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The moderating role of firm age in the relationship between R&D expenditure and financial performance: Evidence from Chinese and US mining firms☆

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ABSTRACT

We examine the impact of Research and Development (R&D) on the profitability and sales of mining firms in China and the United States (US) and the moderating effect of firm age using Coarsened Exact Matching (CEM). For the combined panel of 168 major US and Chinese mining firms, we find that, on average, a firm engaging in R&D activities earns 4% to 11% higher sales and generates 4% to 13% more profits than firms that do not engage in R&D activities. We also show that, in the mining industry, firm age moderates the relationship between R&D activities and financial performance. A comparatively mature R&D active firm earns 4.4% more profit and generates 7.2% more sales than a younger non-innovative firm. The turning point at which R&D activities switch from making a negative, to positive, contribution to profit and sales is 37 years and 22 years, respectively. Our results are consistent with the liability of newness, meaning that firm investment in R&D takes time to have a real impact on bottom line measures of financial performance. We conclude with a discussion of the practical implications of our results for Chinese and US mining firms.

1. Introduction

Considerable attention has been devoted to analyzing the impact of Research and Development (R&D) activities on firm performance. There are at least two major strands of literature. One examines the effect of investment in R&D on firm productivity and sales (Cohen and Levinthal, 1989; Coe and Helpman, 1995; O'Mahony and Vecchi, 2009; Yang and Chen, 2012). The other examines the relationship between R&D and future firm profitability (Grabowski and Mueller, 1988; Hirschey, 1982; Roberts and Hauptman, 1987; Branch, 1974; Schoeffler, 1977). The results from both sets of studies are inconclusive. As Fortune and Shelton (2014, p. 35) put it: "The effect of R&D investment on firm profitability is the most tenuous; while the effect of R&D investment on sales growth and market performance demonstrates the most consistency".

We examine the relationship between investment in R&D and firm performance for Chinese and US mining firms and consider the moderating role of the firm's age on this relationship. We also identify the age of a firm at which investment in R&D begins to have a positive effect on firm performance. A study of the mining sector is timely because the mining super cycle has created unprecedented opportunities for mining companies to invest in R&D. A number of commentators have called on mining companies to take advantage of this opportunity and invest more in R&D to build competitive advantage and create opportunities for further profit growth. For example, Bryant (2011, p. 1) writes:

"…those wanting to capture the full value of [the mining super cycle] will need to realize important transformations in their business systems: rapid and accurate characterization of ore bodies, faster development of mines and speed of extraction, improved recovery rates and mine planning as well as increased use of automation and remote operations. So, despite mining companies producing record profits, there remains substantial value from current operations that is not being captured".

There is, however, surprisingly little empirical evidence on the effect of R&D investment on financial performance in the mining sector.[1] We focus on investment in R&D in mining companies in the US and China because, in a sense, these countries represent the old and the new.

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[1] An exception is Sun and Anwar (2015) who studied the relationship between R&D activities and performance of Chinese coal companies. These authors found that investment in R&D had a significant positive impact on firm productivity and sales, but did not find any linkage between R&D and profitability.

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Since the beginning of market reforms in China in the late 1970s, its economic growth has traditionally been on the back of labor-intensive manufacturing. Now, companies are substituting higher value-added goods for labor-intensive goods as China seeks to move up the value-added ladder. For example, between 2005 and 2014, Chinese companies increased their spending on R&D by a factor of 15 and the number of Chinese companies listed on the PwC Strategy& Global Innovation 1000 increased from eight to 115 over the same period (Casey, 2014). The growth in investment in R&D in the mining sector in recent times in China reflects this broader trend. While US was the market leader in investment in R&D in the mining industry throughout the second half of the last century, China has started to sharply increase investment in R&D since the beginning of this century and aspires to overtake the US in this sector over the next few years (Boeing et al., 2016).

We contribute to the literature in the following ways. First, given that existing studies on the relationship between R&D and firm performance are inconclusive, further research on this topic is needed, particularly for sectors in which investment in R&D is important, but there is little existing evidence. This is one of the very few studies examining the impact of R&D on a firm's financial performance in the mining industry and the first study to examine the R&D-firm performance nexus between Chinese and US mining firms. Second, there is little evidence on the mechanism through which R&D affects firm performance or how the relationship between R&D and firm performance changes over time. This is the first study to examine the moderating role of age in the relationship between R&D and profits while allowing for the fact that R&D is likely endogenous. Third, this is the first study to identify the age of the firm at which investment in R&D begins to have a positive impact on financial performance.[2] To account for the potential endogeneity of R&D we examine the R&D-firm performance nexus in Chinese and US mining firms employing Coarsened Exact Matching (CEM) (see eg. Iacus et al., 2011). Conditioning on observed variables that induce endogeneity between R&D and firm performance helps to minimize the risk of endogeneity.[3]

2. R&D activities in the US and Chinese mining industry

The US and China are competing with each other in investment in R&D across a number of sectors. While the US has long been the market leader in R&D investment, China's State Council released a major policy document in 2006 to guide the country's science and technology development in the coming decades. The development goal is to make China an innovation-oriented society by the year 2020 and a world-leading innovator in the longer term (State Council, 2006). Whereas US R&D expenditure has been steady over the last two decades, Chinese R&D share in GDP has been increasing since the turn of the century. According to OECD Main Economic Indicator data for 2013, China has the second largest R&D expenditure after the US. China also had the largest R&D research team with a total of about 2.9 million full time equivalent researchers in 2011, which was double the figure for the US (Boeing et al., 2016). In terms of R&D intensity, China invested 1.98% of GDP in R&D in 2012, which still lagged behind the US, but, for the first time, was larger than the European Union, as a whole, which invested 1.96% (Van Noorden, 2014). In March 2015, China announced that its R&D intensity had exceeded 2% (Pennay, 2015).

China derives most of its energy from coal and petroleum resources, although natural gas, nuclear power and renewable sources (particularly hydropower) account for non-trivial, and growing, percentages of the energy mix. Most of China's mining companies are in coal mining. Coal currently supplies approximately 65% of China's energy needs, and while its overall contribution to China's energy mix is projected to fall, coal demand will still increase significantly in absolute terms (US Department of Energy, 2005, p. 8).

China's national energy strategy currently focuses primarily on increasing efficiency, reducing reliance on foreign oil and reducing pollution emissions. With these objectives as the backdrop, the China National Coal Association advises the National Development and Reform Commission (NDRC) on adoption of clean coal technologies. In this regard, since the 1990s, billions of dollars in foreign technology purchases have helped China to seed indigenous R&D programs (Steinfeld, 1998). Most commentators are of the view that domestic technology lags behind the international frontier by at least 10–15 years with respect to mining efficiency, safety and environmental protection standards (Nolan, 2001). Some of the large Chinese mining companies, such as the Shenhua Group and the Yankuang Coal Mining Group, have been very active in purchasing foreign technology and adapting it to local conditions. Coal preparation technologies, such as washing, that reduce sulfur content in emissions, are also widely applied in China. The technology is often manufactured domestically, and although perceived to be inferior to imported technologies, homegrown versions can often be 8–10 times cheaper and are, therefore, often preferred (Nolan, 2001). Plant design decisions are usually made by design research institutes in collaboration with local partners, such as universities or other research institutes, and these connections often facilitate the adoption of locally developed R&D in line with government standards (UK Department of Trade and Industry, 2002, p. 3). The importance of R&D in Coal mining is reflected in it being ranked among the top 10 industrial sectors in terms of expenditure on R&D in China (National Bureau of Statistics and Ministry of Science and Technology, 2011).

Investment in R&D activities in the energy sector in the US increased following the OPEC oil crisis in 1973. The oil crisis sparked a fundamental reassessment of the nation's vulnerability to imported energy and also forced a reassessment of the role that energy R&D could play in helping secure the US against such uncertainty. Accordingly, federal investment in energy R&D more than doubled in real terms between 1973 and 1976 and nearly doubled again between 1976 and 1980 (Dooley, 2008). Federal investment in energy R&D rose from $2.45 billion in 1974 to $1.41 billion in 1979 (in constant, inflation adjusted 2005 US$).

Over the next two decades, investment in energy R&D in the US fell. From 1981 to 1998, federal energy R&D expenditure fell by >50% in real terms. Federal support for energy R&D fell from $6.64 billion in 1981 to $3.15 billion in 1988 (Fehner and Hall, 1994). The US extensively invested in clean coal technology during 1989–1995. Yergin (1995) estimates that between 1988 and 1995, the US Department of Energy spent slightly more than $3 billion (in 2005 US$) on developing clean coal technology. While new programs have commenced since the mid-1990s, they have explicitly focused on developing technologies needed to address climate change (Dooley, 2008). Overall, since 2000, R&D investment in the energy industry in the US has been primarily devoted to inventing environmentally friendly mining technologies, such as clean coal.

3. Hypotheses development

We posit that investment in R&D and other observable variables, such as firm age, size and financial strength are related to measures of firm performance, denoted by profit and sales. We include firm age as a moderator of R&D's impact on knowledge creation.

R&D activities in a firm can be expected to improve productivity and sales by either introducing new goods or services, improving the quality of existing products or initiating new and improved production processes (Griliches, 1979). Hall et al. (2010) point out that previous studies using firm level data linking business R&D with productivity usually find output elasticity of own R&D to be between 1% and 25%, with a

[2] Fortune and Shelton (2014) and Wohrl et al. (2009) examine the moderating role of firm age on the relationship between R&D and firm performance in samples of chemical firms and technology-based growth firms respectively. However, neither study addresses the endogeneity of investment in R&D. Moreover, neither study identifies the age at which investment in R&D generates positive financial returns.

[3] Sun and Anwar (2015) also use CEM to minimize the risk of endogeneity in their study of the R&D-firm performance relationship in Chinese coal mining firms. We differ from them in that they only focus on Chinese coal mining firms and do not examine the moderating role of firm age.