022 (0.046)	−0.298 (0.385)				
HHI × upstream_2					−0.023 (0.022)	−0.207** (0.098)		
HHI × downstream_2							−0.049 (0.040)	−0.528** (0.254)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.625	N/A	0.625	N/A	0.625	N/A	0.625	N/A
First-stage results								
IV		0.027*** (0.008)		0.019** (0.008)		0.015** (0.006)		0.013* (0.007)
IV×Input-output linkage		0.378*** (0.054)		0.328*** (0.006)		0.218*** (0.009)		0.314*** (0.006)
Durbin-Wu-Hausman		89.90 [0.000]		91.42 [0.000]		184.88 [0.000]		130.59 [0.000]
Kleibergen-Paap rk Wald F		70.672		60.987		79.912		76.290
Kleibergen-Paap rk LM		84.028 [0.000]		76.104 [0.000]		99.535 [0.000]		97.552 [0.000]
Anderson-Rubin Wald		4.02 [0.013]		4.45 [0.014]		3.32 [0.189]		5.16 [0.076]
Panel C: *Inno3*								
HHI	−0.014 (0.016)	−0.672*** (0.242)	−0.006 (0.010)	−0.651* (0.354)	−0.029** (0.013)	−0.309* (0.160)	−0.005 (0.010)	−0.245* (0.143)
HHI × upstream_1	−0.043* (0.025)	−0.442* (0.237)						
HHI × downstream_1			−0.026* (0.015)	−0.358** (0.156)				
HHI × upstream_2					−0.018* (0.011)	−0.204** (0.089)		
HHI × downstream_2							−0.028**	−0.365***

(*continued on next page*)

Table 14 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
							(0.013)	(0.124)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	106,848	93,891	106,848	93,891	106,848	93,891	106,848	93,891
R^2	0.643	N/A	0.604	N/A	0.643	N/A	0.604	N/A
First-stage results								
IV		0.027*** (0.008)		0.019** (0.008)		0.015** (0.006)		0.013* (0.007)
IV×Input-output linkage		0.378*** (0.054)		0.328*** (0.006)		0.218*** (0.009)		0.314*** (0.006)
Durbin-Wu-Hausman		157.94 [0.000]		145.12 [0.000]		320.06 [0.000]		200.85 [0.000]
Kleibergen-Paap rk Wald F		70.672		60.987		79.912		76.290
Kleibergen-Paap rk LM		84.028 [0.000]		76.104 [0.000]		99.535 [0.000]		97.552 [0.000]
Anderson-Rubin Wald		7.99 [0.018]		4.40 [0.092]		7.86 [0.020]		7.90 [0.036]
Panel D: *Inno4*								
HHI	−0.064 (0.068)	−2.382** (1.061)	−0.127* (0.069)	−2.131** (1.053)	−0.036 (0.074)	−2.038** (1.012)	−0.123* (0.071)	−1.992** (0.973)
HHI × upstream_1	−0.201** (0.085)	−3.341* (1.818)						
HHI × downstream_1			−0.022 (0.089)	−4.302* (2.456)				
HHI × upstream_2					−0.193** (0.082)	−2.136* (1.243)		
HHI × downstream_2							−0.027 (0.082)	−2.023** (0.990)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	139,000	112,731	139,000	112,731	139,000	112,731	139,000	112,731
R^2	0.463	N/A	0.463	N/A	0.463	N/A	0.463	N/A
First-stage results								
IV		0.070** (0.029)		0.122*** (0.032)		0.054** (0.026)		0.118*** (0.032)
IV×Input-output linkage		0.467*** (0.031)		0.450*** (0.031)		0.452*** (0.031)		0.454*** (0.030)
Durbin-Wu-Hausman		149.54 [0.000]		122.42 [0.000]		93.81 [0.000]		90.62 [0.000]
Kleibergen-Paap rk Wald F		37.872		30.770		87.643		86.083
Kleibergen-Paap rk LM		51.275 [0.000]		48.969 [0.000]		144.539 [0.000]		147.229 [0.000]
Anderson-Rubin Wald		8.91 [0.012]		9.55 [0.008]		10.47 [0.005]		8.89 [0.010]

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) Input-output linkage represents indicators such as *upstream_1*, *downstream_1*, *upstream_2* and *downstream_2*. (4) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

explanation on the resource curse phenomenon and present a comprehensive explanation. In accordance with Olson's theory of collective action, this paper provides unique and new evidence from the special case of resource-rich industry. From the perspective of the research on enterprises' innovation behavior, we also provide an explanation regarding the cross-industry effect of enterprise innovation.

Given the results of this paper, we assert that the local monopolies in natural resource industries contribute significantly to the resource curse, and the clues for breaking the resource curse are also presented. First, when formulating and implementing industrial policies in resource-rich cities, policymakers should be committed to solving the possible problems of local monopolies, restricting the merger of resource-rich enterprises at the local level and regulating their concentration at the local level to prevent collusion among local enterprises in natural resource industries, and reasonably exploiting the relevant provisions of anti-monopoly laws. Accordingly, enterprises with monopolistic behaviors should be punished, and local monopoly enterprises should be split up when necessary. Second, for the resource-rich cities that fiscally heavily rely on a single industry, it is necessary to strengthen the corresponding transfer payment to prevent local governments from being captured by local monopoly enterprises. Third, when selecting and appointing government officials in resource-rich cities, local candidates should be ruled out and young and middle-aged cadres with high academic qualifications should be appointed, so as to reduce the possibility that local governments are in close relation or collusion with local monopoly enterprises. Fourth, the advantages and disadvantages exhibited by SOEs and non-SOEs should be treated. Although substantial empirical evidence reveals that SOEs cannot compare with non-SOEs in terms of efficiency, SOEs that do not consider profit as the only goal may be able to leverage unique advantages to alleviate the resource curse attributed to local monopolies. Fifth, the ability of local governments to redistribute resources through taxation, subsidies when formulating and implementing industrial policies should be strategically weakened. In addition, the supervision of the central government to local governments on the local competition policy should be strengthened, and local governments should be encouraged to focus on providing efficient public services, so that market players can exert their creativity and innovation in a fair competition environment.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Appendix A

Appendix Table 1
143 resource-rich prefecture-level cities and regions.

(1)	(2)	(3)	(4)
Qitaihe	Sanming	SanMenXia	Dongying
Linfen	Linyi	Lincang	Lijiang
Wuhai	Yunfu	Bozhou	Yichun
Baoshan	Karamay	Nagqu	Baotou
NanChong	Nanping	Nanyang	ShuangYashan
Jilin	Lvliang	Hulun Buir	Hsienyang
Tangshan	DaXingAnLing	Datong	Daqing
Loudi	Anshun	Yichun	Baoji
Xuancheng	Suzhou	Suqian	Guang'an
Pingliang	Pingdingshan	Guangyuan	Zhangjiakou
Liupanshui	Yan'an	Xinzhou	Puer
Qingyang	Xuzhou	Panzhihua	Xinyu
Zhangye	Fushun	Jincheng	Jingdezhen
ChengDe	JinZhong	Benxi	Songyuan
Zhaotong	Shuozhou	Yulin	Wuwei
Qujing	Ezhou	Hechi	Taian
ZaoZhuang	Chizhou	Jining	Weinan
Bijie	Luoyang	HuaiNan	Jiaozuo
Luzhou	Huaibei	Puyang	Baksaeg
Zibo	Chuzhou	Baiyin	Laiwu
Huzhou	Baishan	Zigong	Hezhou
Mudanjiang	Shizuishan	HengYang	Dazhou
Panjin	Huludao	Liaoyuan	Tibetan Autonomous Prefecture of Garzê
Pingxiang	Chifeng	Xingtai	Wenshan Zhuang and Miao Autonomous Prefecture
Ganzhou	Tonghua	Ordos	Nujiang of the Lisu Autonomous Prefecture
Yuncheng	Chenzhou	Changzhi	Tibetan Qiang Autonomous Prefecture of Ngawa
Shaoyang	Tongling	Ya'an	Haixi Mongolian and Tibetan Autonomous Prefecture
Tongchuan	Altay	Maanshan	Chuxiong Yi Autonomous Prefecture
Yangquan	Shaoguan	Huanggang	Mongolian Autonomous Prefecture of Bayingolin
Anshan	Hegang	Shangluo	Yanbian Korean Autonomous Prefecture

(*continued on next page*)

Appendix Table 1 (*continued*)

(1)	(2)	(3)	(4)
Hebi	Longyan	Longnan	Southwest Guizhou Autonomous Prefecture
Heihe	Shangqiu	Tieling	Tibetan Autonomous Prefecture of Golog
Hami	Bayan Nur	Lhoka	Tibetan Autonomous Prefecture of Haibei
Alxa League	Huangshi	Xilingol League	Liangshan Yi Autonomous Prefecture
Jixi	Ankang	Yinchuan	Buyi and Miao Autonomous Prefecture of Qiannan
Fuxin	Jinchang	Handan	

Appendix Table 2
The number of observations.

	Variable	Observations	Number of Firms	Data sources
Full sample	*Inno1, Inno2, Inno3*	1,450,426	493,653	*Annual Survey of Industrial Production* conducted by the National Bureau of Statistics of China (2001–2007, excluding 2004); *China Patent Database Digest* (1999–2007)
	Inno4	2,054,308	581,705	
Resource-rich cities	*Inno1, Inno2, Inno3*	241,718	97,402	
	Inno4	345,300	103,756	
Drop if total assets less than fixed assets, fixed assets <1 million yuan, and the number of employees <10	*Inno1, Inno2, Inno3*	222,333	83,026	
	Inno4	286,338	79,665	
Drop if total assets, total employees, taxable income are missing or non-positive	*Inno1, Inno2, Inno3*	222,084	83,004	
	*Inno4*B7	285,876	79,650	
Drop the production and supply industry of electricity, gas, as well as water	*Inno1, Inno2, Inno3*	207,434	79,713	
	Inno4	268,545	75,839	
Drop the observations that didn't report R&D expenditure	*Inno1, Inno2, Inno3*	190,613	75,772	
Drop observations with missing variables	*Inno1, Inno2, Inno3*	106,848	50,441	
	Inno4	139,000	55,427	
Final sample	*Inno1, Inno2, Inno3*	106,848	50,441	
	Inno4	139,000	55,427	

Appendix Table 3
Exclusivity test for instrumental variables.

Dependent variable:	*Inno1*	*Inno2*	*Inno3*	*Inno4*
HHI	−0.036*	−0.043**	−0.030*	−0.132*
	(0.020)	(0.021)	(0.018)	(0.072)
IV	−0.173	−0.066	−0.017	−0.044
	(0.124)	(0.130)	(0.011)	(0.049)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
N	93,891	93,891	93,891	112,731
R^2	0.585	0.620	0.648	0.481

Notes: (1) The robust standard errors clustered at the city level are presented in parentheses. (2) Control variables include total assets (*asset*), total employees (*emp*), proportion of mining industry employees (*size*), ownership of enterprise (*SOE*), financial leverage (*leverage*), capital intensity (*capital*), intangible asset intensity (*intangibility*), return on capital (*ROA*), capital liquidity (*liquidity*), age (*age*), government subsidy (*subsidy*), fiscal deficit (*deficit*), budget expenditure ratio (*budget*), fiscal population burden ratio (*population*), fiscal surplus (*surplus*), and financially supported population (*finpop*); fixed effects include firm fixed effects, industry × year effects, and province × year effects. (3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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