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Original Research

Study on the Relationship between Innovation Capability and Profit Growth: Based on the Impact of Environmental Policy

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Abstract

In order to provide suggestions for the reform and transformation of coal mining firms, we construct regression models to analyze the impact of innovation capability. Using a sample of coal mining firms listed on the Shanghai and Shenzhen Stock Exchanges in China from 2013 to 2018, and explaining the innovation capability from three perspectives of R&D intensity, innovation level, and innovation efficiency, this paper is the first to empirically examine the relationship between innovation capability and enterprise profitability, and further investigate the impact of environmental policy on the relationship. We find that the innovation of coal mining firms can effectively promote the improvement of profit growth, especially for the coal mining firms with stronger R&D intensity and higher innovation level. After considering the constraints of environmental policy on coal mining firms, we also find that the greater the intensity of environmental policy, the stronger the positive relationship between R&D intensity and profit growth, which is the effective evidence of applying the Porter's hypothesis to the high-polluting coal mining firms in China. The conclusions facilitate the managers of coal mining firms to further understand the impact of innovation on profitability. At the same time, the study also provides empirical evidence for policy-makers to stimulate innovation of coal mining firms from the perspective of environmental policy.

Keywords: Coal mining firms, profit growth, innovation capability, environmental policy, Porter's hypothesis, neoclassical economic theory.

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Introduction

Over the years, coal has been playing a dominant role in China's energy consumption structure. Although the proportion of coal consumption has decreased year by year, the main position of coal in China's energy consumption structure remains unchanged in the foreseeable future. As China's economy has entered the stage of new normal development, the structure of coal demand and supply has changed significantly. As a result, the coal price is under the downward pressure and the profit margin of coal mining firms is reduced. Facing the challenges of the new environment outside, the development of the traditional coal mining industry has been greatly hindered. Meanwhile, there are many problems faced by traditional coal mining firms, such as backward production technology, insufficient deep-processing of products, and serious environment pollution. Under the dual influence of macro-economic environment and the internal problems of micro-enterprises, the profitability of coal mining firms is gradually weakening. How to improve the profitability of coal mining firms has become a heated topic.

The development of coal mining industry has entered a "bottleneck period". Therefore, the Chinese government has implemented reforms of merger, reorganization, and even closure, and also encouraged coal mining firms to conduct innovative strategies. At the beginning of the 20th century, Schumpeter's innovation theory believes that innovation is the base of economic growth. China's government put forward the major strategic task of building an innovative country in 2006, and then established the dominant position of firms in the process of innovation.

Considering the existing researches, Yang et al. (2006), Saenz et al. (2009) and Hilman & Kaliappen (2015) concur that the innovation is the best choice for firms to transform and upgrade, and the innovation in products is the main way for firms to achieve innovation goals. Olsson et al. (2010) argue that innovation capacity can promote firms to meet market requirements and respond to changes in the economic environment. The level of R&D intensity serves as the criterion of classifying the level of technological innovation, and R&D investment is the key mechanism to improve the firm performance (Ayaydin & Karaaslan, 2014). To improve the firm performance, the firm has the motivation to increase R&D investment that has the long-term positive benefits for the firm performance (Jirásek, 2017; Ruffoni et al., 2018). When the innovation level is fixed, increasing R&D investment can bring about higher probabilities of innovation success (Xing, 2018). Liu & Xia(2018) find that technological innovation is an important driving force for the sustainable development of economy and the social progress; in other words, this is also one of important steps for the transformation of China's economic growth mode from extensive one to green and intensive one.

These prior studies are based primarily on the theoretical discussion and analysis about the positive benefits of innovation, but few studies have empirically examined the impact of innovation capability on enterprise profitability. As for the transformation and upgrading of coal mining firms, scholars mainly analyze in the aspects of macro-policies, and supervision mechanism(Shen & Andrews-Speed, 2001) , but the research on the innovation behaviors of coal mining firms has thus far been inadequate. Thus, can coal mining firms improve the profitability through innovation strategy? This problem has become the core problem of the research.

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Using a sample of coal mining firms listed on the Shanghai and Shenzhen Stock Exchanges in China from 2013 to 2018, and explaining the innovation capability from three perspectives of R&D① intensity, innovation level, and innovation efficiency, we empirically examine the relationship between innovation capability and profit growth. Moreover, considering that the coal mining industry is one of the high-polluting industries in China, environmental policies will inevitably exert stronger constraints on the production and operation of firms. Therefore, this study further tests the moderating effect of environmental regulation on the relationship between innovation capability and profit growth. Compared with the existing researches, the contributions of the study from our perspective are attempted to summarize in several ways.

Firstly, the theoretical research on the coal mining industry is relatively inadequate, and the development of China's coal mining industry is also in the "bottleneck period". The study focuses on the coal mining industry and investigates the relationship between innovation capability and profit growth. We try to provide a new explanation for improving the profitability from the perspective of innovation strategy.

Secondly, although scholars have carried out a large number of studies on innovation, most of them only explain innovation in terms of R&D investment(Booth et al., 2006; Vithessonthi & Racela, 2016), and thus it is necessary to further comprehensively analyze innovation strategy. This study investigates innovation behavior in respects of R&D intensity, innovation level, and innovation efficiency, which provides a theoretical basis for scholars' researches on innovation.

Finally, coal mining industry is one of high polluting industries, and environmental policy has a significant impact on the economic activities of coal mining firms. Scholars suggest that there are two theories about environmental regulation; that is, neoclassical economic theory (Palmer et al., 1995; Gray & Shadbegian, 20013), and Porter's hypothesis (Porter, 1991; Porter & van der Linde, 1995). Thus, there is no consensus on the impact of environmental policy in the academic field. The study explores the moderating effect of environmental regulation so as to make the relationship between innovation capability and profit growth more clear, and meanwhile provide empirical evidence for policy-makers and corporate managers.

Research hypothesis

Coal is a non-renewable energy source, and it is an essential energy source that supports the economic growth. However, owing to the emergency of new energy, the development of coal mining firms has been negatively influenced. The traditional coal mining industry is generally characterized by the backward production technology, crude processing products, and serious environmental pollution. In order to effectively solve the problems confronted by coal mining firms to realize the transformation and upgrading, the Chinese government has carried out reforms, and strengthened the support for the innovation strategy.

Innovation is considered as an individual or collective learning process that is conducive to the solution of problems (Alegrea & Chiva, 2008; Cohen & Caner, 2016). The implementation of innovation strategy involves the creation of new products, the establishment of new production processes, and modification in management and marketing (Gerwin & Barrowman, 2002; Maldonado-Guzmán et al., 2019).

With regard to innovation, studies show that innovation facilitates the improvement of labour productivity, reduction of safety accidents and increase of sales. Stoker et al.(2005) argue that technological progress is the main factor of labour productivity growth for American coal mining firms. Song & Mu (2013) make the point that security matters are difficult to deal with, and further find that enhancing the level of mining technology is the key to the reduction of security matters. Sun & Anwar (2015) find that coal mining firms that conduct R&D activities are more productive and their sales are higher. Furthermore, they also find that productivity gains arising from R&D activities help improve the competitive position in the international market. Rafiq et al. (2016) suggest that a firm engaging in R&D activities earns 4% to 11% higher sales and generates 4% to 13% more profits than firms that don't engage in R&D activities. In addition, Dzonzi-Undi & Li (2016) argue that coal mining firms should depend on technological progress to achieve the goal of safety and cleaner production. Increasing R&D investment to develop the technical abilities of miners is a key point to improve the mining technology for coal mining firms. Engaging in research and development is an important channel for workers to acquire knowledge based capital (Link & Swann, 2016). Firms with stronger competitiveness are associated with higher investment in intangible assets, and meanwhile the intangible investment is closely related to the performance objectives (Chappell & Jaffe, 2018).

Considering the arguments above, we argue that coal mining firms carrying out innovation activities can accumulate scarce, and valuable resources and capabilities, and then they can create a position of competitive advantage in the market; that is to say, the stronger innovation capability coal mining firm has, the higher profit growth rate the firm creates. Hence, we posit the following hypothesis.

Hypothesis 1: Coal mining firm's innovation capability has a positive effect on profitability.

Hypothesis 1a: Coal mining firm's R&D intensity is positively related to profit growth.

Hypothesis 1b: Coal mining firm's innovation level is positively related to profit growth.

Hypothesis 1c: Coal mining firm's innovation efficiency is positively related to profit growth.

The extensive development of traditional coal mining industry has caused serious environmental pollution. To effectively reduce the environmental pollution, the Chinese government departments constrain the coal mining firms' behaviors through environmental regulation policies. Environmental regulation is a set of tools that aim at achieving the mutual coordination between environmental protection and economic development, including laws, rules, and others issued by government departments. Often, environmental policies are used to regulate the external diseconomy caused by firms' activities. Based on Porter's hypothesis, environmental regulation has a positive impact on the survival and development of firms. Innovation compensation theory and first-mover advantage theory are the foundation of Porter's hypothesis, and innovation compensation theory is the core of Porter's hypothesis. According to the innovation compensation theory, environmental regulation can stimulate enterprises' technological innovation, and innovation benefits can not only make up for the costs of complying with the environmental standards, but also gain excess profits. Specifically, under stricter environmental regulations, regulated firms will increase the investment in technological research and development. The cleaner products produced by applying new technologies can help firms increase their sales. Especially, the increased sales exceed the increased costs caused by environmental standards, thus facilitating the survival and development of firms (Porter, 1991; Porter & van der Linde, 1995). Secondly, based on the first-mover advantage theory, a first mover in compliance with the regulations can take the lead in coming onto the market through choosing to produce environmentally-friendly products. In the process of marketing, the first mover accumulates valuable experience and establishes extensive formal or informal relationships, and thus it is more likely to have an advantageous position in the market (Lieberman & Montgomery, 1988; Bryman, 1997). In addition, the first mover establishes the partnerships with consumers, and caters to consumer preferences, thus forming the brand effect and gaining market share (Kardes and Kalyanaram, 1992). In the light of Porter's hypothesis, scholars confirm that environmental regulation can facilitate the survival and development of firms by using different regions' panel data, including the United States(Jaffe & Palmer, 1997), European countries(Carrion-Flores & Innes, 2010), United Kingdom(Kneller & Manderson, 2012), and Taiwan(Yang et al., 2012). For the traditional coal mining industry, environmental regulation policies will promote cleaner production and consumption; that is, environmental regulation will motivate consumers to purchase low-carbon and green products, which accelerates the development of cleaner technology. In summary, the indirect effect of environmental regulation is conducive to the sustainable development of coal mining firms and the enhancement of their competitive advantages. Consequently, we argue that environmental regulation strengthens the positive effect of coal mining firm's innovation capability on profitability. The above arguments lead to the following hypothesis.

Hypothesis 2: Environmental regulation moderates the effect of coal mining firm's innovation capability on profitability. More specifically, environmental regulation strengthens the positive impact of coal mining firm's innovation capability on profitability.

On the other hand, environmental regulation has a negative effect on the survival and development of coal mining firms in view of neoclassical economic theory. Stricter regulations can reduce the incentive to innovate because the innovation yields need to offset the costs of resource consumption and environmental pollution (e.g., in the case of a pollution tax)(Palmer, 1995; Gray & Shadbegian, 2003; Lanoie et al., 2008; Dean et al., 2009; Carballeira et al., 2016). In other words, considering the investment crowding-out effect, environmental regulation will increase compliance costs (e.g., in the case of emission standard) and squeeze R&D investment, which leads to the reduction of the marginal profit from technological innovation. When the government departments carry out environmental regulation policies, the processes of production, management and marketing are constrained in order to meet the environmental standards, thus hindering

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the expansion of market share, especially for high-pollution and high-consumption mineral energy (e.g., coal) that is more affected by environmental regulations. Hence, the investment crowding-out effect of neoclassical economic theory shows that environmental regulation has a moderating effect on the relationship between coal mining firm's innovation capability and profitability, and even weakens the relationship. The above arguments lead to the following hypothesis.

Hypothesis 3: The positive impact of coal mining firm's innovation capability on profitability is negatively regulated by environmental regulation. That is to say, environmental regulation weakens the relationship between coal mining firm's innovation capability and profitability.

Research design

Variable employed

Innovation capability

Innovation capability is one of the basic organizational capabilities that a firm should possess. Existing studies mainly measure technological innovation from the perspective of R&D investment, which is difficult to comprehensively explain the situation of innovation activities. Considering the long-term, cumulative and dynamic characteristics of technological innovation, the study investigates innovation capability from three perspectives, including R&D intensity, innovation level, and innovation efficiency.

Specifically, the R&D intensity (RD) is defined as the ratio of R&D expenditures to total turnover; innovation level (IL) is calculated by estimating the following equations (1) and (2); and innovation efficiency (IE) is measured as the following equation (3).

$$Patent2_{i,t} = \beta_0 + \beta_1 Patent1_{i,t} + \beta_2 Patent1_{i,t-1} + \beta_3 Patent1_{i,t-2} + \varepsilon \tag{1}$$

$$IL = \beta_1 Patent1_{i,t} + \beta_2 Patent1_{i,t-1} + \beta_3 Patent1_{i,t-2} \tag{2}$$

$$IE = \frac{Patent1_{i,t}}{RDI_{i,t} + RDI_{i,t-1} + RDI_{i,t-2}} \times 10^7 \tag{3}$$

where $Patent1$ is the number of applications for patents; $Patent2$ is the number of licensed patents; and RDI is the total R&D expenditures.

Profit growth

For the evaluation of profit growth, we use the firm's profit growth rate as the proxy variable. The use of profit growth is theoretically consistent with the notion that the motivation of firm is to make a profit. Each firm has one profit growth rate, and thus the profit growth is both concrete and singular. As such, consistent with existing arguments for the measurement of profitability, we focus on the profit growth, and use the profit growth rate to evaluate the profitability.

Environmental policy

It is difficult to find data directly used to measure the intensity of environmental regulation, and thus there are three main proxy variables to measure it, such as the ratio of investment in pollution control to GDP in each province, pollutant discharge, and the cost and expenditure on pollution control. The ratio of investment in pollution control to GDP in each province proposed by Zhou et al.(2019) is adopted in the paper to evaluate the intensity of environmental regulation. This method is used because the greater the ratio of investment in pollution control to GDP in a region, the stricter environmental regulation in this region. Additionally, the emission of sulfur dioxide (SO2) in each province is calculated to substitute for the ratio of investment in pollution control to GDP in each province as the proxy variable of environmental regulation in section of robustness test.

Control variables

Consistent with earlier studies, we conclude that some contextual factors may affect the hypothesized relationships. Thus, we control for firm size, age, leverage, the fixed asset ratio, ownership in our regressions. To control for year fixed effects, year dummy variables are also included in our regressions. The definitions for variables are summarized in Table 1.

Table 1. Definitions of variables

Variables	Definitions
PG	Profitability, profit growth rate
RD	R&D intensity, the ratio of R&D expenditures to total turnover
IL	Innovation level, equation (2)
IE	Innovation efficiency, equation (3)
ER	Environmental regulation, the ratio of investment in pollution control to GDP in each province
Lnsize	Firm size, the natural logarithm of total assets
Age	Firm age, the number of years from the date of establishment to the end of the period in which the sample is selected
Lever	Leverage, the ratio of total debt to total assets
Asset	The fixed asset ratio, the ratio of fixed assets to total assets
Owner	Ownership, a state-owned firm is assigned the value of 1, otherwise, the value of 0
Year	Year dummy, the base year is 2013, and there are 5 year dummy variables

Notes: All financial indicators are manually collated and calculated.

Sample selection

The samples are coal mining firms② listed on the Shanghai and Shenzhen Stock Exchanges in China during 2013-2018, and we select these firms through the following steps: (1) We exclude the samples of ST and *ST coal mining firms (*Special Treatment*, that is, the financial conditions of these firms are abnormal); (2) We remove the samples of missing variable data. To eliminate the influence of outliers, all continuous variables are winsorized at the 1st and 99th percentiles. Finally, we obtain the sample data that consist of 38 coal mining firms.③

The data are collected in following ways. To be specific, we collect the data related to innovation from the patent gazettes issued by State Intellectual Property Office and annual financial reports disclosed by firms. The data related to profitability and control variables are collected from the China Stock Market and Accounting Research (CSMAR) database. Finally, the data related to environmental regulation are collected from China Statistical Yearbook and China Environmental Statistics Yearbook.

Model specification

Based on the previous theoretical analysis, we construct the models (4) and (5) to verify the relationship between innovation capability and profitability, and the impact of environmental policy. The innovation capability, the independent variable, is used as the core explanatory variable. Model (4) is used to confirm the relationship between innovation capability and profitability, and model (5) is to verify the moderating effect of environmental policy on the relationship.

$$PG = \alpha_0 + \alpha_1 RD(IL, IE) + \alpha_2 Lnsize + \alpha_3 Age + \alpha_4 Lever + \alpha_5 Asset + \alpha_6 Owner + \sum Year + \varepsilon \tag{4}$$

$$\begin{aligned} PG = {} & \beta_0 + \beta_1 RD(IL, IE) + \beta_2 ER + \beta_3 RD(IL, IE) \times ER \\ & + \beta_4 Lnsize + \beta_5 Age + \beta_6 Lever + \beta_7 Asset + \beta_8 Owner + \sum Year + \varepsilon \end{aligned} \tag{5}$$

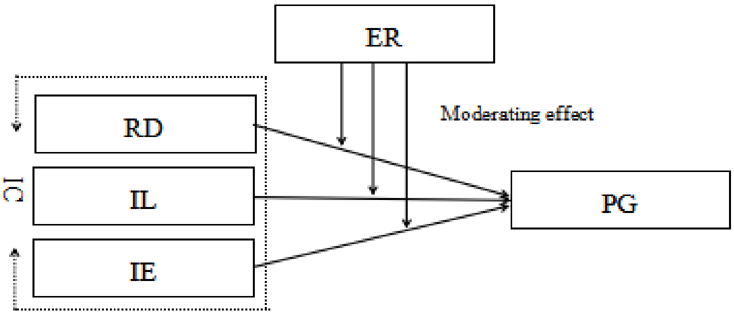

Figure 1. The relationships among innovation capability, profitability and environmental regulation

Empirical research

We report summary statistics for the sample of covering 2736 observations in our study in Table 2. The mean value of profit growth rate (PG) is 0.1041, which is approximately consistent with the existing literature related to profitability. Meanwhile, the minimum value of profit growth rate (PG) is -0.0235, and its maximum value is 0.3701, indicating that the difference between maximum and minimum is 0.3936. The measure of innovation capability, R&D intensity (RD), has a mean value of 0.0309 and a minimum value of 0; the mean value of innovation level (IL) is 47.3063 and its minimum value is 0; the mean value of innovation efficiency (IE) is 0.1156 and its minimum value is 0.0051. In the process of data collection, we find that the firm with the largest number of licensed patents is China Shenhua Energy Company Limited. Moreover, as for the evaluation of environmental regulation, we find that the maximum of the ratio of investment in pollution control to GDP in each province is 0.0426; that is, the intensity of environmental regulation in Shanxi province is the greatest. In addition, we also conduct the descriptive statistics of main control variables in Table 2, such as firm size ($Lnsize$), firm age (Age), leverage ($Lever$), and the fixed asset ratio ($Asset$).

Table 2. Descriptive statistics of the main variables

Variables	Mean	Std. dev.	Median	Maximum	Minimum	Skewness	Kurtosis
PG	0.1041	10.0603	0.0947	0.3701	-0.0235	2.0315	22.0152
RD	0.0309	1.3602	0.0252	0.1703	0	-0.4701	12.0451
IL	47.3063	130.1024	15	968	0	13.8026	37.0145
IE	0.1156	7.0054	0.0949	0.7044	0.0051	1.6921	13.5732
ER	0.0307	5.2083	0.0406	0.0426	0.0026	0.4087	3.0262
$Lnsize$	14.4876	2.0841	13.5073	17.0887	9.9974	-0.1152	4.4019
Age	16.2064	6.2772	16	26	5	1.1728	9.7090
$Lever$	0.5019	0.1597	0.5524	0.9025	0.1703	1.3827	5.0029
$Asset$	0.3049	1.1344	0.3279	0.7093	0.0210	0.0163	3.0267

Notes: Covering 2736 observations.

Table 3. Correlations among main variables

Variables	PG	RD	IL	IE	ER	Lnsize	Age	Lever	Asset	Owner
PG	1									
RD	0.2057***	1								
IL	0.1003*	0.0209	1							
IE	0.0092	0.0350	0.1410**	1						
ER	0.0051	0.0416	0.0622	0.0303	1					
Lnsize	0.0155*	0.3715***	0.2031**	0.0672	0.3317***	1				
Age	-0.0617***	-0.3601***	-0.4211***	-0.1037**	0.0241**	-0.2507***	1			
Lever	-0.3019***	-0.2273***	-0.2904***	0.1610**	0.1083*	0.3003***	-0.1417**	1		
Asset	0.1015	0.2807**	0.0506	0.1007**	-0.0971	0.0721	0.0056*	0.0412**	1	
Owner	0.0166*	0.1034*	0.0847	0.0085	-0.1064**	0.2685***	0.0192*	-0.1560*	0.0473*	1

Notes：*, **, and *** respectively indicate at the 10%, 5%, and 1% significance levels.

Table 3 presents the correlation between main variables for the sample of 2736 observations during the period 2013-2018. As we can see, results of correlation matrix show that there is a significant positive association between innovation capability (i.e., RD and IL) and profitability (PG), thus providing the evidence that innovation activities help improve profitability. On the other hand, environmental regulation is unrelated to innovation capability and profitability, showing that we use the proxy variable of environmental regulation as the moderating variable, which is effective and reasonable. The highest significant correlation is noted between innovation level (*IL*) and firm age (*Age*); that is, the correlation coefficient is -0.4211. As we expected, the correlation coefficients among variables are not high enough so that the problem of multicollinearity should not be a concern in our study.④

Table 4. OLS regressions of profitability on innovation capability

Variables	Dependent variable: *PG*			
	(1)	(2)	(3)	(4)
RD		0.1082** (2.32)		
IL			0.1102*** (4.05)	
IE				0.0105 (0.57)
Lnsize	0.0262* (1.93)	0.0194 (0.95)	0.0139* (2.02)	0.1083* (2.15)
Age	-0.1073** (-2.25)	-0.0917** (-2.47)	-0.1046* (-1.97)	-0.0802 (-1.59)
Lever	-0.1907*** (-3.44)	-0.1014* (-2.18)	-0.1521*** (-4.83)	-0.1051*** (-3.40)
Asset	0.0812 (1.46)	0.0105 (0.92)	0.1034 (0.91)	0.1029** (2.42)
Owner	0.0724* (1.97)	0.1061** (2.33)	0.0372** (2.44)	0.1404*** (2.74)
Constant	0.1401*** (4.02)	0.1526** (2.27)	0.1021** (2.32)	0.1046* (1.91)
Year	YES	YES	YES	YES
Observations	2736	2736	2736	2736
R^2	0.5728	0.6301	0.5788	0.4902
Adj_R^2	0.5005	0.5044	0.5041	0.4203
F -Statistic	14.62	14.96	14.84	13.84

Notes: *, **, and *** respectively indicate at the 10%, 5%, and 1% significance levels, and t-statistics are reported in parentheses.

Table 4 presents panel OLS regressions of Model (4) where profitability is the dependent variable. Column (1) of Table 4 is our baseline regression where we only add the control variables to the regression analysis. In columns (2), (3), and (4), we introduce innovation capability (i.e., *RD*, *IL*, *IE*) into the regression analyses. We find that the coefficient of *RD* is positive, and it is significant (0.1082, t_stat=2.32) in column (2), thus showing that R&D intensity has a direct effect on enterprise profitability. In column (3), the results indicate that there is a positive and statistically significant relationship between innovation level and enterprise profitability (0.1102, t_stat=4.05), thus showing that the more licensed patents firm obtains, the stronger enterprise profitability firm will have. In other words, the innovation level is positively associated with firm's profits. In addition, we also find that innovation efficiency has no direct effect on enterprise profitability (0.0105, t_stat=0.57) in column (4), thus indicating that innovation efficiency is not the driving force for the improvement of enterprise profitability.

In order that the relationship between innovation capability and enterprise profitability is further analyzed, we explain the innovation capability from three perspectives of R&D intensity, innovation level, and innovation efficiency. In summary, the findings in columns (2) and (3) provide support for our hypothesis 1a and hypothesis 1b predicting that coal mining firms' R&D intensity and innovation level have a positive effect on profit growth.

To accurately test the moderating effect of environmental regulation, the independent variable (i.e., RD and IL) and moderating variable (i.e., ER) are centered around the group mean respectively.

Table 5. The impact of environmental regulation

Variables	Dependent variable : PG			
	(1)	(2)	(3)	(4)
RD	0.0158*** (4.02)	0.0205*** (4.31)		
IL			0.0135** (2.55)	0.1003*** (3.23)
ER	0.0017 (0.39)	0.0237 (1.09)	0.0375 (1.03)	0.0301 (1.25)
$RD \times ER$		0.0398** (2.33)		
$IL \times ER$				0.0049 (0.24)
$Lnsize$	0.0103** (2.37)	0.0016 (1.52)	0.0092 (1.04)	0.0047* (2.04)
Age	-0.1017*** (-3.32)	-0.1224** (-2.52)	-0.1205** (-2.37)	-0.1007** (-2.26)
$Lever$	-0.1021*** (-3.40)	-0.1301*** (-3.49)	-0.0903*** (-3.24)	-0.1061*** (-3.30)
$Asset$	0.0004 (0.72)	0.0103 (1.43)	0.0092 (1.22)	0.0107 (1.22)
$Owner$	0.0301** (2.38)	-0.0283** (-2.37)	-0.1025* (-2.02)	-0.1092** (-2.42)
Constant	0.1207** (2.52)	0.1069** (2.58)	0.0402** (2.26)	0.1011** (2.23)
Year	YES	YES	YES	YES
Observations	2736	2736	2736	2736
R^2	0.5205	0.7036	0.7071	0.6096
Adj_R^2	0.4752	0.6580	0.6709	0.5739
F -Statistic	15.57	15.72	14.27	13.73

Notes：*, **, and *** respectively indicate at the 10%, 5%, and 1% significance levels, and t-statistics are reported in parentheses.

Table 5 reports the results of hierarchical multiple regression of model (5). We use R&D intensity and innovation level to capture innovation capability, and findings show that innovation capability (i.e., RD and IL) has a positive impact on the enterprise profitability, whereas the coefficients of environmental regulation (ER) are not statistically significant.

To test the moderating effect of environmental regulation on the relationship between innovation capability and enterprise profitability, we add an interaction term between RD and ER in column (2), and another interaction term between IL and ER in column (4). The coefficient of interaction term ($RD \times ER$) is positive and statistically significant at the 5% level (0.0398, t_stat=2.33), and meanwhile coefficient of interaction term ($IL \times ER$) is not significantly positive at the 10% level (0.0049, t_stat=0.24).

Compared to the existing results, these findings provide empirical evidence for the moderating effect of environmental regulation suggesting that environmental regulation moderates the effect of coal mining firms' R&D intensity on enterprise profitability; that is, environmental regulation strengthens the positive effect of coal mining firms' R&D intensity on profit growth.

In addition, we find that environmental regulation policies moderate the impact of R&D intensity on profit growth, but environmental regulation policies have no direct effect on the relationship between innovation level and profit growth, implying that affected by environmental regulation policies, coal mining firms will pay more attention to the improvement of profit growth through the increase of investment in R&D, whereas the increase of investment in R&D may not have a significant impact on the level of innovation.

Robustness tests and Endogenous analysis

In this section, we perform additional tests to check the robustness of our study results.

Firstly, we substitute the ratio of R&D personnel to total personnel for the ratio of R&D expenditures to total turnover to examine whether there is a change in the intensity of R&D. Then we test the relationship between R&D intensity and profit growth, and the moderating effect of environmental regulation. The results show that the intensity of R&D does not significantly change and the regression results are roughly consistent with the above conclusions. Specifically, there is a positive and significant relationship between the intensity of R&D and profit growth (0.1076, t_stat=2.23).

In addition to the relationship between R&D intensity and profit growth, the results show that the coefficient of interaction term between R&D intensity and environmental regulation is positive and statistically significant (0.0752, t_stat=2.88), implying that the moderating effect of environmental regulation is positive; that is, environmental regulation policies can strengthen the relationship between R&D intensity and enterprise profitability.

Secondly, we use the emission of sulfur dioxide (SO2) in each province to measure the intensity of environmental regulation, and then examine the moderating effect of environmental regulation (0.0150, t_stat=2.07). The regression results are also the same as before; that is, the moderating effect of environmental regulation remains unchanged. Thus, our conclusions are robust and convincing.

Table 6. Robustness tests

	Variables	Dependent variable： PG		
		Coe.	T_stat	Sig.
(1)	RD	0.1076	2.23	**
	$RD \times ER$	0.0752	2.88	***
(2)	$RD \times ER$	0.0150	2.07	*

Notes：*, **, and *** respectively indicate at the 10%, 5%, and 1% significance levels; Firm size, age, leverage, the fixed asset ratio, ownership, and year dummy are included in all regressions, but the detailed analysis is not reported for brevity.

There may be endogenous problems caused by missing variables and two-way causality in our empirical research. To deal with the endogenous problems, we use instrumental variables, and meanwhile we add one-period lagged profit growth to control variables in order to reduce the missing variables. To be specific, we use one-period lagged and two-period lagged R&D intensity as instrumental variables. Due to the absence of technological innovation’ s time lag, the number of observations decreases to 2232.

The results show that the value of F_statistic is 15.03, and the value of Wald Chi2 is 40.5240 (P<0.01), thus implying that it is necessary to use instrumental variables. Column (2) of Table 7 reports the results of the moderating effect of environmental regulation, and the coefficient of interaction term between R&D intensity from the first-stage OLS regression ($F\_RD_{i,t}$) and environmental regulation is significant, indicating that Porter’s hypothesis is confirmed by using sample of coal mining industry; that is, environmental regulation can stimulate coal mining firms’ R&D investment activities, which may just be based on the innovation compensation theory and the first-mover advantage theory.

Table 7. The regressions of instrumental variables

Variables	Dependent variables: $RD_{i,t}$	Dependent variables: $PG_{i,t}$
	（1）	（2）
$RD_{i,t-1}$	0.0137^{**} （2.32）	
$RD_{i,t-2}$	0.0171^{***} （2.72）	
$F\_RD_{i,t} \times ER_{i,t}$		0.1071^{*} （2.04）
Constant	0.0755^{***} （3.64）	-0.1088^{***} （-4.07）
Observations	2232	2232
R^2	0.6009	0.5402

Adj_R^2	0.5310	0.5117
F -Statistic	15.05	16.12

Notes：*, **, and *** respectively indicate at the 10%, 5%, and 1% significance levels, and t-statistics are reported in parentheses；Firm size, age, leverage, the fixed asset ratio, ownership, one-period lagged profit growth, and year dummy are included in all regressions, but the detailed analysis is not reported for brevity.

Conclusions

Traditional coal mining industry is confronted with many challenges brought about by the adjustment of energy structure. The development of coal mining firms is constrained by complex factors, such as the backward production technology, inefficient use of resources, and serious environmental pollution. In a competitive business environment, profitability of coal mining firms is negatively affected. As we expected, innovation strategy has been recognized as the most essential strategy for firms to maintain profit margins. Thus, whether the innovation capability of coal mining firms can help improve enterprise profitability has become a key issue that is necessary to carry out research. The coal mining industry is one of the high polluting industries in China. The production and consumption of coal bring about increasingly serious negative effects, including air pollution, waste water pollution, solid waste pollution, noise pollution, and so on. Environmental pollution control is an essential task for the central government. Environmental regulations are a set of tools that government departments regulate the impact of economic activities. It is no doubt that environmental regulation has an important impact on firms’ behaviors.

Based on the theoretical analysis, we use coal mining firms listed on the Shanghai and Shenzhen Stock Exchanges in China from 2013 to 2018 as empirical sample. The study empirically examines the relationship between innovation capability and enterprise profitability, and further investigates the impact of environmental regulation on the relationship. We find that the innovation capability of coal mining firms can effectively promote the improvement of profit growth, especially for the coal mining firms with stronger R&D intensity and higher innovation level. After considering the constraints of environmental regulation policies on coal mining firms, we also find that the greater the intensity of environmental regulation, the stronger the positive relationship between R&D intensity and profit growth, thus indicating that regulated coal mining firms put more emphasis on improving profit growth by increasing investment in R&D activities. The conclusion is the effective evidence of applying the Porter’s hypothesis to the high polluting coal mining firms in China.

Recomendations

For the sake of the improvement of enterprise profitability, we put forward the following suggestions. First, the government departments take measures of merger, reorganization, and even closure to regulate the structure of coal mining industry. Especially, government departments should guide coal mining firms through incentive mechanism, help entrepreneurs recognize the importance of R&D, arouse the enthusiasm and creativity of researchers, and strengthen the practicality of innovation. It is necessary to help coal mining firms establish the feasible transformation mechanism of R&D achievements, and to promote the smooth development of innovation.

Second, it is a basic task for the government departments to provide policy-based financial support for coal mining firms' technological innovation activities. For example, the government departments give incentives and preferential treatment to coal mining firms that carry out the energy saving and emission reduction projects. These incentives and preferential treatment include tax incentives, financial subsidies, etc.

Third, it is essential to establish the sound laws and regulations system of environmental protection, and promote the development of circular economy. More importantly, coal mining firms should improve the utilization of resources to reduce the waste of resources. Firms should correctly understand and practically comply with the environmental regulation policies to realize the win-win situation between environmental protection and enterprise profitability.

Coal, as the basic energy, plays an important role in China's economic growth, but the theoretical research related to coal is quite inadequate. Traditional coal mining industry is confronted with serious problems, such as backward production technology, insufficient deep-processing of products, and serious environment pollution, which has a negative effect on enterprise competitiveness. Our study provides new insights for management practice of coal mining firms and lays a theoretical foundation for the research on enterprise profitability and innovation strategy. This study bridges the profit growth and innovation capability by using the empirical method, but it also has some limitations. For instance, the additional research is necessary to explore some areas such as the firm performance and R&D investment. In particular, our sample data are only from coal mining firms in China. Thus, whether the relationship between variables still be confirmed in other industries in China is also worth exploring. Furthermore, the comparison of relationship between them across countries may have new findings. This certainly places another limitation for this study.

Notes

①R&D is the abbreviation of the Research and Development.

②Judging by the Guidelines for the Industry Classification of listed companies (2014 revision) issued by the China Securities Regulatory Commission, we identify the firms in coal mining industry.

③The stock codes of firms used in our study include 000552, 000723, 000780, 000937, 000968, 000983, 002128, 600121, 600123, 600157, 600188, 600348, 600395, 600397, 600403, 600408, 600508, 600546, 600725, 600740, 600758, 600792, 600971, 600985, 600989, 600997, 601001, 601011, 601015, 601088, 601101, 601225, 601666, 601699, 601898, 601918, 603113, and 900948.

④Following prior studies, an approximate guide of correlation is as follows. 0.20: slight correlation; 0.20-0.40: low correlation; 0.40-0.70: moderate correlation; 0.70-0.90: marked correlation; and the coefficient that is greater than 0.90 is regard as very high correlation. Based on the criteria mentioned above, the correlation coefficients among variables in Table 3 are not high enough to cause the problem of multicollinearity.

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