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The Role of Coal Mine Regulation in Regional Development

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The Role of Coal Mine Regulation in Regional Development*

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Abstract: In response to the high mortality rates and low productivity in coal mining, China began regulating coal mines in the 1990s, which has reshaped its coal economy. We empirically investigate the relationship between coal mine regulation and economic growth in China. Using two difference-in-difference approaches to compare the pre- and post-regulation periods, as well as regions with and without rich coal endowment, we find that regulation positively affects regional economy. This result is further illustrated using an OLS estimation that uses mortality rate in coal mining as a proxy for measuring the quality of regulation. The impacts are not limited only to the intra-coal industry but also spillover to the economy of related regions by relieving the crowding-out effects of coal abundance, that is, resource abundance tends to crowd out investment, human capital and innovation in non-resource sectors and thus hinders economic growth.

Keywords: coal mine regulation; crowding-out effects; mortality rate; resource curse; regional development

JEL Classification: L71; O43; P28; Q32; R11

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1 Introduction

Coal is the dominant primary energy in China, accounting for approximately 80% of China's energy structure and 70% of primary energy consumption. In addition, over 90% of China's coal consumption is domestically provided. China's coal mining and coal industry therefore are crucial for the social economy. Consistent with high coal production, coal mine accidents are also frequent in China and are considerably more highlighted. China produces 35% of global coal. However, because of insufficient safety facilities and poor mining productivity, coal mine deaths account for 80% of the global coal industry mortality (2003). The overall coalmine labor productivity is also low reaching approximately 2.2% of that of the United States in 2003. One of the main reasons is that small-size town and village enterprise (TVE) coal mines were once permitted in China.

These poor conditions have prompted the Chinese government to attach importance to regulation in the coal industry. China started regulating the coal industry earlier (i.e., since the 1990s) by expanding fixed-asset investments and closing small-sized mines with low productivity and high mortality rates. However, as shown previously, its productivity rates and mine accidents are still far from satisfactory. In 2008, mortality still accounted for 70% of the world total; however, this is a fruitful improvement compared to the 1990s. From 1997 to 2009, the mortality rate (death worker/ton) declined by 80%, labor productivity (ton/worker) improved by 205%, and national coal output increased by 123% (source: Statistical Communiqué of the National Economic and Social Development and China Coal Industry Yearbook).

This paper evaluated the regulation in terms of the regional economic growth. According to the existing arguments on the resource curse and its impact mechanism on economic performance, crowding-out effect, which suggests that resource abundance crowds out investment, human capital and innovation in non-resource sectors and thus hinders economic growth, is criticized as a main cause of the resource curses in many regions globally (see, e.g., Sachs and Warner, 1995; 2001; Frankel, 2010). In addition, strong institutions can help avoid the resource curse, whereas weak institutions deteriorate it (Hodler, 2006; Andersen and Aslaksen, 2007; Bhattacharyya and Hodler, 2010). Upgrading the regulation and management of coal mines, the coal mining productivity is improved and the crowding-out effect is expected to be relieved. Under this background, we investigate whether China's coal mine regulation has positively affected the economic growth of regions with high coal industry dependence since the 1990s by investigating the relief of crowding-out effects.

Our analysis is as follows. To guide our empirical investigations, we develop a simple framework that shows the relationship between the resource crowding-out effects of entrepreneurs and regional economic growth. Without reasonable regulation, entrepreneurs tend to devote to the coal mining industry because of high profit, and, thus lower both the overall productivity of the coal mining industry (with economies of scale) and other industries (with economies of agglomeration).

Regarding the empirical strategy estimating the effects of regulation on regional development, first, we apply two difference-in-difference (DID) approaches. The first is a comparison between the pre- and post-regulation periods as well as between regions with and without rich small-size coal mines in the provincial-level, regions with rich small-size coal mines are more largely affected by the regulation; the second is a comparison between the pre- and post-regulation periods as well as between cities rich in coal mines and those rich in other mines (except coal mines) in the prefecture-level. We found a positive economic spillover effect of regulation both at the provincial-level and at the prefecture-level. Then, using a robustness check of the regulation impacts, the key and most difficult procedure is finding a good measurement for coal industry regulation. Because regulation is a complex and comprehensive policy, a computable official indicator is not available. We present arguments showing that mortality rate in coal mining is a suitable proxy for the quality of coal mine regulation. Using provincial-level panel data from 1995–2009, we confirm that coal mine regulation positively improves the economic performance of related regions. The results remain stable under various settings. The positive effects are not observed only in the coal industry but also in other economic activities, and we address these spillover effects to the moderation of natural resource crowding-out effects.

This paper contributes to the recent studies on the relationship between institutions and the resource curse. Although most of studies associated with the resource curse and institutions addresses the whole social institution, this paper is concerned with the coal industry institution; thus, controlling endogeneity is easier, and the impact of the institution can be more directly observed. Then, although empirical works such as Angrist and Kugler (2008) and Sala-i-Martin and Subramanian (2003) confirm that a relationship exists between poor institutions and poor economic performance in some resource-dependent countries, they did not confirm this using the dynamic improvements of the institutions. In this paper, we try to empirically present that the improving management of natural resources can positively affect the social economy of related regions.

The remainder of this paper is organized as follows. Section 2 contains a brief review of issues related to the relationship between the resource curse and institutions, and the within-country resource curse. Section 3 presents an introduction of China's coal industry regulation, and Section 4 shows the theoretical framework and empirical strategy. Sections 5 and 6 provide the empirical results on regulation effects. Section 7 presents the mechanisms of regulation quality affecting regional development. Section 8 concludes.

2 Resource curse

2.1 Resource curse and institutions

Natural resource endowments generate economic gains in related regions, but may provide few sources of income to local people because of poor institutions. Accounts of the relationship between the resource curse and poor institutions are available in many cross- and within-country literatures.

Natural resources cause fighting between rivaling groups, which reduces productive activities and weakens property rights, making productive activities less attractive. Natural resources lower incomes in fractionalized countries but increase incomes in homogenous countries (Hodler, 2006). Andersen and Aslaksen (2007) indicate that the so-called resource curse is present in democratic presidential countries but not in democratic parliamentary ones. Bhattacharyya and Hodler (2010) predict that resource rents cause an increase in corruption only if the quality of the democratic institutions is relatively poor. The relationship between resource rents and corruption depends on the quality of the democratic institutions.

Oil revenues per capita in Nigeria increased from US$ 33 in 1965 to US$ 325 in 2000, but income per capita stagnated, placing Nigeria among the 15 poorest countries in the world. Successive military dictatorships have plundered oil wealth, and waste and corruption from oil rather than the Dutch disease has been responsible for the poor long-run economic performance of Nigeria. Improving the quality of public institutions is a method for transforming economics and politics (Sala-i-Martin and Subramanian, 2003). The disruption of the “air bridge” since 1994 has shifted the production of coca paste from Peru and Bolivia to Columbia, causing a boom in the demand for Columbian coca leaf. This has led to more self-employment and work for teenage boys in rural areas but not to widespread economic spillover effects, and the financial opportunities that coca provides have fuelled violence and civilian conflict; furthermore, rural areas with accelerated coca production subsequently became considerably more violent (Angrist and Kugler, 2008). Caselli and Michaels (2013) find that living standards have not been improved although the revenue and reported government expenditures have greatly increased because of oil windfall in some regions of Brazil. The "missing money" is accounted for by embezzlement around the oil windfall.

By contrast, some researchers discuss more positive experiences. Norway is a large petroleum exporter but is one of the least corrupt countries in the world and enjoys well-developed institutions, far-sighted management, and market-friendly policies. It has shown remarkable growth of both manufacturing and the overall economy compared with its neighbors despite phenomenal growth in oil exports since 1971 (Larsen, 2006; van der Ploeg, 2011). In total, 40% of Botswana's GDP stems from diamonds, but Botswana has managed to beat the resource curse. It has the second highest public expenditure on education as a fraction of GNP, enjoys the world's highest growth rate since 1965, and its GDP per capita is at least 10 times that of Nigeria (Sarraf and Jiwanji, 2001).

2.2 Within-country resource curse

Although the resource curse has been mainly studied using cross-country samples (e.g., Sachs and Warner, 1995, 2001; Gylfason, 2001; Mehlum, Moene, and Torvik, 2006), a substantial amount of literature claims a within-country resource curse. James and Aadland (2011) and Papyrakis and Gerlagh (2007) find evidence of a natural resource curse in which mining is negatively related to economic outcomes across the United States using county-level and state-level data, respectively. Deaton and Niman (2012) and James and Aadland (2011) argue that in the United States, an area dependent on coal mining is likely to have deep poverty because of weaker local governance, entrepreneurship, and educational attainment, as well as environmental degradation, poor health outcomes, and limitations on other economic opportunities. Michaels (2011) finds positive evidence on this. After the oil discovery in the Southern United States, related regions reached higher employment density, higher population growth, and higher per capita income.

On the regional level in China, results of resource curse-related works vary across measurement and estimation strategies. Some studies argue that within China, the resource curse exists at the provincial-level through crowding-out of human resource accumulation and innovation, causing rent-seeking and corruption (Xu and Han, 2005; Hu and Xiao, 2007; Shao and Qi, 2008). Ji, Magnus, and Wang (2012) analyze a cross-province sample of China by focusing on the interplay between resource abundance, institutional quality, and economic growth. They find that resource abundance had a positive effect on economic growth at the provincial-level between 1990 and 2008 that depends nonlinearly on institutional quality. Ding, Wang, and Deng (2007), Fang, Ji, and Zhao (2008), and Fan, Fang, and Park (2012) show that there is no significant evidence to support the existence of a resource curse phenomenon in China both at the city-level and at the prefecture-level.

3 China's coal mines and coal mine regulation

Since the 1980s, to meet the increasing demands of coal in society, the central government of China began encouraging coal mining wherever possible and by whatever means. A coal mining license, once not permitted for non-stated-owned enterprises (non-SOEs), was opened to town and village enterprises (TVEs). Thus, TVE coal mines, generally small and with poor production equipment, began flourishing countrywide. By the end of 1996, China had 84,000 operating coal mines, in which 81,000 were small-size TVE mines with an annual coal output of less than 0.3 million tons. Compared with the United States, whose total coal production was similar to China's in 1997 but it had only 2,196 coal mines (Pan, Pu, and Xiang, 2002). In the 1990s, almost 60% of national total coal output in China was generated by small-size TVE mines.

Although TVE coal mines greatly contributed to the energy supply at the time, its disadvantages are obvious. Most TVE mines have less than 10 workers, but coal mining is an industry with economies of scale. Serious problems concerning workers' safety and their long-run health, as well as environmental damage and low productivity (i.e., waste of coal resources) were highlighted all over the coal resource-rich regions. The exploitation rate of TVE mines is typically approximately 10%–15%, with some under 10%. However, that of state-owned key coal mines is generally approximately 50%. This means that in TVE mines, each ton of coal mined wastes approximately eight tons of coal and discarded resources that cannot be mined repeatedly (Wang, 2006). In addition, coal mining licenses have created significant opportunities for rent-seeking and corruption to the local economy. Because of the large number of small-size mines, management of the coal industry has become very difficult.

Further, the prosperity of small-size TVE mines indirectly reduces the competitiveness of large-size SOE mines. Coal is a product with no diversity preferences, that is, no preference as to whether it is from a large-size SOE mine with developed facilities and skilled employees or a small-size TVE mine with rough facilities and unskilled employees: It can be sold to the same customer at the same price. However, although SOE mines have higher labor productivity, they face a higher sunk cost and heavier social burdens (e.g., issues such as recovery of destroyed environment, safety and medical insurance for employees, and education of employees' children). By contrast, TVE mines, particularly illegal mines, can hire enough employees with a relatively low wage and without other social costs. Compared to the high coal price for TVE mines, production costs are relatively low.

As a result, TVE mines flourish but cause serious social problems; however, SOE mines are unprofitable and uncompetitive (this is the case whereby SOEs cannot profit was found across many industries in China in the 1990s. Since then, China has experienced large-scale reform of SOEs countrywide). China's coal industry has become disordered, coal mine accidents are increasingly frequent, and the regional economy is negatively affected. Since the mid-1990s, the central government has decided to regulate the coal industry. Because most accidents happened in the TVE mines because they lack production safety investments and employees mainly consist of the surrounding agricultural population (i.e., they lack knowledge and training in coal mining). Most small-size TVE mines have been gradually closed, and coal mining licenses have been restricted to small-size mining entrants. The remainder of the small-size mines have been required to improve their technology and facilities or merge with large-size SOE mines.

The policy outcome has been satisfactory. As discussed in Section 1, the coal mining mortality rate reduced by 80% and productivity improved by 205% during the period 1997–2009. Although small-size mines have been largely closed, the total national coal production has not been reduced; it has increased gradually because the exploitation rate in large-size mines has increased. Hence, the degree of industry concentration has increased rapidly. The production share of the largest four or eight enterprises within an industry (C4 and C8, respectively) is a general indicator for industry concentration in a country. The degree of coal industry concentration is high in almost all main coal-producing countries whether they are developed or developing economies: The United States (C4 is 45%), South Africa (C4 is 87%), Germany (C4 is 65%), and Australia (C4 is 50%). In India, more than 90% of total coal produced by one enterprise (source: Authors' own collection from various sources). Although still low, the degree of industry concentration (C4) in China increased from 6.9% in 1996 to 20% in 2009 (Pan, Pu, and Xiang, 2002). Because coal is crucial to China's energy supply and coal mines in China are only located in specific regions, the economies of these regions are particularly affected by coal. Therefore, strong coal mine regulation and significant change in the coal industry should be associated with their recent economic performance, making this research interesting and informative.

4 Theoretical framework and empirical strategy

4.1 Theoretical framework

To provide guidance for empirical analysis, this section presents a simple framework that formalizes the impacts of coal mine regulation on regional development. Following the framework by Torvik (2002), two sectors exist in the region: a coal mining sector (c) and other sectors (o). The number of total entrepreneurs (G) is provided exogenously. They can choose to engage in one of the two sectors, such that $G = G_c + G_o$. G_c is the number of entrepreneurs engaging in the mining sector, and G_o is that of the other sectors.

The mineral reserves (R) are provided exogenously, and the total amount is divided equally to all mining entrepreneurs, such that each mining entrepreneur holds the same amount of resources. The total output in the coal mining sector is F_c, which is a function of G_c and R (which is provided), and $\frac{\partial F_c(G_c)}{\partial G_c} < 0$ [in the coal mining sector, a high degree of concentration indicates high industrial productivity (i.e., economies of scale) because of huge sunk costs]. The profit for each mining entrepreneur is set to be homogeneous, $\pi_c = \frac{F_c}{G_c}$.

$f_o(G_o)$ is the profit for each entrepreneur engaging in other sectors, and is a function of G_o. We assume $\frac{\partial f_o(G_o)}{\partial G_o} > 0$, that is, agglomeration economies exist in other sectors, and high firm density indicates high productivity.

The equilibrium is reached when $\pi_c = \pi_o$, that is, for each entrepreneur no profit difference is seen between the two sectors, $\frac{F_c}{G_c} = f_o$.

We set the total social profit function (i.e., the total profit of both sectors) as

$$\text{Total Profit (TP)} = F_c(G_c) + f_o(G_o) \times G_o.$$

The equilibrium is thus

$$\text{TP} = f_o(G_o) \times G_c + f_o(G_o) \times G_o = f_o(G_o) \times G.$$

The first-order partial differential to G_c is

$$\frac{\partial \text{TP}}{\partial G_c} = \frac{\partial f_o(G_o)}{\partial G_c} = -f_o^{'}(G_o) < 0.$$

Proposition (relief of crowding-out effects): When the central government chooses to close small-size coal mines, coal mining entrepreneurs move from the coal mining industry to other sectors (i.e., G_o increases), the total profit of both sectors increases, and the relief of crowding-out effects improves the overall social output.

[Figure 1]

As shown in Figure 1, with no restrictions on G_c, entrepreneurs naturally move from other sectors to coal mining because π_c is always larger than π_o until point A, $\pi_o = \pi_c = \pi_A$. The social welfare is $\pi_A \times G$.

When the government places restrictions on G_c (point B in Figure 1), G_o is fixed as well. Because the profit of coal mining is higher than other sectors at point B, profit differences exist, that is, attributed to tax, markup, or corruption. In sum, the social welfare becomes $\pi_B \times G > \pi_A \times G$; we can observe an increase in social welfare by closing small-size mines (Although we assume that size is homogeneous in the model, real coal mining firms are of different sizes and small-size mines are closed first when G_c is restricted. This does not affect the conclusion: Crowding-out effects are relieved when the industrial concentration degree of the coal mining industry is increased). Ideally, coal mining should be undertaken by a single firm to reach the highest productivity. However, because of geographical features, the coal mining industry may not be highly concentrated in China.

[Figure 2]

This setting is reasonable and may be explained by Figure 2. After the 1980s, easing the policies on TVE coal mines caused the number of TVE mines to increase rapidly in China, reaching a peak of approximately 100,000 TVE mines in 1991. In 1997, the central government began rectifying TVE coal mines that failed to meet basic safety standards, and over 10,000 mines were closed that year. The government has increased its efforts since then, requiring all unregistered illegal mines to be shut down. By the end of 2010, the number of TVE mines had been reduced to approximately 10,000. Thus, over 85% of small-size coal mines have been closed since 1997. Therefore, the setting of G_c is acceptable.

Another important issue concerning the model is the firm size and economies of scale in coal mining. In the model, we set the productivity in coal mining to be positively correlated with firm size. Coal mining is an industry with economies of scale, and, intuitively, small-size mine owners should have the incentive to merge and reach higher productivities and profits. However, typical cases in China do not follow this logic, possibly for four reasons.

First, there is no incentive for mine owners to put considerably investments in coal mining because of an unstable coal mining policy. The mining license might be withdrawn by the government, and, thus, mine owners are more concerned with short-term profits rather than long-term ones; therefore, they try to maximize exploitation while the mines are still in operation. Second, coal mining requires little knowledge and skilled workers. Therefore, employees are pulled from the agricultural population, that is, mining wages may be rather low[1], and labor substitutes for advanced technology. Third, unlike other industries, the investment threshold for mining is too high for private capi-

[1]One picture taken in 2007 shows a typical case of coal mining in China. A 17-year-old miner carried over 50 kg of coal for 1 km. For each trip, he is paid 1 yuan (about 0.16 USD), showing that despite heavy work, the wage is low. (http://blog.sciencenet.cn/home.php?mod=space&uid=4699&do=blog&id=33987)

tal: Even if two or three small-size mines are merged, the investment threshold cannot typically be met. Generally, only the large-size SOE mines can afford the total technology investment. Furthermore, after the large investment, mines require advanced management. Most mine owners cannot manage this effectively because of insufficient management knowledge. Additionally, returns on coal mine investment are very slow and accompanied by high risk. Fourth, there is no difference between the coal products produced in SOE mines or in TVE mines, and, thus, small-size TVE mines have already been competitive on the market. Because of these reasons, small-size mine owners tend to exploit the coal resource extensively but not intensively, and labor-intensively but not capital-intensively.

4.2 Empirical strategy

In the empirical sections, we use two DID approaches and the mortality rate in coal mining as a proxy of regulation quality to estimate the regulation effects on regional development. For the first DID approach, we compare economic performance before and after regulation to estimate the effects of policy change in the coal mining industry between regions with many or few small-size coal mines. The role of regulation may vary in these regions: Regions with many small-size coal mines (determined by coal endowment and local geology) are affected by the regulation more than other regions are because regulation was mainly targeted to small-size mines. For the second DID approach, we compare the economic performance before and after regulation between regions with rich coal mine endowments and those with other rich natural resource endowments. Both regions are highly dependent on natural resources and have a similar regional industrial structure; however, only coal mines were strongly regulated during the study period.

Next, we provide evidence showing that mortality rate is a suitable proxy of overall coal mine regulation quality, and, thus, we estimate the regulation effects using provincial-level panel data. Furthermore, to determine the crowding-out effects of natural resources, we distinguish between the regulation effects on overall economic performance and that on the intra-coal mining industry.

5 DID approaches

5.1 Baseline results

We cannot observe the exact number of existing small-size coal mines, and the heterogeneity between mines is large. Alternatively, we use the output of small-size coal mines to reflect the approximate number of small-size coal mines. Because the central government decided to close small-size mines nationwide in 1997, we set this as the starting point of the regulation policy.

We test the coal mine regulation effects by DID. According to the official classification, there are two kinds of small-size TVE mines:

***tiny mines*: with an annual output of less than 30,000 tons;**

***small mines*: with an annual output of between 30,000 and 300,000 tons.**

Most coal mine accidents occurred in *tiny mines*, and, thus, the central government decided to gradually close the *tiny mines* or require them to integrate into *small mines* or large-size SOE mines. Because we use a provincial-level dataset and the geological heterogeneity among provinces is large, some regions are able to develop large-size mines, whereas others cannot do so because of natural reasons. That is, the amount of output of small-size mines (sum of *tiny and small mines*) can be viewed as exogenous, whereas the output of *tiny mines* is greatly affected by regulation. The total production of *tiny mines* and *small mines* has not decreased in the past decade, from 89,000 ton in 1996 to 96,000 ton in 2008. In 1996, the output of *tiny mines* was 59,000 tons and that of *small mines* was 30,000 tons. By 2008, the output of *tiny mines* decreased to 6,000 tons and that of *small mines* increased to 90,000 tons. Thus, stable output of small-size mines and decreased output of *tiny mines* provide an exogenous source for checking coal mine regulation effects on GDP growth. Regions with higher outputs of small-size mines are expected to be more affected by regulation (close of *tiny mines*). Governments in those regions prioritize regulation, and, thus the regions are expected to benefit more from this policy change. That is, we estimate the following equation. The annual GDP per capita growth in province i and year t is a function of the output of small-size coal mines (the sum of *tiny mines* and *small mines*), the interaction term between the output of small-size coal mines and the post-regulation dummy variable (=1 if year >1996), and controls such as coal dependence in the related province and year. η_i and μ_t are the province and year dummy, respectively. If the regulation policy improved economic performance, there should be a difference before and after regulation, and α_2 is expected to be positive.

$$\begin{aligned}\text{GDPGROWTH}_{i,t} = \alpha_0 + \alpha_1 \text{small-size}_{i,t} + \alpha_2 \text{small-size}_{i,t} \times \text{POST}_t + \alpha_3 \text{coal dependence}_{i,t} \\ + \alpha_4 \text{CONTROLS}_{i,t} + \eta_i + \mu_t + \epsilon_{i,t}\end{aligned} \quad (1)$$

We use annual data from 1986–2008 in 18 sample provinces, including all main coal producers in China. To control the regional economic disparity and convergence among regions, we control for the distance to the coast (i.e., the minimum distance of the related provincial capital to Beijing, Shanghai, and Guangzhou) and for three regional development policy dummies (i.e., "Go West Campaign," "Revitalizing Northeast China," and "the Rise of Central China"). In Table 1, we find that small-size mine output is not significantly associated with economic performance; however, its interaction term with the post-regulation dummy is positively significant. Evidently, there is a difference before and after regulation.

[Table 1]

Based on the theoretical framework, we show that the regulation on coal mine sector relieves the crowding-out effects of entrepreneurs in other sectors. Similar to the number of small-size mines, the exact number of entrepreneurs in each sector is not available, and we cannot distinguish between resource-intensive and non-resource-intensive industries. Alternatively, we use the tertiary industry to represent non-resource-intensive industries (in the theoretical model, this is related to the "other sectors") and determine the crowding-out effects. Specifically, we apply this strategy using prefecture-level data of the performance of the tertiary industry. Two considerations exist: First, ordinary cities significantly differ from mine cities and cannot perform as a suitable control in DID estimates. Therefore, other mine cities with rich oil, metal, or non-metallic minerals are suitable candidates for controls because they have a similar industrial structure to coal mine cities, that is, high dependent on natural resource. Second, other mining industries were not regulated during our study period, providing a chance to observe the policy change effects using DID. Identification of mine cities is based on China's mining city database (http://www.chinamining.com.cn/city/city.asp), and we selectively exclude the mine cities in which mined resources have almost been completely exploited by 1999. Based on the database, we choose 24 prefecture-level coal mine cities as the treated samples and the other 36 mine cities as the control samples. Table 2 shows the DID results with annual data for 1988–2007 and the following estimated equations.

$$\text{Tertiary Industry}_{i,t} = \alpha_0 + \alpha_1 \text{POST}_t \times \text{coal city}_i + \alpha_2 \text{coal city}_i + \mu_t + \epsilon_{i,t}. \qquad (2)$$

Tertiary Industry$_{i,t}$ is the value-added growth of tertiary industry in city i and year t, POST$_t$ is a dummy variable indicating pre- and post-1996, and coal city$_i$ is a dummy variable for whether the related city is a coal mine city. In Column 1 of Table 2, both city and year effects are fixed, in Column 2 only the year effects are fixed, and in Column 3 we fix the region and year effects by dividing the location of these cities into four regions of China: East, Central, West, and Northeast. In the interaction term between POST$_t$

and coal_i, the coefficients are consistently positive and significant, whereas the coefficient of coal city is negative. This provides evidence that the non-resource intensive industries benefited from coal mine regulation in related regions.

[Table 2]

5.2 Fluctuations of safety inspection policy

The baseline DID approaches present the results that support our assumption on the regulation effects. However, even after 1996 when the central government decided to limit the number of TVE coal mines, the regulation policies fluctuated. We further check the robustness of the DID approaches based on the changes to the safety inspection policy.

China's coal mine production and safety administration policy changed frequently during 1998–2002 [see a detailed discussion in Nie and Jiang (2011) and Wang (2006)], which induced confusion as to the responsibilities of coal mine safety inspection, and the validity of coal industry regulation weakened. China's State Council decided to restructure the government in 1998. The Ministry of Coal Industry was downgraded to a bureau within the State Economic and Trade Commission (SETC). The Bureau of Coal Industry no longer controlled any mines directly, because the management of key SOE mines was shifted to local government departments in the same year. At the end of 1999, the State Council decided to setup the State Administration of Coal Mine Safety (SACMS) alongside the Bureau of Coal Industry. For the first time, China's mechanism for coal mine safety inspection was institutionally separated from that for coal mine production administration. In 2000, a new round of government restructuring eliminated the Bureau of Coal Industry altogether, ending the history of state administration of coal production. In the same year, the State Administration of Work Safety (SAWS) was established, and, since, China's coal industry safety inspection gradually stabilized and strengthened despite that the local government could still affect safety inspection.

Finally, in 2003, SACMS/SAWS was upgraded to a vice-ministerial level institution directly under the State Council, leading SACMS/SAWS to become an independent institution in charge of coal mine safety inspection. These institutional changes caused considerable confusion within the coal mine safety inspection system during 1998–2002. Those who worked in the system were in a constant state of anxiety throughout the process and unsure whether they would lose their jobs or where they would be transferred to. The chain of responsibility for safety matters became less clear, and safety rules were not enforced as strictly as before (Wang, 2006). Consequently, during this period, coal mining industry was disorganized even under regulation, because the regulation quality was low. If we observed an unbiased regulation effect in the baseline DID approach, intuitively, the regulation effects during 1998–2002 is expected to have been weaker than in other years. During this period, the mortality rate in coal mining increased because of the policy fluctuation despite that small-size mines were well-regulated and shut down.

Empirically, we re-run the estimation of Tables 1 and 2 by adding another time dummy for the period 1998–2002 (POST9802=1 during 1998–2002, and POST=1 if the year is after 1996 and POST9802=0). Table 3 shows that the interaction term coefficients are larger in POST than in POST9802, although they are both significant at the 1% level. In Table 4, the coefficient of POST becomes more significant than in the baseline estimate (Table 2), and the coefficient of POST9802 is not significant, suggesting that during 1998–2002, coal mine regulation did not benefit related coal mine cities because of policy fluctuations[2].

[Tables 3 and 4]

[2] Another potential explanation for the insignificant results for the period 1998–2002 is that the relief of crowding-out effects needs more time to be presented in the economic indicators of tertiary industry.

6 Robustness checks using mortality rate

The DID approaches may provide straightforward evidence of regulation effects. However, these approaches cannot offer evidence on the degree of regulation impacts on economic performance. We present another estimate in this section as further evidence. Two problems arise. First, there is no comprehensive indicators representing regulation, because regulation is a complex policy mainly, but not limited to, addressing the shuttering of small-size mines. Second, some regions are not naturally suitable to develop large-size mines, so regulation must focus on other aspects. Even after regulation, the output share of small-size mines to total coal output in these regions is still considerably high. Ideally, we have an alternative choice, that is, *tiny mines* are first considered for shut down, so the trend of *tiny mines* output may be a good proxy of regulation quality. However, some provinces have already closed all their *tiny mines* by the beginning of the 21st century; so they focus on closing other small-size mines and on other regulation policies. Therefore, it is difficult to apply these points to estimates. Alternatively, we use the mortality rate in coal mining as a proxy of overall regulation quality.

6.1 Coal mine regulation measurement: Why mortality rate is a suitable proxy

Coal mine regulation is a comprehensive policy that includes cancellation or rejection of coal mining licenses to small-size mines with insufficient investment and low annual output, closing illegal mines and most existing small-size mines with low productivity, improving mining technology, and enhancing the standard of compensation for mining accidents. Because a computable official indicator is not available, we present the argument that mortality rate is a potential suitable indicator for the quality of regulation because it is highly correlated with the main regulation events. Mortality rate is highly associated with investment improvements in the coal mine industry, an increase in standards of compensation for mining accidents, and the closure of small-size mines.

Improved mining technology and investments not only enhance productivity but also better guarantee safety in coal mining. High compensation standards for mining accidents force mine owners to invest more in safety facilities and technical training of employees, as well as further relieve the frequency of mining accidents. Before 2000, the owners of TVE mines paid limited reparations for mining accidents, generally less than US$ 5,000 to each of the victim's families. Compared to the revenue gained from mining, reparations were very affordable, that is, there was no incentive for mine owners to improve production technology and safety or to provide vocational training of mine employees. Furthermore, because of the low education levels, most employees in TVE mines could not effectively protect their rights after accidents using the judiciary system. Post-regulation (though still far from sufficient compared to developed countries), compensation and safety supervision have been significantly increased: Compensation for mining accidents to each victim's families was approximately US$ 30,000 in 2004, US$ 40,000–60,000 in 2009, and US$ 90,000–100,000 in 2011[3]. Consistently, China's mortality rate in coal mining declined rapidly by 80% from 2000-2009. Thus, compensation standard has a negative relationship with mortality rate.

To regulate the coal industry, the Chinese government has withdrawn coal mining licenses for many small-size mines, particularly *tiny mines* (with annual coal output of less than 0.03 million ton), and has stopped issuing licenses to new small-size mining entrants since the mid-1990s. During the period 1995–2010, more than 85% of the TVE mines were shut down (see Figure 2), most of which were *tiny mines*. In 1995, *tiny mines* accounted for 43% of national coal output, but this figure largely decreased by 2009, to less than 3%. The process of shutting down *tiny mines* is a main characteristic of recent Chinese coal industry. Consistently, in this period, mortality rate was highly

[3]Data is from various online news. There is no official standard or detailed record for compensation standards of mining accidents, and it differs between regions, the type of the mine, and the social consequences.

associated with the shuttering policy, decreasing from 4.89 to 0.89 person/million tons coal (see Figure 3). Mortality rates have varied greatly across different types of mines, and most accidents have happened in small-size mines. Whereas the safety record for large-size SOE mines is as good as their counterparts in advanced countries, small-size mines are potential death traps (Wang, 2006). In 1995, 10,572 people in China died in mining accidents, of which 70% occurred in TVE mines. Overall, Table 5 presents the correlation between mortality rate and investment on coal mines, as well as the output of *tiny mines*. Both are highly associated with mortality rate, suggesting that it is a suitable proxy for regulation quality. The correlation is high even when the period 1998–2002 is included, in which we present evidence that because of policy fluctuations, mortality rate increases despite the shuttering of small-size mines. With the fluctuation of regulation policy, the mortality rate reflects that the overall regulation quality is low.

[Table 5 and Figure 3]

6.2 OLS relationship between mortality rate and GDP growth

We estimate the regulation effects by using the mortality rate in coal mining as a proxy of regulation quality. Following the general setup of the estimate on economic growth, we use the control variables of social investment, labor resources, and technology. Coal dependence varies among provinces, so we add controls for the region's coal dependence. Specifically, we model the real GDP per capita growth rate on the mortality rate (i.e., the logarithm of the mortality rate in coal mining), coal dependence (i.e., the logarithm of coal production per capita), and other controls: investment (i.e., the share of total fixed-asset investments in the GDP), human resources (i.e., the share of population with an educational level higher than senior high school in the provincial workforce), technology (i.e., using the logarithm of foreign direct investment per capita as a proxy). Furthermore, the logarithm of initial real GDP per capita to control converges across provinces. We employ provincial panel data for the 15 years 1995–2009. Because not all provinces have coal mines, we choose 20 provinces and provincial-level cities of mainland China based on the coal mine locations and data availability. In total, these account for 93.2% (98.2%) of total coal production in 1995 (2009). To mitigate the noise caused by the volatility of the year-after-year short-term economic growth and short-term mortality rate, we set the panel data using five time series (i.e., 1995–1997, 1998–2000, 2001–2003, 2004–2006, and 2007–2009) and employ the mean of the indicators into the regression. Throughout the paper, data is calculated using the yearly arithmetic and logarithmic mean (if the indicator is a growth rate), except for initial real GDP per capita. Details are presented in the appendix. Then, panel regressions include both provincial and time dummies to control for heterogeneity denoted by η_i and μ_t, respectively. The baseline setup is as follows:

$$\text{GDPGROWTH}_{i,t} = \alpha_0+\alpha_1\text{mortality}_{i,t}+\alpha_2\text{coal dependence}_{i,t}+\alpha_3\text{CONTROLS}_{i,t}+\eta_i+\mu_t+\epsilon_{i,t}. \tag{3}$$

The benchmark result is presented in Column 1 of Table 6. Mortality rate proves to be negatively associated with GDP growth. In this estimate, coal dependence does not seem to negatively affect economic growth, meaning that the resource curse may not naturally exist.

[Table 6]

The degree of coal dependence varies widely among provinces. To control for geographical heterogeneity and to determine whether the benchmark result is driven by specific province features, we exclude Shanxi, Inner Mongolia, Ningxia, Xinjiang, and Heilongjiang, which were the five provinces highest in coal dependence during 1995–1997. Mongolia and Shanxi have most large opencast coal mines in China. We know that an opencast coal mine is naturally safer than underground mines and mine accidents are easier to mitigate. Unsurprisingly, the estimated coefficient (Column 2 of Table 6) is reduced by 40% because these five excluded provinces are China's main coal producers, accounting for 40.0% (50.4%) of national coal output in 1995 (2009). However, the coefficient is still significant at the 1% level. Next, we must consider that the coal industry mortality rate differs naturally among provinces because of the geological features of the mines. Mining is considerably more dangerous in coal mines deep under the surface of the earth than in opencast coal mines. To control for the heterogeneity in the mortality rate, we exclude Guizhou, Hunan, Sichuan, Chongqing, and Xinjiang, the five provinces and provincial-level cities with the highest mortality rate during 1995–1997. The results presented in Column 3 are almost unchanged, the coefficient of mortality rate is still significant at the 1% level, and the magnitude becomes slightly larger. Furthermore, we insert an intersection of mortality rate and coal dependence into the regression in Column 4. Thus, the coefficient of the mortality rate becomes insignificant, and the coefficient of the intersection is significant. Therefore, reasonably, the effects of coal mine mortality rates on GDP growth heavily depend on a region's coal dependence, which we can interpret as additional evidence that the benchmark result is not endogenously caused by disturbances not associated with the coal industry.

In Column 5, we address the robustness with respect to the newly issued regional development policies. During the high growth of the 1990s, China's coastal regions gained significantly more than inland regions during the "Reform and Opening Up" policy. To relieve the widening regional disparities, three regional development plans, the "Go-West Campaign," "Revitalizing Northeast China," and "the Rise of Central China" were gradually issued and enacted after 1999. They aimed to stimulate development of inland regions and moderate the large income gap between coastal and inland China. These strategies proved to be efficient, and the overall GDP growth of inland regions began overtaking that of coastal regions after 2004. Although the year effects are fixed in our estimates, these development policies were enacted in specific periods and regions, controlling the regional policy effects on the estimates is necessary. Therefore, we add three dummies for relative provinces and periods into the baseline setup: "Go-West Campaign" for 2001–2009, "Revitalizing Northeast China" for 2004–2009, and "the Rise of Central China" for 2007–2009. Results in Column 5 remain consistent. Then, in Column 6, we use the initial value of all control variables instead of the mean values to check these results; they are almost unchanged.

The potential endogeneity of the mortality rate to GDP growth must be controlled. First, GDP growth rate is an important measuring index for China's local government performance; therefore, if the economic performance is poor, the government may overlook safety inspection in the social production, whereas good economic performance encourages the local government to more closely monitor production safety. This criticism has always existed in developing economies, whereby governments tend to rapidly develop their economy at the cost of high environmental pollution and frequent production accidents. In this case, the inference mentioned previously might be biased.

We use another indicator of mortality rate to verify this concern. If a mortality rate drop in the coal industry is attributed to the improving social economic performance, then the safety of all industries improves but not limited to coal industry. That is, in other industries, similar empirical results between the mortality rate and real GDP per capita growth may be obtained. We employ the total mortality rate in non-agricultural industries (i.e., industry, mining, construction, commerce, and trade) as a substitute for mortality rate in the coal industry, and run the same regression. Column 1 of Table 7 shows that the result is significant, which potentially suggests that the benchmark result is biased. However, the coal industry accounts for a high share of total mortality accidents among the non-agricultural industries. In the mid-1990s, victims in coal mines accounted for over 50% of total mortality accidents in social production, and coal mining became the highest-risk occupation. The significant result in Column 1 may be caused by the large proportion of the coal industry for this indicator. In Column 2, we insert both mortality rate indicators into the regression, and the mortality rate in all non-agricultural industries thus becomes insignificant, whereas the mortality rate in coal mining is still significant. In Column 3, we exclude the coal industry mortality from the total non-agricultural industry mortality, and the modified mortality rate becomes insignificant. That is, the significant result found in Column 1 can be mainly attributed to the coal industry. For other industries, the mortality rate has no significant effects on provincial GDP per capita growth.

[**Table 7**]

7 Mechanism

Based on the previous sections, we can suppose that coal industry regulation has a positive effect on the economic growth of regions with high coal dependence. Two mechanisms can be used to interpret this result. First, productivity of the coal mine industry is improved because of increased investment in fixed assets and economies of scale originating from industrial concentration. Second, the crowding-out effect is potentially relieved because coal mining licenses in TVE mines are, to some extent, prohibited. Even after obtaining the license, environmental recovery and technological investment are strongly required, and production safety is inspected more seriously. In this case, private capital in the coal industry may transfer to other industries that can stimulate local labor resource accumulation and strengthen the agglomeration economies. Primary mining is an industry with low labor resource accumulation, and the social total factor productivity (TFP) growth is heavily dependent on labor resource accumulation. In this paper, we are concerned more with the second mechanism, which might improve overall economic performance.

For the first mechanism, Table 8 shows that after controlling for the initial labor productivity of the coal industry, product share of *small* (*tiny*) *mines*, the investment in the coal industry, and the skill of employees (here, we take the relative wage as the proxy of skill: Average wage of coal mining/average wage of all industries), the mortality rate is still highly associated with coal mine labor productivity whether the independent variable is based on the mean value (Column 1) or the initial value (Column 2).

[Tables 8 and 9]

Thus, we try to distinguish the effects of regulation on the relief of crowding-out effects between intra-industry productivity improvements. Regarding the estimation of the crowding-out effects of coal resources, it is impossible to find a suitable measurement directly. In the implementation, we first insert the labor productivity of the coal industry into the baseline setup. In Column 1 of Table 9, the mortality rate coefficient remains significant and the magnitude only slightly decreases after controlling for coal mining labor productivity. Thus, intra-industry productivity improvement may not fully explain the coal mine regulation effects on regional economic growth, because otherwise, the coefficient of the mortality rate should become much smaller. The results of Column 2 further confirm this. We calculate the modified real GDP per capita growth rate by excluding the coal industry value-added in the total GDP. The estimated result supports this assumption. Even without considering the coal industry, the mortality rate is still highly associated with GDP per capita growth. Compared to the benchmark estimates using the original GDP per capita growth rate in Column 3, the magnitude is reduced from -0.0185 to -0.0174, and the t-test doesn't present significant differences between these two GDP growth rate indicators. Therefore, the regulation impacts are not limited only to the coal industry, and the spillover effect originating from the relief of crowding-out effects may play a role here.

8 Conclusion

Although rich resource endowment is not necessarily negatively associated with regional economic growth, the resource curse is observed in many countries worldwide, and institution is seen as one of the main factors determining the role of resource abundance. Using the ongoing regulation of the coal industry in China, empirical evidence indicates that, after the regulation, labor productivity in coal industry is improved and the crowding-out effect of coal mining to other economic activities is relieved. Both consequences positively improve regional economic performance. Our findings present evidence that the relationship between resource abundance and regional economic performance is subject to the resource management and institution. In addition, we find coal mine regulation has gradually reduced frequent mine accidents and deaths in China.

[**Appendix: Data**]

The data was obtained from many sources. We collected data at the provincial-level for various years. Samples used in this paper refer to 20 provinces (or provincial-level cities): Shaanxi, Gansu, Ningxia, Xinjiang, Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, Inner Mongolia, Henan, Hunan, Anhui, Shanxi, Heilongjiang, Jilin, Liaoning, Shandong, Fujian, and Hebei. We exclude Sichuan and Chongqing in the DID approach, because Chongqing was part of Sichuan before 1999, so separate data on these two regions before 1999 is not available. The GDP indicators were deflated. Data was calculated using the yearly arithmetic and logarithmic means (if the indicator is a growth rate), except for the initial values of the indicators.

Real GDP per capita growth rate (GDPGROWTH) is calculated as:

$$\text{GDPGROWTH} = \frac{\ln \text{GDP}_{i+3} - \ln \text{GDP}_i}{3}$$

GDP: real GDP per capita, from "China Statistical Yearbook."

small-size: logarithm of small-size coal mines output per capita (ton/person), from "China Coal Industry Yearbook."

mortality: logarithm of mortality rate in the coal industry (people/100 million tons), from "China Coal Industry Yearbook," and "Statistical Communiqué of the National Economic and Social Development," at the provincial-level.

coal dependence: logarithm of (coal output/total population) (ton/10,000 people), from "China Coal Industry Yearbook."

initial GDP: logarithm of the initial real GDP per capita, from "China Statistical Yearbook."

invest: the total social investment in fixed assets/GDP, from "China Statistical Yearbook."

educ: share of workers with an education level higher than senior high school of total employment (%), "China Labor Statistical Yearbook."

FDI: logarithm of (FDI/total population; US$/person), from "China Statistical Yearbook."

mortality total: logarithm of the mortality rate in non-agricultural industries (persons/million workers), from "China's Work Safety Yearbook" and "Statistical Communiqué of the National Economic and Social Development," at the provincial-level.

mortality total excoal: logarithm of the mortality rate in non-agricultural industries after excluding the coal industry (persons/million workers), from "China's Work Safety Yearbook" and "Statistical Communiqué of the National Economic and Social Development," at the provincial-level.

small: product share of small mines (i.e., annual output less than 300,000 tons) to total coal output, "China Coal Industry Yearbook."

tiny: product share of tiny mines (i.e., annual output less than 30,000 tons) to total coal output, "China Coal Industry Yearbook."

West: dummy for Shaanxi, Gansu, Ningxia, Xinjiang, Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, and Inner Mongolia during 2001–2009.

Northeast: dummy for Heilongjiang, Jilin, and Liaoning during 2004–2009.

Central: dummy for Henan, Hunan, Anhui, and Shanxi during 2007–2009.

labor productivity: logarithm of (coal output/coal industry employment; ton/person), from "China Coal Industry Yearbook" and "China Labor Statistical Yearbook."

investment in coal mines: logarithm of [investment of coal industry in fixed assets (including only SOE mines)/employment in the coal industry; 10,000 yuan/person], "China Energy Statistical Yearbook."

skill: average wage of coal industry/average wage of all industries, from "China Labor Statistical Yearbook."

GDPGROWTH excoal: modified GDPGROWTH after excluding the value-added of the coal industry in total GDP, from "China Statistical Yearbook," "China Industry Economy Statistical Yearbook," and "Statistical Yearbook (Provincial-level)."

Prefecture-level data on the value-added growth of tertiary industries is from the

"China City Statistical Yearbook."

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Table 1: DID approach checking for the policy change impacts at the provincial level

	(1) GDPGROWTH	(2) GDPGROWTH
small-size	-0.854	-1.066**
	(0.637)	(0.418)
small-size × POST	1.146***	1.303***
	(0.338)	(0.424)
coal dependence	0.776	-0.176
	(1.063)	(0.409)
distance to coastal × POST	-0.639	-1.032*
	(0.466)	(0.570)
West	0.884	1.153
	(0.775)	(0.854)
Northeast	1.959**	1.316*
	(0.810)	(0.723)
Central	0.046	-0.078
	(0.920)	(0.975)
constant	108.470***	118.690***
	(9.951)	(4.416)
Year FE	yes	yes
Province FE	yes	no
Year sample	1986-2008	1986-2008
N	414	414
R^2	0.575	0.571

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 2: DID approach to check for the policy change impacts within mine cities

	(1) Tertiary Industry	(2) Tertiary Industry	(3) Tertiary Industry
POST × coal city	0.028*	0.028*	0.027*
	(0.016)	(0.016)	(0.016)
coal city		-0.011	-0.011
		(0.013)	(0.012)
constant	0.276***	0.281***	0.267***
	(0.023)	(0.023)	(0.024)
Year FE	yes	yes	yes
City FE	yes	no	no
Region FE	no	no	yes
Year sample	1988-1991&1995-2007	1988-1991&1995-2007	1988-1991&1995-2007
N	939	939	939
R^2	0.278	0.278	0.278

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. In 1992–1994, the statistical yearbook did not include the related data.

Table 3: Modified DID approach to check for the policy change impacts at the provincial level

	(1) GDPGROWTH	(2) GDPGROWTH
small-size	-0.908	-1.096***
	(0.631)	(0.418)
small-size $\times$ POST9802	1.036***	1.113***
	(0.331)	(0.389)
small-size $\times$ POST	1.213***	1.398***
	(0.386)	(0.491)
coal dependence	0.679	-0.191
	(0.984)	(0.406)
distance to coastal $\times$ POST9802	-0.204	-0.531
	(0.416)	(0.359)
distance to coastal $\times$ POST	-1.024	-1.444*
	(0.687)	(0.840)
West	1.024	1.219
	(0.813)	(0.871)
Central	-0.118	-0.284
	(1.073)	(1.136)
Northeast	1.902**	1.245
	(0.857)	(0.814)
constant	109.800***	119.100***
	(8.848)	(4.332)
Year FE	yes	yes
Province FE	yes	no
Year sample	1986-2008	1986-2008
N	414	414
R^2	0.578	0.574

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 4: Modified DID approach to check for the policy change impacts within mine cities

	(1) Tertiary Industry	(2) Tertiary Industry	(3) Tertiary Industry
POST9802 × coal city	0.006	0.006	0.006
	(0.017)	(0.015)	(0.016)
POST × coal city	0.048**	0.047**	0.046**
	(0.020)	(0.020)	(0.020)
coal city		-0.011	-0.011
		(0.013)	(0.012)
constant	0.276***	0.281***	0.267***
	(0.023)	(0.023)	(0.024)
Year FE	yes	yes	yes
City FE	yes	no	no
Region FE	no	no	yes
Year sample	1988-1991& 1995-2007	1988-1991& 1995-2007	1988-1991& 1995-2007
N	939	939	939
R^2	0.282	0.282	0.282

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. In 1992–1994, the statistical yearbook does not include the related data.

Table 5: Correlation of mortality rate with coal mine investment and output of tiny mines

correlation	mortality	investment	tiny mines
mortality	1		
investment	-0.6661	1	
tiny mines	0.6565	-0.5177	1

Note: Result is based on panel data [20 provinces with five periods (1995–2009). For details, see the appendix].

Table 6: Regressions with mortality rate

	(1) GDPGROWTH baseline	(2) GDPGROWTH ex top 5 in coal output	(3) GDPGROWTH ex top 5 in mortality rate	(4) GDPGROWTH with interaction term	(5) GDPGROWTH with regional policy dummy	(6) GDPGROWTH initial value
mortality	-0.016***	-0.009***	-0.019***	0.010	-0.015***	-0.014**
	(0.005)	(0.002)	(0.005)	(0.013)	(0.005)	(0.006)
coal dependence	-0.000	-0.004	-0.003	0.012	0.001	0.003
	(0.008)	(0.006)	(0.008)	(0.009)	(0.008)	(0.008)
mortality × coal dependence				-0.0025*		
				(0.0014)		
initial GDP	-0.122***	-0.190***	-0.109***	-0.147***	-0.126***	-0.107***
	(0.035)	(0.061)	(0.035)	(0.033)	(0.037)	(0.034)
educ	0.000	0.001	-0.000	0.001	0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
invest	0.072***	0.030	0.084***	0.069***	0.075***	0.082***
	(0.026)	(0.030)	(0.032)	(0.027)	(0.027)	(0.028)
FDI	0.008	0.007	0.004	0.007	0.009	-0.000
	(0.006)	(0.008)	(0.008)	(0.006)	(0.006)	(0.003)
West					-0.001	
					(0.006)	
Northeast					0.002	
					(0.005)	
Central					-0.013*	
					(0.007)	
constant	1.109***	1.646***	1.085***	1.179***	1.114***	1.108***
	(0.267)	(0.476)	(0.282)	(0.249)	(0.279)	(0.345)
year sample: 1995–2009 (3 years per period); includes two-way fixed effects						
N	100	75	75	100	100	80
R^2	0.809	0.849	0.835	0.817	0.819	0.836

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Column 6 refers to the period 1998–2009 (four periods) because of data restrictions.

Table 7: Regressions with additional mortality rates

	(1) GDPGROWTH	(2) GDPGROWTH	(3) GDPGROWTH
mortality coal		-0.016**	
		(0.007)	
mortality total	-0.0198*	-0.004	
	(0.0104)	(0.012)	
mortality total excoal			-0.003
			(0.014)
initial GDP	-0.069	-0.137***	-0.080**
	(0.044)	(0.053)	(0.041)
invest	0.052*	0.054*	0.049
	(0.031)	(0.028)	(0.031)
educ	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
FDI	0.006	0.009	0.006
	(0.009)	(0.009)	(0.010)
constant	0.073*	1.301***	0.777*
	(0.042)	(0.466)	(0.403)
year sample: 2001–2009 (3 years per period); includes two-way fixed effects			
N	60	60	60
R^2	0.734	0.773	0.719

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Data refers to the period 2001–2009 (three periods) because of data restrictions.

Table 8: Mechanism (intra-industry)

	(1) Labor Productivity	(2) Labor Productivity
mortality	-0.248***	
	(0.073)	
mortality initial		-0.132*
		(0.073)
small	0.128	0.206
	(0.210)	(0.234)
tiny	0.211	0.211
	(0.192)	(0.182)
labor productivity initial	0.295***	0.310***
	(0.082)	(0.097)
investment in coal mines	0.205***	0.247***
	(0.045)	(0.040)
skill	0.166	-0.006
	(0.259)	(0.200)
constant	4.145***	4.132***
	(0.912)	(1.041)
year sample: 1995–2009 (3 years per period); includes two-way fixed effects		
N	100	80
R^2	0.892	0.866

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Column 2 refers to the period 1998–2009 (four periods) because of data restrictions.

Table 9: Mechanism (whole economy)

	(1) GDPGROWTH	(2) GDPGROWTH excoal	(3) GDPGROWTH
mortality	-0.014***	-0.017***	-0.019***
	(0.004)	(0.006)	(0.006)
labor productivity	0.014**		
	(0.007)		
coal dependence	-0.008	-0.006	-0.004
	(0.008)	(0.005)	(0.006)
initial GDP	-0.125***	-0.120***	-0.127**
	(0.032)	(0.047)	(0.057)
educ	0.000	-0.001	-0.000
	(0.001)	(0.001)	(0.001)
invest	0.068***	0.078**	0.073**
	(0.026)	(0.033)	(0.034)
FDI	0.007	0.004	0.008
	(0.006)	(0.006)	(0.007)
constant	1.132***	1.188***	1.209***
	(0.250)	(0.343)	(0.406)
year sample: 1995-2009 (three years per period); with two-way fixed effects			
N	100	80	80
R^2	0.817	0.789	0.834

Note: Heteroskedasticity-robust standard errors are reported in parentheses, and standard errors are clustered at the province level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Columns 3 and 4 refer to the period 1995–2006 (four periods) because of data restrictions.

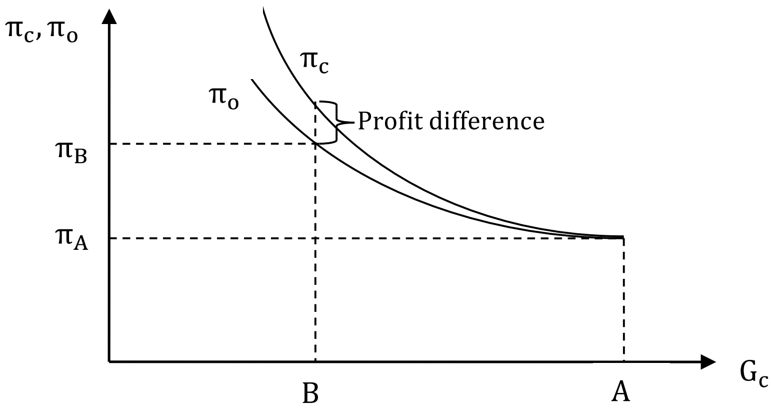

Figure 1: The relationship between entrepreneurs and productivity

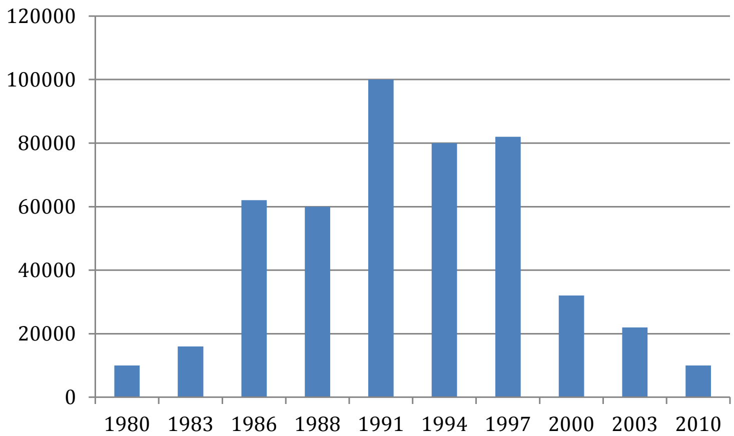

Figure 2: The number of TVE coal mines in China

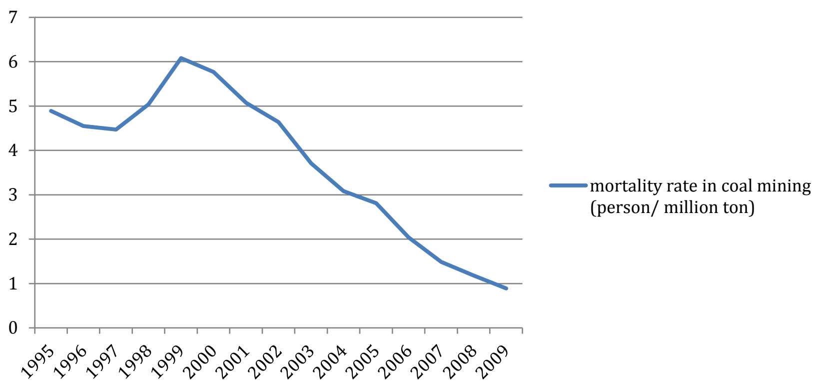

Figure 3: The mortality rate of coal mining in China