R&D Expenditure and Firm Performance: Empirical Evidence from Australian Mining Firms

A thesis submitted in fulfilment of the requirements of the degree of Master of Business (by research)

by

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Abstract

In the context of the Australian economy, the mining industry has played a significant role, with an increasing percentage of export share over the years, with 60 per cent of the national export hare in 2019 as its peak. However, the mining industry faces a challenge in determining mineral prices that heavily rely on the condition of the global economy, particularly the change in global demand for and supply of minerals. This situation makes it imperative for mining firms to maintain their sustainability and competitive advantage. Previous studies suggest that conducting and spending on research and development (R&D) is essential to reducing operational costs while increasing productivity, which indirectly influences firm performance. In fact, on the contrary, spending on R&D among firms in the mining industry is very low and in steady decline. To identify the influence of R&D activities and the quantum spend on firm performance, this study focuses on Australian Securities Exchange (ASX) listed mining firms

The data for this study come from mining firms listed on the ASX in the period 2006-2017. Firm performance is measured using profitability, revenue growth and Tobin's q. Leverage, firm size, previous year profit, prior year revenue growth, and year dummies are used as control variables since they influence a firm's decision to conduct R&D activities. System Generalised Method of Moments (GMM) is used to analyse the influence of spending on R&D activities on profitability and revenue growth to obtain estimators that exploit all linear moment restrictions, the presence of endogeneity bias, the heteroskedasticity in the data and the use of a dynamic regression model. Linear regression is used to analyse the influence of R&D on Tobin's q in the absence of endogeneity. The findings show that spending on R&D activities in mining firms has a significant relationship with firm profitability and revenue growth, confirming similar studies by Rafiq, Salim and Smyth (2016) and Sun & Anwar (2015). A similar finding for the relationship between spending on R&D activities and Tobin's q after controlling profitability is also reported.

Overall, the results confirm the importance of focusing on R&D activities among mining firms which contributes to the body of knowledge and addresses the paucity of research on the influence of R&D expenditure on firm performance of the Australian mining industry. For policymakers and the industry, this study provides empirical evidence to design more effective policies and adopt broad-ranging stimulus programs and adjust various taxes and spending

programs simultaneously. Finally, this study recommends that the Australian Government, especially the Department of Industry, Science, Energy, and Resources, maintain a strong relationship with the mining industry as one of the top economic growth contributors. This strong relationship is essential to provide support for the mining equipment, technology and service (METS) sector to sustain the mining industry in Australia.

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Declarations

I hereby certify that,

This thesis does not contain any material that has been accepted for the award to the candidate of any other degree or diploma, except where due reference is made in the text of the examinable outcome

To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the examinable outcome.

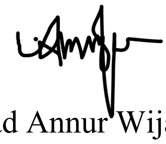

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

2SLS	Two-Stage Least Squares
AASB	Australian Accounting Standard Board
ABS	Australian Bureau of Statistics
ASX	Australian Stock Exchange
BP	Breusch Pagan
CEM	Coarsened Exact Matching
CFI	Certified Financial Institute
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DWH	Durban-Wu-Hausman
EBITDA	Earnings Before Income Tax, Depreciation and Amortisation
EDR	Economic Demonstrated Resources
GDP	Gross Domestic Product
GMM	General Method of Moments
METS	Mining Equipment, Technology and Services
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
R&D	Research and Development
RBA	Reserve Bank of Australia
RBV	Resource-Based View
VIF	Variance Inflation Factors

List of Variables and Measures

Variables	Description	Measures
ROA	Profitability	Ratio of EBITDA to total assets
Growth	Revenue growth	Difference logarithm of current and previous revenue
Q	Tobin's q	Measured using simple Tobin's q (Q) as suggested by Chung and Pruitt (1994). $approximate\ q = (MVE + PS + Debt)/TA$, Where MVE is the number of common shares outstanding times the market price, while PS represents the liquidated value of the preferred stock, $Debt$ is the book value of total liabilities, and TA represents the book value of total assets.
RDI	R&D intensity	Ratio of R&D expenditure to revenue
Lev	Leverage	Ratio of total assets to total liabilities
Size	Firm's size	Logarithm of total assets
Year	Year	Dummy variable

Chapter 1 - Introduction

This study investigates the influence of spending on R&D activities on firm performance in the Australian mining industry. Previous studies on the mining industry argue the merit of spending on research and development (R&D) to build a competitive advantage and create opportunities for future profit growth (Apergis & Sorros, 2014; Rafiq, Salim & Smyth, 2016). However, the mining industry often acts as a price taker rather than a price maker (Bryant, 2011) since the price of minerals is driven by the global price and is dictated by the status of the global economy, demand, and supply (Filippou & King, 2011). Therefore, companies in the mining industry need to focus on cost efficiency, in which a cost leadership strategy can become an effective approach (Filippou & King, 2011). Companies also need to pay attention to the transformation of their business systems, for example, speed extraction, rapid and accurate characterization of ore bodies, and improved recovery rates (Bryant, 2011). In its implementation, this strategy suggests that R&D activities are needed to make the extraction process more efficient (Filippou & King, 2011).

Despite the need for R&D activities in the mining industry to make the extraction process more efficient, R&D activities have a high degree of uncertainty about whether they will succeed and return a profit (Alam, Uddin & Yazdifar, 2019). They also tend to be long-term in nature (Alessandri, & Pattit, 2014; Alarcón, & Sánchez, 2013). Consequently, R&D requires a large amount of capital to support it over time (Lai, Lin & Lin, 2015), affecting firms' short-term earnings. This short-term effect creates tension between managers, who tend to be risk-averse and favour short-term earnings (Hall, 2002), and shareholders, who favour long-term growth (Cao & Laksmana, 2010). This tension makes investigating the relationship between spending on R&D activities and firm performance interesting.

In this study, firm performance is measured using two different perspectives: first, accounting-based internal measures, profitability and revenue growth (Venkatraman & Ramanujam, 1986) and second, a shareholder valuation perspective, Tobin's q, an external market-based measure that combines internal financial data and the expectations or assumptions used by shareholders to predict firms' future performance (Al-Matari, Al-Swidi & Hanim, 2014).

This chapter first provides the necessary background to the Australian mining industry from its peak in 2003 to the recession in 2016. The next section (section 1.2) explains the problem statement of this study. This section also explains the need for innovation and R&D activities in the mining industry. The problem statement is explained in section 1.2, followed by a list of research aims and objectives of this study are explained in section 1.3. A brief outline of the research method is provided in section 1.4. A range of definitions of R&D used in this study is explained in section 1.5 to clarify the key terms of innovation and R&D used interchangeably throughout. Section 1.6 identifies the contribution and implication of this research. Finally, this chapter ends by outlining the structure of the thesis.

1.1 Background

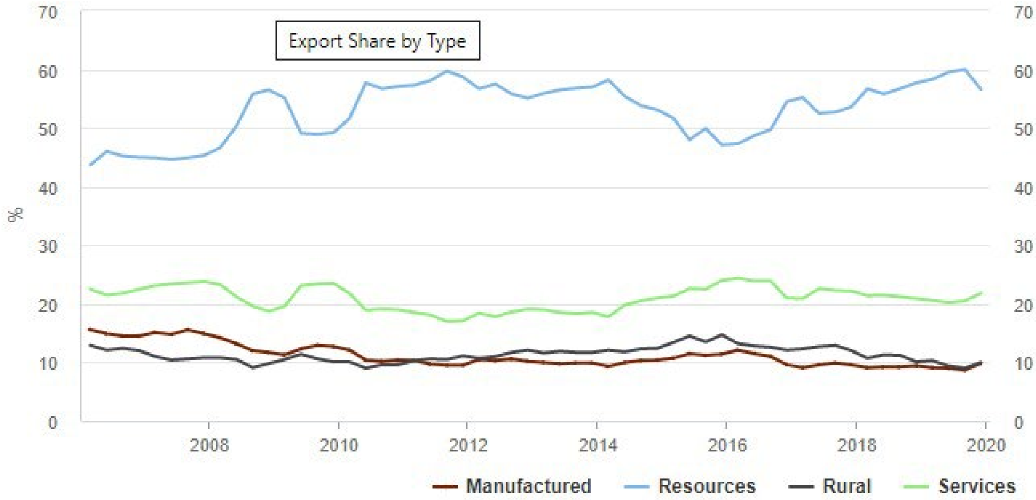
Australia is a global leader in the mining industry with large resources of natural endowment. In 2016, Australia topped the world Economic Demonstrated Resources (EDR) for gold, iron ore, lead, nickel, rutile, tantalum, uranium, zinc and zircon, while globally at a top-five producer of other mining commodities including antimony, bauxite, black coal, brown coal, cobalt, copper, diamond, ilmenite, lithium, magnesite, manganese ore, niobium, silver, thorium, tin, tungsten and vanadium (Geoscience, 2017). Instead of having a large natural endowment, 56 per cent or worth 78.4 billion US dollars of global iron ore export came from Australia in 2020[1] (Garside, 2021). This export contribution is beyond Brazil as the second-largest global iron ore export, which contributes 18.4 per cent, while China contributes 1.2 per cent of global export iron ore.

This mining industry has become the central pillar of Australia's economic growth. This can be seen from the export contribution to Australia since export is the engine for economic growth (Poon, 1994). Instead of being the largest global mining export, this industry contributed to Australia's export share by between 42 per cent to 60 per cent between 2000 and 2019. This contribution keeps increasing to the highest contribution being 60 per cent or worth 227.2 billion Australian dollars in 2019 (Australian Bureau of Statistics, 2020; Reserve Bank of Australia, 2019). In comparison, other industries during the same period (2000-2019), for example, the services industry, including education and tourism, contributed 20-25 per cent of the export share, the second largest. Moreover, the significant economic contribution from the mining industry was more than other industries such as manufacturing and rural commodities that remained steady in the 2000s and contributed between 15-17 per cent.

[1] The global iron ore export is collected by Statista website that published on the website: https://www.statista.com/statistics/300328/top-exporting-countries-of-iron-ore/

Figure 1 depicts a comparison of export share between the mining industry and other sectors from 2006 to 2020. It shows that the mining industry plays a significant role in the Australian economy, supporting the claim that Australia's economic growth and development depend on the mining industry (Deloitte, 2017).

Figure 1 Export share by sector between 2006 - 2020



The comparison of Australian export share percentage based on value contribution by sector.
Source: Australian Bureau of Statistics (ABS, 2006 -2020) based on catalogue 5368.0

Apart from the significance of the mining industry in the Australian economy, the industry's major and constant challenge is the continuous and unpredictable change in the world's economic conditions that also change the life cycle of the mining industry. The change in the mining life cycle started in 2003 with high demand for minerals from countries like China and India (Filippou & King, 2011). However, this demand was not responded to with sufficient minerals supply (Filippou & King, 2011). This lack of supply caused an abrupt surge in mineral prices to a level never reached before (Humphreys, 2010). The price of iron ore, for instance, increased nearly fivefold in 2008 and rose to around US$156 per metric ton, much higher than its 2003 price of around US$32 per metric ton. This boom in demand for and the price of minerals ended abruptly in 2008 with the global financial crisis (Filippou & King, 2011).

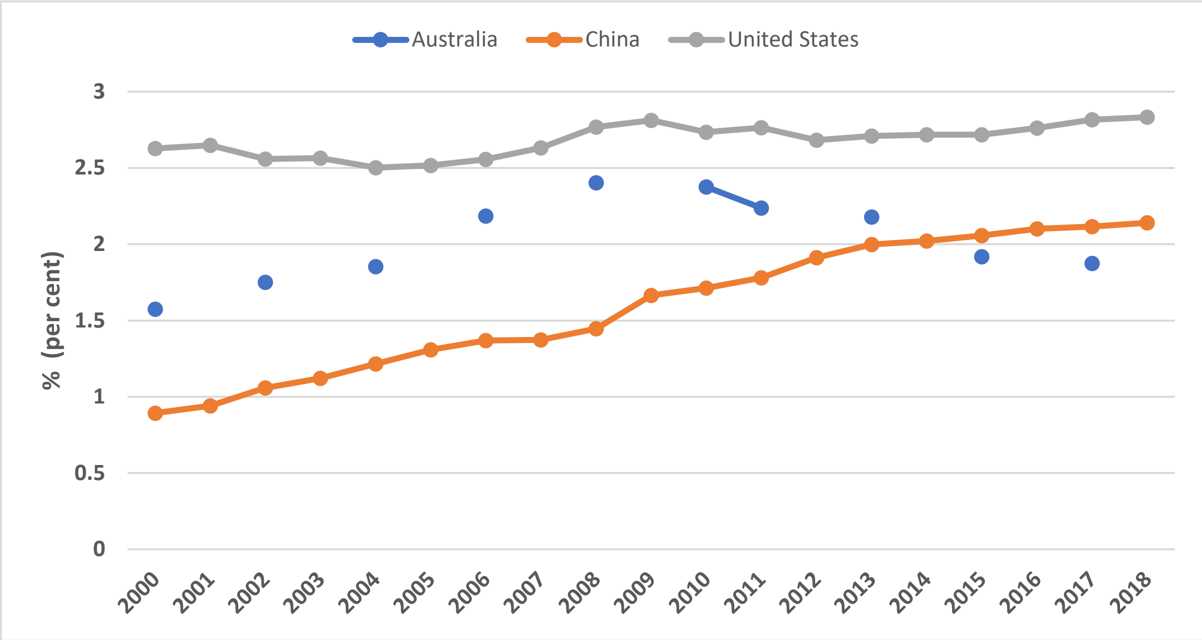
However, the boom in demand and inadequate supply of minerals (Deloitte, 2017) attracted more capital investment to increase production capacity. As a result, growth in the value of extracted minerals grew from 7.6 - 9.1 per cent from 2013 to 2015 (Productivity

Commission, 2014; 2016). Unfortunately, the increase in the volume of mineral extraction coincided with a drop in mineral prices due to a reduction in global demand and an oversupply of minerals from the production phase (Fan, Yan & Sha, 2017). The mining boom eventually came to an end in 2013.

A number of studies anticipated the dropping mineral price and encouraged mining firms to invest more in R&D (Bryant, 2011; Filippou & King, 2011; Rafiq, Salim & Smyth, 2016) because mining firms were known to have high operating expenses but low productivity (Bryant, 2011). R&D enables the mining industry to process minerals more efficiently (Deloitte, 2017; Fan, Yan & Sha, 2017), reduces operational costs and improves productivity, enabling greater profitability, positive cash flow and creating opportunities for future profit growth (Deloitte, 2017).

Being aware of the importance of R&D activities in the mining industry, China and the US compete with each other in investment in R&D activities (Rafiq, Salim & Smyth, 2016). Both countries are known as the biggest miners in the world (Buchholz, 2020), and in 2020, China aimed to be a world-leading innovator in the longer-term (Rafiq, Salim & Smyth, 2016). This aim was achieved by China, which sharply increased R&D expenditure after the beginning of the 2000s from below 1 per cent in 2001 to double it to exceed 2 per cent of its Gross Domestic Product (GDP) in 2013 (Boeing, Mueller & Sandner, 2016). China occupies the second rank behind the US in terms of total R&D expenditure. In contrast, total R&D expenditure in Australia is declining as a percentage of its GDP below China. The comparison of R&D expenditure as a percentage of GDP for three countries is depicted in Figure 2.

Figure 2 R&D expenditure proportion of GDP



The Comparison of R&D expenditure (percentage of GDP) among Australia, China and the United States (US). Source: World Bank (2021)

Previous studies of R&D activities have attempted to measure the influence of these activities through firm performance (Alarcón & Sánchez, 2013; Busru & Shanmugasundaran, 2017; Coad & Rao, 2010; Demirel & Mazzucato, 2012; García-Manjón, & Romero-Merino, 2012; Griliches, 1986; Lichtenberg & Siegel, 1991; Militaru, 2011; Rafiq, Salim & Smyth, 2016; Shin, Kraemer & Dedrick, 2016). Some of these studies questioned whether firms that engage in R&D activities are more profitable than those that do not engage. They asked research questions such as ‘do R&D activities affect subsequent revenue growth?’ and ‘what is the influence of R&D activities on the productivity growth of firms?

Most of these studies focus on a particular industry, such as the high technology, manufacturing, service, pharmaceutical, or mining industries. Methods of quantitative analysis used in these studies are varied, such as coarsened exact matching (CEM), two-stage least squares (2SLS), and Granger causality tests. Many adopt the Generalised Method of Moments (GMM), which is recommended to obtain estimators that exploit all the linear moment restrictions (García-Manjón & Romero-Merino, 2012) and to address the presence of endogeneity bias (Rafiq, Salim & Smyth, 2016). Some studies use a dynamic model, which includes lagging of the dependent variable using the system Generalised Method of Moments

(GMM) as appropriate for this situation (García-Manjón & Romero-Merino, 2012). However, the empirical results were inconclusive for some specific industries using different firm performance measures.

1.2 Problem Statement

The mining industry has a unique characteristic influencing mining firms to choose generic strategies to obtain a competitive advantage. The mining industry acts as a price taker[2] rather than a price maker (Bryant, 2011) since mining firms cannot set the price of minerals. Rather, the price is driven by the global market and dictated by the status of global demand and supply (Filippou & King, 2011). Moreover, the mining industry produces similar products that are not significantly different among mining firms (Filippou & King, 2011). Thus, mining firms need to apply a strategic plan to lower the cost of mineral extraction and improve the existing processes. Several studies suggest a transformative step through conducting R&D activities (Bryant, 2011; Filippou & King, 2011; Rafiq, Salim & Smyth, 2016). The transformation, as Bryant (2011) suggests, can be achieved through discovering a new approach to mining resources based on knowledge-based analysis and planning.

Discovery can drive value creation in the mining process and products, continuing to a new operating platform that transforms potential value into reality. The new approach and operating platform involve a technical risk, so R&D activities are needed to counter the pressure (Bryant, 2015; Deloitte, 2017). Mitra (2019) also suggests the depletion of mining resources is another reason requiring R&D activities. The mining industry needed to focus on R&D activities and develop new techniques to economically extract the maximum possible volume of minerals from existing bases with minimum disturbance to the environment (Mitra, 2019). In this way, R&D activities enable firms to obtain a competitive advantage and sustain their business by managing profitability and positive cash flow (Deloitte, 2017).

Several studies of the mining industry suggest the importance of investing more in R&D activities (Bryant, 2011; Filippou & King, 2011; Rafiq, Salim & Smyth, 2016), but total R&D expenditure in the mining industry is very low and in steady decline (Filippou & King, 2011). The mining industry needs to step forward with a transformative change to build a competitive advantage (Bryant, 2011), reduce operational costs and improve productivity that can assist in

[2] The meaning of price taker based on the Oxford dictionary and Certified Financial Analyst (CFI) organisation is a firm that must accept the prevailing price in the market and its own transactions cannot dictate the price in the market.

managing profitability, achieving positive cash flow and creating opportunities for future profit growth (Deloitte, 2017). Unfortunately, there are limited studies in the mining industry that investigate the influence of R&D activities on firm performance. Most studies have been done in the contexts of US and China mining firms, which might not be relevant to other contexts.

This study focuses on the mining industry in Australia, considering the potential significance of the study to fill the gap in the existing literature about the influence of spending on R&D activities on firm performance. Australia's economic growth and development remain dependent on the mining industry (Deloitte, 2017), so studying any aspect of this industry makes a potential contribution to the country's economy. In addition, Australia is known as a global leader in the mining industry with a large natural endowment of iron ore, coal, bauxite, and base metal (Geoscience, 2017). Being a global leader in the industry makes it important to investigate strategies to improve the performance of Australian mining firms. However, there have also been pressures on the industry in recent years. From the perspective of the environmental footprint, existing mining methods are unacceptable to society (Bryant, 2011), leading to increasing costs of mine development to meet environmental regulatory requirements and increased environmental activism (Humphreys, 2010). Hence, R&D activities in the mining industry are encouraged (Bryant, 2011; Deloitte, 2017; Filippou & King, 2011).

As an essential part of the development of corporate governance, R&D is prone to any policy or strategic decision taken by the government. As Filippou and King (2011) state, "… being at the forefront of government or corporate developments, R&D is the first to feel the consequences of any strategic decisions—good or bad" (p.277). In the Australian context, the government provided R&D incentives for all industries through its tax policy in 1985. Under this policy, firms that undertake R&D activities in Australia are eligible to claim a great proportion deduction of R&D related expenses. However, an investigation of the effect of the R&D tax policy on investment in R&D in Australia shows that the policy is not effective (Thomson, 2010). Despite the benefits for firms eligible to apply the policy, as Thomson (2010) states, the R&D incentives do not significantly increase the investment in R&D in Australia. In fact, growth in sales is more influential and becomes the main determining factor for R&D investment (Thomson, 2010).

At the firm level, a study of the effect of R&D activities in Australia, focusing on large Australian firms between 1994-1996, finds that the Australian context of assessing private returns to R&D is different from other contexts (Bosworth & Rogers, 2001). This difference, as Bosworth and Rogers (2001) argue, is probably caused by the undervaluation of R&D by the Australian stock market, although this still reflects the low level of returns to R&D among Australian firms. Therefore, focusing on the influence of R&D activities on firm performance in the Australian mining industry has the potential to fill a gap in the literature. Apart from focusing the analysis at the firm level, this study also potentially adds to the existing body of knowledge about the relationship between R&D and firm performance because, until recently, few empirical studies have focused on the mining industry in Australia.

1.3 Research Aim and Objectives

The study aims to understand whether there is a significant influence of spending on R&D activities on the economic outcomes of mining firms. To achieve this aim, the study sets the following research objectives:

i. To identify the influence of engaging versus not engaging in R&D activities on firm performance, and

ii. To identify the influence of higher versus lower spending on R&D activities on firm performance.

Based on the aim and problem outlined in the previous sections, the following research questions are formulated to address the knowledge gap:

RQ1*: Does spending on R&D activities influence the profitability and revenue growth of mining firms in Australia?*

RQ2*: Does spending on R&D influence Tobin's q of mining firms in Australia*?

1.4 Brief Overview of the Research Method

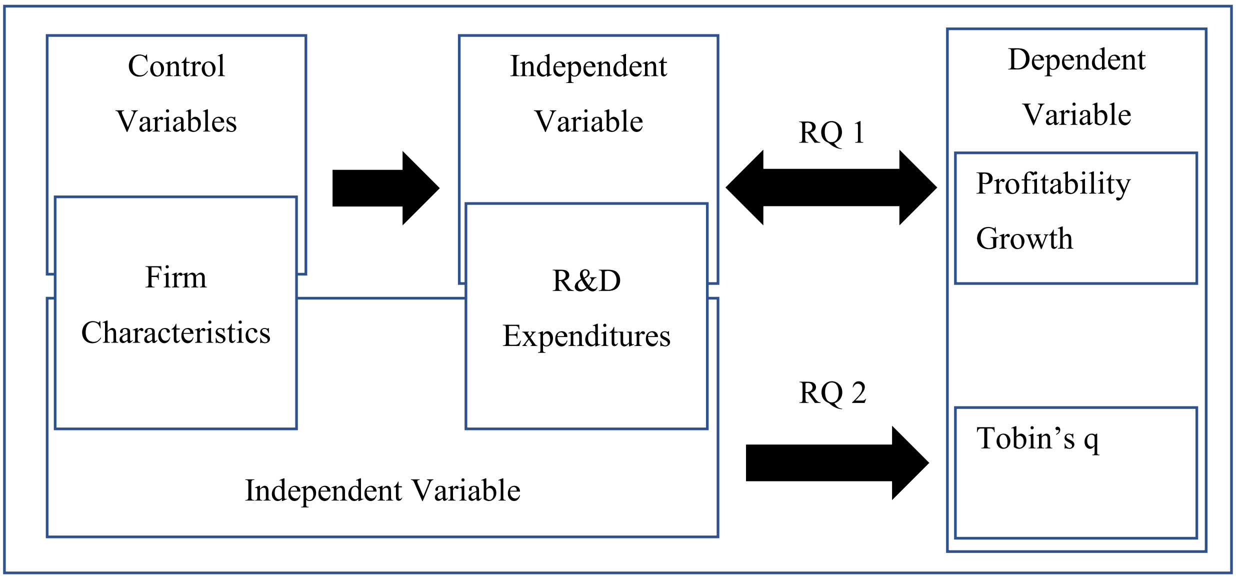
The observation of a declining R&D expenditure trend in mining firms in Australia leads to the use of the positivism research paradigm to investigate the influence of spending on R&D activities on firm performance at the firm level. Observation will lead to the production of credible evidence through developing and testing the hypotheses. Using the resource-based view (RBV) as the foundation to develop the hypotheses, this study adopts a mono-method archival approach, resulting in a quantitative method.

A quantitative method used for this study follows the work of García-Manjón and Romero-Merino (2012), who measure the influence of spending on R&D activities on firm performance. Their study indicated firm performance as firm growth, an accounting-based measure. However, to have an extended understanding of the influence of spending on R&D activities, this study adds profitability as another accounting-based internal measure and market-based measure, using Tobin's q approach.

Furthermore, this study uses a dynamic model to analyse the data as the possibility exists of a simultaneous effect between spending on R&D and profitability or spending on R&D on revenue growth running in a two-way direction. García-Manjón and Romero-Merino (2012) established the dynamic model to analyse the data where a dynamic left-hand-side variable depends on its past realisation, which means the model includes lags of the dependent variable as independent variables in the model. (Roodman, 2009; García-Manjón & Romero-Merino, 2012). GMM is an appropriate estimator for the situation (García-Manjón & Romero-Merino, 2012; Schultz, Tan & Walsh, 2010). Another condition handled by GMM is where data is heteroskedastic and autocorrelated within individuals but not across them (Baum, Schaffer & Stillman, 2003; Roodman, 2009). The variance of the residual for the data in this study is unequal over a range of measured values.

The market-based measurement calculated using Tobin's q approach is measured using simple Tobin's q (Q) as suggested by Chung and Pruitt (1994). The inclusion of Tobin's q as an indicator of the influence of spending on R&D activities represents the public's opinion of a firm's net worth, the value of the firm's equity, and becomes information about future implications of the current decision (Ehie & Olibe, 2010). Furthermore, this study adds the squared term of the R&D variable to control the possibility of a non-linear influence of the R&D activities on Tobin's q. The general conceptualised framework, including the variables as well as the relationship between variables, is shown in Figure 3.

Figure 3 General conceptual framework of the study



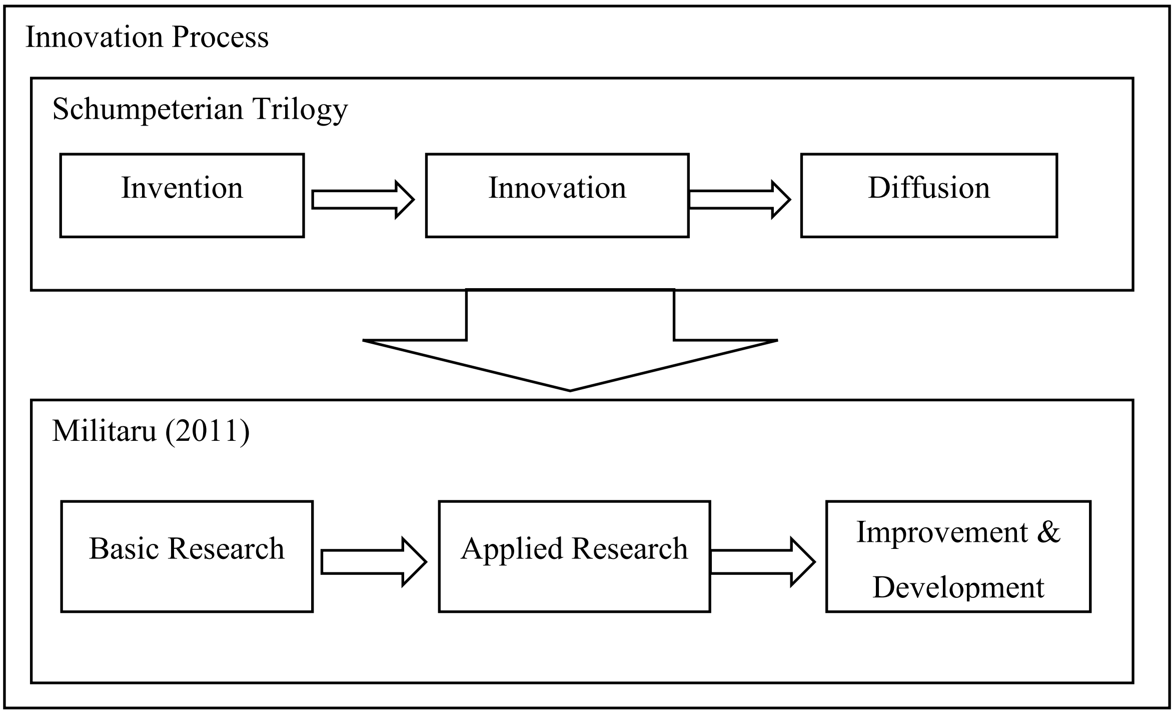
1.5 Definition of R&D

The notion of innovation has become a subject of investigation in a range of different industries. An early investigation was conducted by Schumpeter (1947), who defined innovation as "simply the doing of new things or the doing of things that are already being done in a new way" (Schumpeter, 1947 p.151). In this definition, Schumpeter emphasises the term "newness" in innovation, which can be a new product, a new process, or a new service. The term "newness in innovation" refers to the first occurrence of an event (Freeman & Soete, 1997; Stoneman, 1995), meaning a new product, process or service and implies discontinuing or changing the existing event and fundamental technology (Peters, 2008). However, innovation can also refer to an improvement made to an existing product or process (Peters, 2008). In addition, for an improvement to be considered an innovation, the change in the product or process should lead to competitive consequences in the future (Clark, 1987). The change need not necessarily be a major or significant event but can be a small change known as an incremental innovation (Tirole, 2000). The competitive consequences for mining firms from innovation can be in the form of increased productivity or reduced production cost. Innovation is conceptualised in this study as the newness or an incremental change of an event that has competitive consequences on a product, process, or service in the mining industry.

For incremental innovation, despite a requirement for competitive consequence, there is a requirement that a new idea or change must be realised or else it is considered an invention (Peters, 2008). To make a clear distinction among the notions of invention, innovation and diffusion, Peters (2008) conceptualises the "Schumpeterian trilogy" based on Schumpeter's work. In this trilogy, the invention is defined as generating a new idea, whereas innovation is a realisation of the invention into marketable products, processes, or services, then followed by diffusion that spreads them into application or sales channels. Hence, inventions do not automatically lead to innovation nor automatically diffusion (Peters, 2008). This implies when the idea of innovation is used, it means that the idea is marketable and has been realised into a product or service.

The realisation of ideas from an invention to become an innovation is similar to the second phase of the R&D definition by Militaru (2011) based on research activities. He describes three activities to define R&D as follows. The first is basic research, which is an observation of facts and phenomena and then analyse them to be applied for commercial purposes as the second activity is called applied research. The last activity is the development of new products or services using knowledge gained from research in previous activities. Comparing the Schumpeterian trilogy (Peters, 2008) and Militaru's definition of R&D (Militaru, 2011), there is a similarity between innovation and applied research activities since both refer to the application or realisation of ideas or changes. Therefore, the terms 'innovation' and 'R&D' in this study are used interchangeably, emphasising the realisation of an idea or invention. Figure 4 illustrates intertwining ideas about innovation from the Schumpeterian trilogy and Militaru's activities-based R&D definition.

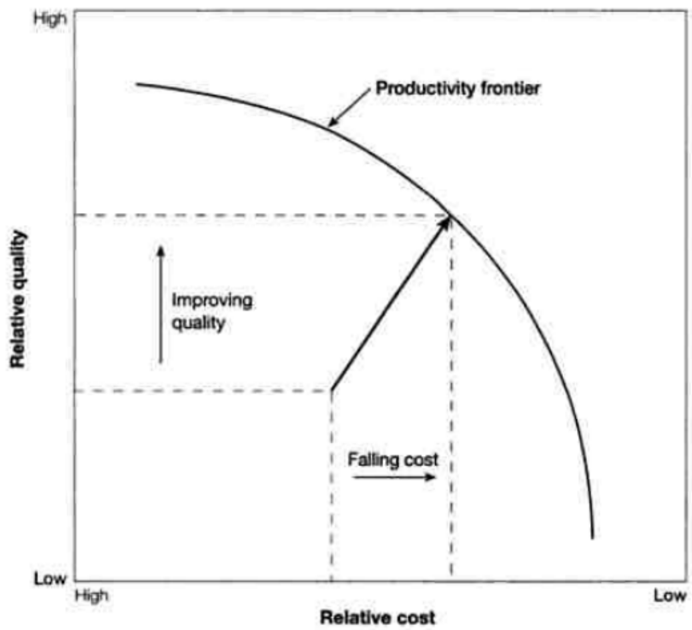
Figure 4 Innovation process according to Schumpeterian trilogy and Militaru (2011)



The term R&D is not specifically mentioned in the Schumpeterian trilogy, nor is there an indication of where it sits among the three notions of invention, innovation, and diffusion. However, the term R&D is commonly used in accounting standards. For instance, in Australian Accounting Standard AASB 1011 (AASB 1011, 1987), R&D is defined as an experiment that involves technical risk for acquiring new knowledge, product or improving an existing product. The term 'newness' in acquiring new knowledge or product is defined as the original investigation (AASB 138, 2015), including devising a new application, as pointed out by the Organization for Economic Cooperation and Development (OECD, 2002). On the other hand, the term 'improvement in an existing product' means a substantially improved material, product, or service before starting production (AASB 138, 2015).

In the AASB 1011 definition of R&D, it is also pointed out that R&D inherently involves technical risk. Viki (2016) defines technical risk as related to the capability of firms to apply new or existing technology and make it work efficiently in the production process or services. This definition emphasises working efficiently in the production process or service provided and is related to the notion of operational effectiveness proposed by Porter (1996). Porter's operational effectiveness cannot be separated from the productivity frontier, which is the maximum value of a firm that can be created at a given cost using the best inputs such as technologies, skills, and management techniques. The productivity frontier shifts constantly outward the operating effectiveness when new technologies are developed and new inputs become available (Porter, 1996). In this case, the productivity frontier cannot be achieved. However, firms might try to get closer to it by reducing the technical risk involved to achieve efficiency in the process or service through conducting R&D activities. Therefore, R&D focuses on reducing technical risk to bring out the firm's operational effectiveness. The correlation between the operational effectiveness and productivity frontier is depicted in Figure 5.

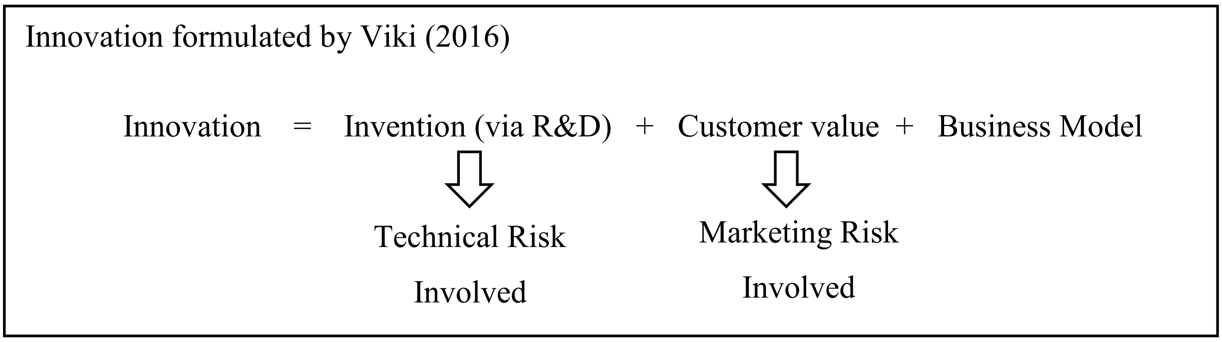
Figure 5 Operational effectiveness by Porter productivity frontier: operational effectiveness



Source: Porter and Teisberg (2006)

Even though firms can create products or services effectively and the use of technology can make the products work efficiently, there is a possibility that customers do not want to buy the products (Viki, 2016). In this case, apart from the technical risks involved in the operation or service, firms also face another risk related to understanding customer needs and preferences. This risk is known as marketing risk, which means that producing a "better" product is not enough to reduce the risk. Instead, firms need to produce a product with an added or new value to the customer. Thus, innovation is expected to cover marketing risk by developing a deep understanding of customer needs and delivering value to customers in a sustainably profitable manner (Viki, 2016). However, Viki (2016) adds that innovation should also minimise technical risk while delivering customer value rather than only addressing marketing risk. This explanation brings innovation to cover both risks and places R&D as a part of the innovation. The formulation of innovation and R&D by Viki (2016) is depicted in Figure 6.

Figure 6 Modification of innovation formulation by Viki (2016)



In conclusion, this study addresses R&D activities representing the process of developing new knowledge or ideas with the technical risk involved in the evolution of new or improved products and processes. However, it takes time for R&D results to be applied or realised, and once applied, they can be considered an innovation to obtain a competitive advantage. Therefore, it can be concluded that R&D is part of the invention that discovers an opportunity, whereas innovation exploits the profitable opportunity (Alvarez & Busenitz, 2001). Further exploration of competitive advantage will be discussed in Chapter 2.

1.6 Contribution of the Study

Substantial research on the influence of spending on R&D activities on firm performance exists, but it mostly uses sample companies from industries other than the mining industry. This study focuses on the influence of spending on R&D activities on firm performance in the mining industry. A quantitative research method is used to establish, confirm, or validate the influence and develop generalisations that contribute to theory. These outcomes provide both knowledge improvement and practical implications that will benefit three groups of stakeholders.

1.6.1 Academic Literature

With the focus on examining the influence of spending on R&D activities on firm performance in the Australian mining industry, this study contributes to the academic discussion in this context. Most previous studies in the mining industry have been conducted in Europe, the US, or China, and findings may not apply in an Australian context. Additionally, Rafiq, Salim and Smyth (2016) indicate the need to study R&D and firm performance in the mining industry in Australia as this country is heavily dependent on the resources sector. This study proposes to answer this call.

Also, since this study is situated in the Australian context, it will bring forward the empirical evidence from this context to contribute to the body of literature about R&D expenditure worldwide. This also simultaneously addresses the paucity of research on R&D expenditure on firm performance within the Australian context.

1.6.2 Policymakers

Several scholars have emphasised the importance of R&D activities in the mining industry. However, the mining industry has been known for having low spending on R&D, which is steadily declining (Filippou & King, 2011). Even though the government encouraged activities by providing an R&D tax incentive, the decline continues in the Australian mining industry (Thomson, 2010) since that policy is not the primary determinant for firms to conduct and spend more on R&D activities. Therefore, it is important to understand the reason for declining R&D investment in the mining industry from other perspectives, in this case, from the firm level.

1.6.3 Business Practitioners

Every industry experiences upturn and downturn periods. So does the mining industry, which has faced a roller-coaster period. From periods of normal to mining boom then followed by a downturn period, mining firms need a life jacket to survive in their business. As the condition mining firms cannot dictate the mineral price while the depletion of mining resources (Mitra, 2019), the transformation through R&D activities by discovering a new approach to resource-based knowledge-based analysis and planning (Bryant, 2011) is needed. Conducting R&D activities in mining firms has become increasingly essential (CSIRO, 2015) in maintaining a competitive position and surviving every period of the business cycle. However, managers are afraid to conduct R&D activities with its long process and uncertainty of success ((Lai, Lin & Lin, 2015), which favours short-term benefits for firm performance (Parcharidis

& Varsakelis, 2010). Thus, highlighting the influence of spending on R&D activities on mining firms' performance is needed to develop a better understanding of managers' wariness.

1.7 Brief Outline of the Thesis

This thesis is structured into eight chapters.

- The **first chapter** provides the background of the study. It explores the need for R&D activities in the mining industry and explains the difference between innovation and R&D. Also, this chapter outlines the research focus, research objectives, and a brief description of the research method used in this study.
- **Chapter 2** examines the literature relating to the influence of spending on R&D activities on firm performance. It starts with literature that discusses the internal factors that affect firms' decisions to conduct R&D activities, followed by a discussion of firm performance as a measure of the influence of spending on R&D activities. In the last section, this chapter identifies the gap in the literature as the contribution of this study.
- **Chapter 3** reviews the theoretical framework for innovation and R&D. It discusses the RBV that emphasises firms' internal resources as important factors in conducting R&D activities to gain competitive advantage. This chapter explains the competitive advantages in the mining industry that influence firm performance.
- **Chapter 4** provide the rationale behind the choice of research method to answer research questions. Supported by the positivism research paradigm, this chapter justifies the use of a mono-method archival study approach using a quantitative research approach. It also establishes an empirical model to test hypotheses and explains variables used and how they are measured. It continues by discussing how the data analysis method is conducted, including preliminary testing (multicollinearity, heteroskedasticity, endogeneity and the Hansen test).
- **Chapter 5** presents the data analysis results. It commences by describing the data for this study, followed by conducting preliminary tests. It continues with applying GMM and ordinary least squares (OLS) linear regression to test the hypotheses as appropriate based on statistical tests. The robustness tests are also explained in each section of the data analysis.
- **Chapter 6** presents a synthesises of the findings and a discussion of them. It begins by briefly outlining the internal resources that influence firms in conducting R&D activities. It continues by discussing the finding of the influence of spending on R&D

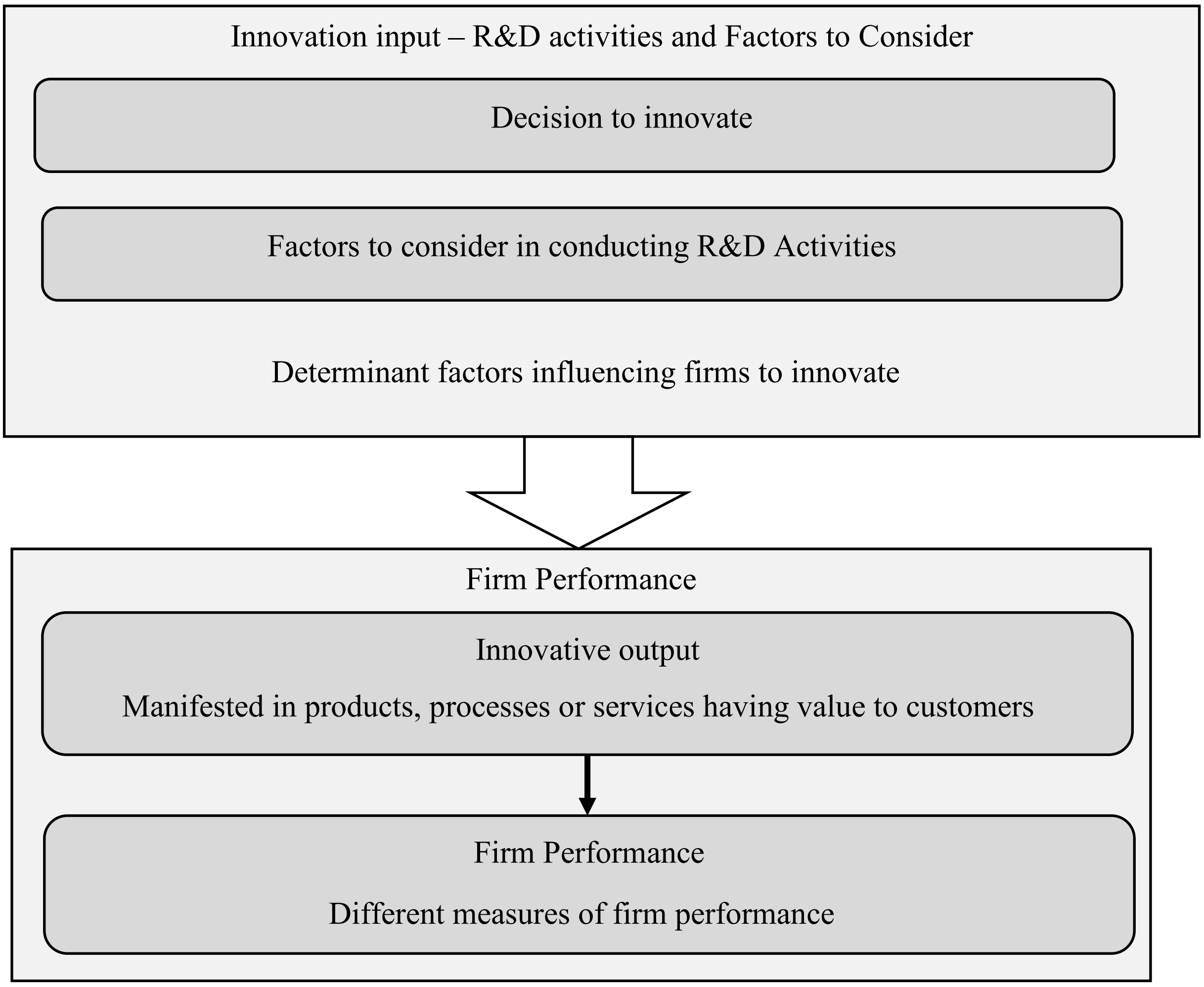
activities on profit and revenue growth, followed by a discussion of the findings concerning the influence of activities on Tobin’s q in terms of implications.

- **Chapter 7** presents the conclusion of this research study, its potential contributions and its limitations. Finally, directions and areas for future research are provided.

Chapter 2 - Literature Review

This chapter presents a review of the literature relevant to the influence of spending on R&D on firm performance that helps shape this study. It starts with discussing R&D activities as a strategic decision to gain a competitive advantage in section 2.1. The next section, section 2.2, explains factors for firms to consider in conducting R&D activities and how R&D activities are financed. Section 2.3 presents a review of previous studies of the influence of spending on R&D activities on firm performance, followed by identifying the gap in the literature addressed in this study in section 2.4. Finally, this chapter ends with a summary of the literature review. The structure of the literature review is summarised in Figure 7.

Figure 7 Structure of the literature review



2.1 R&D Activities as an Innovation Strategy

R&D activities, as an integral part of innovation become the main focus of firms to gain a competitive advantage. A firm's decision to conduct R&D activities indicates a commitment to grow (Fortune & Shelton, 2014; Wang & Thornhill, 2010) and is the first step for the firm to innovate. According to Hashi and Stojčić (2013), this step is categorised as the first of two steps input to the innovation. The second step is deciding how much to spend on innovation activities (Hashi & Stojčić, 2013). Both input steps are challenging because firms need to consider productive resources (Grant, 1996) that are valuable, rare, inimitable, and distinctive to obtain a competitive advantage (Barney, 2001). Therefore, a firm with productive resources combined with a strong commitment to innovation can address the ever-changing market and build a competitive advantage to achieve superior performance (Fortune & Shelton, 2014; Wang & Thornhill, 2010).

Superior performance is an indicator of the firm's success in gaining a competitive advantage by producing products or delivering services (Hashi & Stojčić, 2013). According to Santos and Brito (2012), performance can be measured by seven dimensions and classified into financial and strategic performance. The selection of dimensional indicators in measuring the effect of gaining a competitive advantage depends on which aspect of firms' performance is to be measured. This aspect should be evaluated carefully because the indicators are not interchangeable (Santos & Brito, 2012). The most common firm performance measure used is financial performance, consisting of three indicators: profitability, market value and growth.

The decision by firms to conduct R&D activities represents a long-term commitment to innovation due to the characteristics of these activities that have multi-stage timeframes and last a long time (Bakker, 2013). The long process of conducting R&D activities involves a high degree of risk and uncertainty of success (Lai, Lin & Lin, 2015). Therefore, firms need to consider certain factors before deciding to conduct the activities. Once the decision is made, allocating dedicated resources is required (Kemp et al., 2003). Hashi and Stojčić (2013) list factors that firms need to consider when conducting R&D activities. They include firm export intensity, public support for innovation, the culture and, more specifically at the firm level, firm size and the availability of working capital or financing. Furthermore, the education level of employees is also a factor to consider (Kemp et al., 2003).

In grouping factors to consider for innovation, OECD/Eurostat (2018) categorises them based on the capability of firm managers to control them. The first category is external resources, where factors are beyond the immediate control of the manager. This includes the culture of a country, public support, and the country's legal and regulatory, competitive, and economic conditions (OECD/Eurostat, 2018). The other category is internal resources, with factors ostensibly under the manager's control, as they are at the firm level (Hashi & Stojčić, 2013). These resources include the firm's production, the business model, working capital or financing, firm size and employee skills or human resources (OECD/Eurostat, 2018). Internal and external resources are both important, but internal resources are considered more important in deciding to conduct R&D activities because of the firm's ability to control them (Lai, Lin & Lin, 2015). These resources distinguish firms from competitors and permit competitive advantage (Barney, 1991; Wernerfelt, 1984).

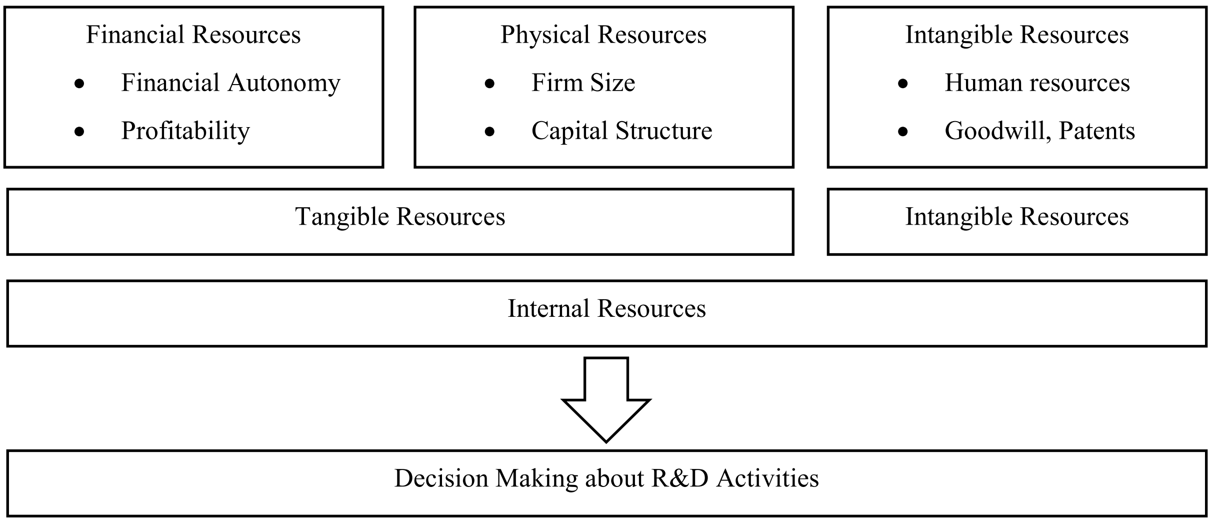
Internal resources can be categorised into tangible and intangible resources. Tangible resources consist of financial and physical resources (Del Canto & González, 1999; Lai, Lin & Lin, 2015). The financial resource category consists of financial autonomy and profitability. Financial autonomy represents the capital resources embodied in firms' self-owned assets of firms such as cash holdings (Lai, Lin & Lin, 2015). In relation to R&D activities, financial autonomy is an important factor for firms because they may face borrowing constraints in funding activities since it is more difficult to assess the firm's value than its tangible investments (Baldi & Bodmer, 2018; Hall et al., 2016). An example of a capital resource is cash holdings (Kim & Park, 2012). Ughetto (2008) specifies this resource as free cash flow, that is, cash left over after paying for operating and capital expenditures. Scholars who conducted studies on financing R&D activities possible agree that financial autonomy as the cash flow generated by firms is very important that make the R&D activities possible (Del Canto & González, 1999; Kim et al., 2018; Kim & Park, 2012; Lai, Lin & Lin, 2015). Except for Japanese firms, these resources are not considered the determinant factor for R&D investment. In fact, Japanese firms are still active in conducting R&D activities despite low financial autonomy (Lai, Lin & Lin, 2015). The other financial autonomies that support the decision to conduct R&D activities are equity or debt and are explained in section 2.3.

Profitability is another factor to consider in conducting R&D activities and is included in the financial resources category. With its characteristics of high risk with uncertain success (Lai, Lin & Lin, 2015), as well as multi-stage and long timeframe (Bakker, 2013), R&D needs to be supported by long-term financial support. This support can be gained from profits to reduce financial risk (Coad & Rao, 2010; OECD/Eurostat, 2018). Previous empirical studies prove that high profitability encourages firms to conduct R&D activities to gain a competitive advantage so that the profitability trend becomes pivotal when making decisions about R&D activities (Busru & Shanmugasundaram, 2017; Lai, Lin & Lin, 2015). However, Japanese and

Korean firms (Lai, Lin & Lin, 2015) and US firms do not consider profitability when undertaking R&D activities (Coad & Rao, 2010). Other empirical evidence from Militaru (2011) found that increasing profitability does not lead firms to conduct R&D activities. However, firms tend to increase the amount of R&D expenditure following sales growth rather than profit (Coad & Rao, 2010). Gomory (1992) suggests the amount of R&D committed depends on sales and is calculated as a fixed percentage of sales. Interestingly, firms committed to growing their businesses are less willing to reduce or stop R&D activities even when sales decrease or show negative growth (Coad & Rao, 2010).

Physical resources consist of firm size and capital structure, whereas intangible resources are identified as goodwill, patents, human resources, and business resources (Lai, Lin & Lin, 2015). In the literature, other scholars confirm that patents (Arora, Ceccahgnolu & Cohen (2008), human resources (Coad & Rao, 2010) and business resources (Park, Shin & Kim, 2010) are important factors affecting the probability of firms conducting R&D activities. However, the literature discussing physical resources and capital structure is inconclusive. Firm size is explained further in section 2.2. Capital structure is calculated as the ratio of assets to liabilities. Firms with a high ratio for their capital structure have ample self-owned assets rather than debt (Lai, Lin & Lin, 2015). The grouping of internal factors affecting the decision to conduct R&D activities, as described by Del Canto and González (1999) and Lai, Lin and Lin (2015), is depicted in Figure 8.

Figure 8 Internal resources determining R&D Activities



Source: research framework of Del Canto & González (1999) and Lai, Lin & Lin (2015).

2.2 Consideration Factors in Conducting R&D Activities

2.2.1 Firm Size

The effect of firm size on the decision to conduct R&D activities is inconclusive in the literature. Cohen, Levin and Mowery (1987) argue that firm size positively affects the decision to conduct R&D activities. Large firms are relatively more likely to conduct these activities (Del Canto & González,1999) since they have greater resources, such as human capital, skilled workers and working capital. These resources allow larger firms to possess an advantage in accessing financing for R&D activities that support the decision (Cockburn & Henderson (2001). Thus, through capital, labour and financing resources, larger firms can accumulate knowledge that leads to technological changes, gaining market power to prevent other firms from entering the market (Revilla & Fernández, 2012).

On the other hand, some studies have found a negative or insignificant relationship between firm size and the decision to conduct R&D activities. Larger firms have greater inertia and lack flexibility in deciding to conduct R&D activities due to their complex bureaucracies (Revilla & Fernández, 2012). This inflexibility does not occur in small firms, and this becomes an advantage in having a better network of communication and coordination among components (Del Canto & González, 1999). Therefore, smaller firms are considered better innovators (Revilla & Fernández, 2012), disrupting the status quo and driving innovation from low barrier to entry markets (Malerba & Orsenigo, 1996; Oakey, 2015). Tsai and Wang (2005) also find that firm size is not significant in influencing the probability of conducting R&D activities. Hence, the evidence for firm size as a determinant of conducting R&D activities is inconclusive.

Managers need to be cautious in allocating resources to R&D activities as firms need to trade off the productive resource commitment with the risk involved in the activities (Schwartz & Vertinsky, 1977). Productive resources can involve the ability of employees, which is the most important factor to consider in the decision to conduct R&D activities (Tsai & Wang, 2005) and access supporting financial resources (Cockburn & Henderson, 2001).

2.2.2 Equity or Debt in Funding R&D Activities

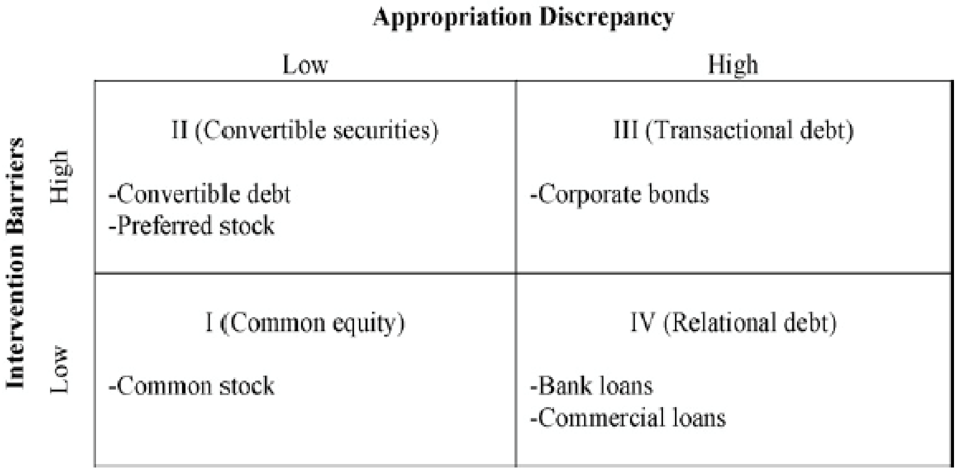
Internal financial resources are the major driver for a firm in deciding to conduct R&D activities (OECD/Eurostat, 2018) and can be gained from equity or debt (Del Canto & González, 1999). The financial resources, in this case, are related to how to finance and make the R&D activities possible. However, financing in R&D activities differs from traditional financing because R&D activities have a high level of uncertainty risk, adverse selection, moral hazard, and agency problems (Alam, Uddin & Yazdifar, 2019; Hall et al., 2016).

These differences exist due to asymmetric and incomplete information between firms and investors (whether debt or equity), respectively (Alam, Uddin & Yazdifar, 2019; Bakker, 2013; Hall & Lerner, 2009). This situation implies that investors cannot objectively establish the likelihood of a technical venture's success because firms have better information about the activities. Similarly, firms can take more risk than originally agreed to obtain success, whereas investors bear the additional risk of bankruptcy. Therefore, debt is not well suited for funding R&D-intensive activities (Alam, Uddin & Yazdifar, 2019; Ughetto, 2008).

It has been suggested by Myers and Majluf (1984) that under the pecking order theory, firms need to prioritize financing from internal funds that are equity-based (Alam, Uddin & Yazdifar, 2019; Hall et al., 2016). Equity is preferred as it has several advantages over debt (despite the tax shield of debt) as shareholders share in upside return, there are no collateral requirements, and additional equity does not magnify problems associated with financial distress (Brown, Fazzari & Petersen, 2009). Bakker (2013) suggests that to finance the activities, firms need to make sure there is no collateral involved, so equity's no collateral requirement meets this suggestion. Hall and Lerner (2009) also state that equity-based sources are best to fulfil the no collateral requirement. This suggestion does not mean that using debt is not possible for financing R&D activities. However, lenders probably require information about firms' past R&D activities to ensure a permanent or continuous profit threshold because persistence in productivity or profit is explained by persistence in R&D activities (Triguero & Córcoles, 2013). Ughetto (2008) suggests that debt has limitations in financing innovation and is embodied in physical capital rather than technological progress.

Wang and Thornhill (2010) categorise equity into common stocks and convertible securities (preferred stock and convertible debt). They group the sources based on the degree of intervention barriers and appropriation discrepancies. Common stock has an advantage (Wang & Thornhill, 2010) because it does not force firms to pay regular interest. This condition is important to minimise the distress of failure in R&D activities (Wang & Thornhill, 2010) and increase discretionary slack (Bourgeois, 1981). Furthermore, common stockholders may benefit from an increase in R&D investment that may increase the firm's residual value (Wang & Thornhill, 2010).

Figure 9 Financial instruments; Intervention barriers and appropriation discrepancies



Source: financial instruments based on Wang and Thornhill (2010)

2.3 Spending on R&D Activities' Influence on Firm Performance

2.3.1 The influence of Spending on R&D Activities on Profit and Revenue Growth

Continuous improvement of firm performance is essential for the firm to maintain its competitive advantage. Therefore, it is imperative for the firm to measure its performance from time to time. Performance measurement of the subsequent effect of the activities (Lome, Heggeseth & Moen, 2016) helps the firm to measure the efficiency and effectiveness of activities (Al-Matari, Al-Swidi & Hanim, 2014; Neely, Gregory & Platts, 2005). This measurement of firm activities is important to identify how the firm improves across time (Pavlov & Bourne, 2011). R&D activities have been examined across different countries and industries to understand their influence on firm performance. Scholars have studied the R&D activities of US manufacturing firms (Coad & Rao, 2010), Spanish food firms (Alarcón & Sánchez, 2013), US pharmaceutical firms (Demirel & Mazzucato, 2012), Norwegian manufacturing firms (Lome, Heggeseth & Moen, 2016), US and Chinese mining firms (Rafiq, Salim & Smyth, 2016) and US semiconductor firms (Shin, Kraemer & Dedrick, 2017).

The findings from these studies show that, in general, R&D activities influence firm performance. An interesting aspect of R&D activities is that they can lead to the development of resources that are valuable, rare, non-substitutable and difficult to imitate to sustain a competitive advantage (Alarcón & Sánchez, 2013; Lome, Heggeseth & Moen, 2016; Wang & Thornhill, 2010), subsequently improving firm performance (Wang & Thornhill, 2010).

The most common performance dimension used to measure the influence of R&D activities is financial performance; however, indicators for the measurement vary among scholars. For example, as an accounting-based measure, some scholars use a growth measure to indicate the effect of R&D activities. Growth is drawn from revenue or sales growth (Coad & Rao, 2008; 2010; Lome, Heggeseth & Moen, 2016) or productivity (Bönte, 2003). Other scholars use profitability as an accounting-based measure to measure the effect of the activities (Busru & Shanmugasundaram, 2017; Rafiq, Salim & Smyth, 2016) or ROA (Alarcón & Sánchez, 2013; Bae, Park & Wang, 2008; Gunday et al., 2011). Other scholars use a market-based measure (Masa'deh et al., 2015) to identify the effect of R&D activities on future growth opportunities (Gentry & Shen, 2010). Most scholars calculate the market value by using Tobin's q or the market value to book value ratio (MVBV) as a close proxy for Tobin's q (Bae, Park & Wang, 2008; Bosworth & Rogers, 2001; Bracker & Ramaya, 2011; Connolly & Hirschey, 2005; Ehie & Olibe, 2010).

Despite various indicators used to identify the effect of R&D activities, the results from studies using the same indicators vary and remain inconclusive. For example, Alarcón & Sánchez (2013) use ROA as an indicator of profitability. They argue that firms spending more on R&D activities are the most profitable firms. Busru and Shanmugasundaran (2017) agree that firms that conduct R&D activities positively affect profit. However, the profit can be noticed only in the subsequent year. Rafiq, Salim and Smyth (2016) find that firms that engage in R&D activities earn 4 - 13 per cent more profit than firms that do not engage in R&D activities. Moreover, other studies confirm that firms engaging in R&D activities have higher profits (Coad & Rao, 2010) and a positive effect on profitability or returns (Lichtenberg & Siegel, 1991). In contrast, Shin, Kraemer and Dedrick (2016) argue that firms spending more on R&D activities reduce their profit significantly.

Another indicator in the financial performance dimension is growth, and a few scholars use it to measure the effect of R&D activities. Similar to using profitability as the indicator, the result is not conclusive. A few empirical studies show a negative influence of R&D activities on growth performance, while others show the opposite. Demirel and Mazzucato (2012) argue that R&D activities slow sales growth instead of boosting it. Busru and Shanmugasundaram (2017) also confirm that R&D expenditure harms revenue growth.

On the other hand, other empirical studies have found that R&D activities are a significant determinant of productivity growth (Griliches, 1986; Lichtenberg & Siegel, 1991). Militaru (2011) also agrees that there is a strong association between R&D activities and subsequent sales growth; however, he noted that the growth happens when the spending on

R&D exceeds a certain level as he found a U-shaped correlation between them. Even though there is no conclusive evidence on the effect of R&D activities on growth, Fortune and Shelton (2014) are confident that "the effect of R&D investment on firm profitability is most tenuous; while the effect of R&D investment on sales growth and market performance demonstrated the most consistency" (p.35).

2.3.2 The Influence of Spending on R&D Activities on Firm Market Value

The market value of firms is a good outcome indicator of activities conducted by firms. One of the reasons for this is that market value is determined in the financial market every day and represents investors' value placed on firms. Firms consist of intangible and tangible assets, and accountants measure tangible assets but have not been so willing to measure all intangible assets (Bosworth & Rogers, 2001). According to ACCA global, intangible assets consist of those that are purchased and those internally generated. R&D activities are categorised as intangible assets that are internally generated. Thus, observing a market where the good is traded is important to the valuation of the good (Hall, 1999). In this case, a capital market is a place to evaluate the market value of firms. Firm market value captures the future implications of firms' current decisions (Carton & Hofer, 2006; Ehie & Olibe, 2010).

The benefit of forward-looking performance using market value has attracted numerous studies about the effect of R&D activities on firm market value. This stream of literature started from the seminal contribution of Griliches (1981), who found a significant relationship between market value and past R&D activities. Other empirical studies found that higher levels of R&D spending led to higher market values because R&D activities can sustain cash flow that subsequently generates a rise in market value (Connolly & Hirschey, 2005). Shin, Kraemer and Dedrick (2016) found that R&D activities positively affect market valuation for semiconductor firms. This positive market valuation also occurs for firms in the US, Germany, and Japan (Bae & Kim, 2003), Finland (Rahko, 2014), India (Kanwar & Hall, 2015) and France (Hall & Oriani, 2006; Nekhili, Boubaker & Lakhal, 2012). However, firms in Italy lose market value when they conduct R&D activities (Hall & Oriani, 2006). In China, where the market welcomes firms that conduct R&D activities at a certain threshold, the market values firms negatively, creating an inverted U-shaped response (Kim et al., 2018).

2.4 The literature gap on the Influence of R&D Activities on Firm Performance

Few empirical studies of the mining industry examine the influence of R&D activities on firm performance, with most in the context of Chinese mining firms. The context matters because China seeks to move up the value-added ladder by substituting higher value-added goods for labour-intensive goods. Labour-intensive manufacturing started in the late 1970s when the market reform occurred in China and contributed to its economic growth. The movement to value-added goods can be seen in the increase in spending on R&D between 2005 and 2014 by a factor of 15, and the number of Chinese companies conducting R&D activities increased from eight to 115 over the same period (Rafiq, Salim & Smyth, 2016). The growth in spending on R&D activities is also reflected in the mining industry in China (Rafiq, Salim & Smyth, 2016), which ranks second behind the US and aspires to overtake the US in this sector (Boeing, Mueller & Sandner, 2016).

On the other hand, Australia is known as a global leader in the mining industry, but its spending on R&D activities in the mining industry continues to drop after steady growth and a significant increase in 2012. R&D expenditure increased significantly in 2012 because of an increase in productive capacity in response to a sharp rise in accumulated global demand in the 2000s (Deloitte, 2017). Even though Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) emphasised the importance of R&D investment in the Australian mining industry (CSIRO, 2015; Rafiq, Salim & Smyth, 2016), from the following year onward, the spending on R&D activities steadily decreased below the 2010 level. The Australian Bureau of Statistics (ABS) identified the mining industry's contribution to R&D expenditure as the largest decrease at 31-35 per cent every year after 2012. The largest dollar decrease was in 2013 when R&D expenditure dropped by A$1,274 million, or around 31 per cent of the previous year (ABS, 2015).

The CSIRO saw an opportunity for Australia to seize the initiative and become a world leader in mining innovation. However, in the view of managers, R&D activities conducted by mining firms do not promote firm growth (Fan, Yan & Sha, 2017). In contrast, other studies find that mining firms conducting R&D activities earn higher sales, generate higher profit (Rafiq, Salim & Smyth, 2016) and are more productive (Sun & Anwar, 2015). The inconclusive result among studies in the mining industry is interesting to identify. Interestingly, there are limited studies focused on the mining industry in Australia despite Australia being known as a global leader in the mining industry (Geoscience, 2017). Some studies in the Australian context are related to the R&D tax incentive such as a study by Thomson (2010). A small number of empirical studies focus at the firm-level on the effect of R&D activities in Australia, such as Bosworth and Rogers (2001); however, their focus is not on the mining industry. This limited empirical study of the Australian mining industry in the context of R&D creates a knowledge gap concerning the influence of spending on R&D activities on firm performance. Accordingly, this study seeks to identify the influence of spending on R&D activities in the mining firms as emphasised by CSIRO. Moreover, this study seeks to fill the literature gap on the mining industry in the context of Australia by establishing the research questions:

RQ_1: Does spending on R&D activities influence the profitability and revenue growth of mining firms in Australia?

RQ_2: Does spending on R&D activities influence Tobin's q of mining firms in Australia?

2.5 Summary

This chapter presents a literature review of R&D activities as a commitment by firms to grow to gain a competitive advantage. With a strong commitment by firms to conduct R&D activities, they can address the ever-changing market and build a competitive advantage to achieve superior performance. This superior performance indicates firms' success in gaining a competitive advantage in producing products or delivering services and gaining profitability.

R&D activities represent a long-term commitment to innovation because of their characteristics that have multi-stage timeframes and last a long time. The long process of conducting R&D activities involves a high degree of risk and uncertainty of success; hence, considering certain factors and allocating resources is required. Some factors to be considered are firm size and the availability of working capital or financing for R&D activities.

The subsequent effect of R&D activities that help achieve continuous improvement in firm performance needs to be measured. The performance measurement of the subsequent effect of the activities helps the firm to measure the efficiency and effectiveness of activities and is important to identify how the firm improves across time. The influence of R&D activities on firm performance has been examined across different countries and industries. However, there are limited studies in the context of the mining industry and especially in Australia.

Australia has a unique situation where it is known as a global leader in the mining industry and the highest global mining exporter, especially of iron ore. However, spending on

R&D activities has continuously dropped. Even though the Australian Government provides support through an R&D tax incentive and the CSIRO emphasises the importance of R&D investment in the Australian mining industry, spending on R&D activities in the mining industry steadily decreases. In contrast to China, which is far below Australia in terms of global mining exports, growth in spending on R&D activities keeps increasing and takes the second rank behind the US, with aspirations to overtake the US in this sector (Boeing, Mueller & Sandner, 2016).

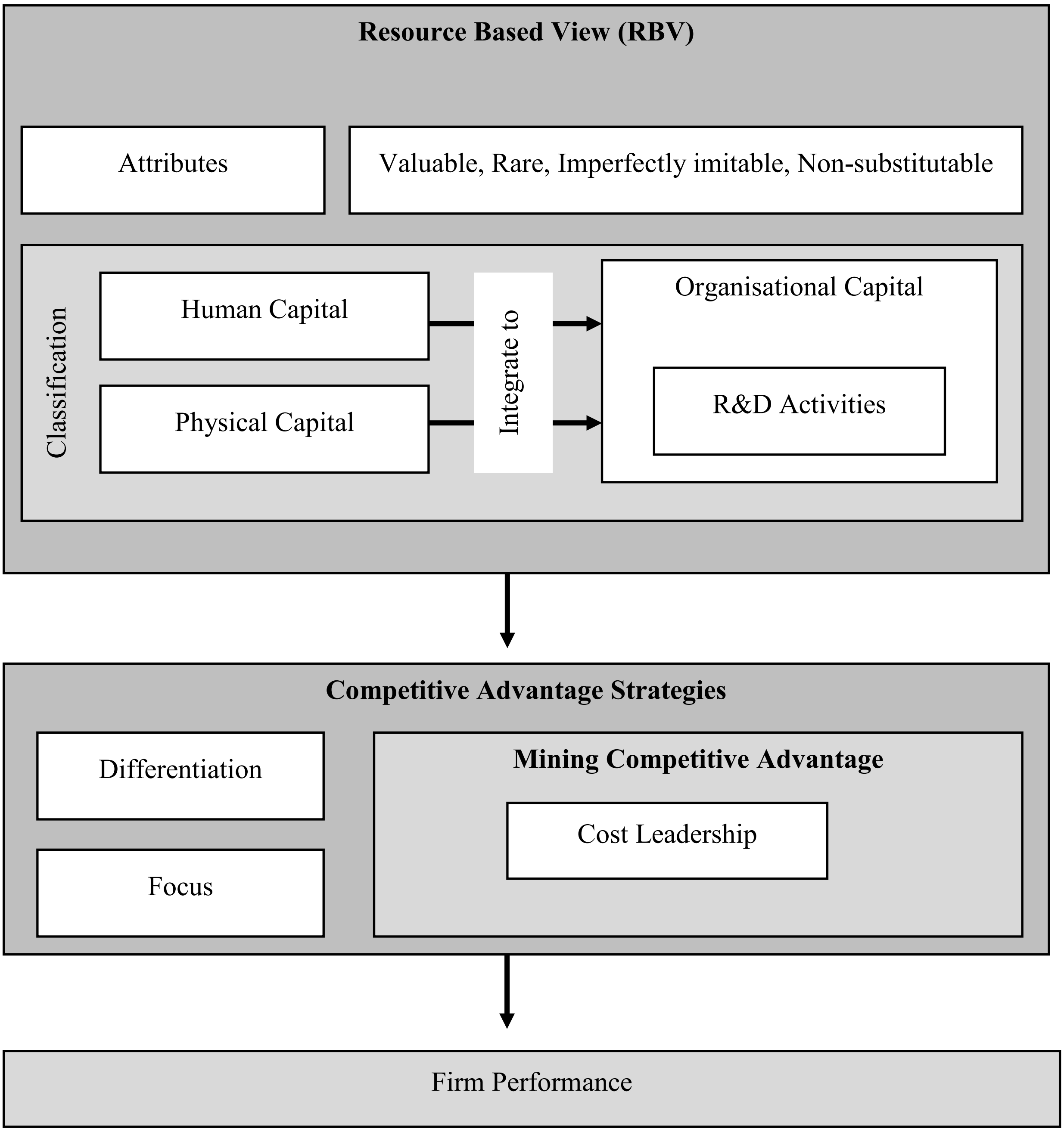
A study in the Australian context related to the R&D tax incentive and a small number of empirical studies focus at the firm level on the effect of R&D activities in Australia. However, their focus is not on the mining industry. This limited empirical study of the Australian mining industry in the context of R&D creates a knowledge gap concerning the influence of spending on R&D activities on firm performance. Accordingly, two research questions were formed related to the influence of R&D activities on firm performance. The research method used to seek answers to these research questions is detailed in the following chapter.

Chapter 3 - Theoretical Framework

In this chapter, theoretical concepts from the Resource-based View (RBV) of competitive advantage are explained as the framework for this research. These concepts become conceptual and analytical tools for investigating the influence of R&D activities on firm performance. The framework is built mainly on the underpinning notion that a firm's internal resources are important for its sustained competitive advantage (Barney, Ketchen Jr. & Wright, 2011). The ability of a firm to leverage its valuable resources whose purpose is to improve productivity and, in turn, develop the firm's performance is organisationally embedded in firm-specific resources, in this case, R&D activities.

This chapter is divided into four sections. The first section explains the RBV by classifying internal firm resources and their attributes leading to competitive advantage. Section 3.2 explains organisational capital as firm capabilities to integrate internal resources to gain a sustainable competitive advantage. This integration is represented through R&D activities to lead to a competitive advantage. The explanations of competitive advantage and competitive advantage in mining firms, in particular, are covered in section 3.3, followed by how a leading competitive advantage improves firm performance in section 3.4. Through the explanation in this chapter, section 3.5 develops the hypotheses to answer research questions. Finally, this chapter ends with a summary of the theoretical framework used to analyse the findings of this study (section 3.6). The flow of explanation of the theoretical framework in this study is depicted in Figure 10.

Figure 10 RBV factors that lead to firm performance



3.1 Resources Based on the Resource-based View (RBV)

The RBV is a theory that has been widely used to understand organisations. This theory's use has been particularly strong and influential in recent years in exploring the usefulness of a firm's resources. The RBV explains why a firm uses resources complementary to the perspective of its product (Wernerfelt, 1984) with the underlying idea that resources are one of the essential factors for understanding the origin of a firm's sustained competitive advantage

(Barney, Ketchen Jr. & Wright, 2011). This competitiveness is very important and should be maintained for a firm to focus on its productive resources, especially in an era of a rapidly changing world and global industries (Grant, 1996). Although the importance of resources has been acknowledged, their role remains under-addressed in the literature (Barney, Ketchen Jr. & Wright, 2011). Therefore, the prominence of the RBV for analysing resources needed to sustain competitive advantage is the main reason for its use as the theoretical framework for this research.

Under the RBV, a resource can be understood as anything owned by a firm that is essential for the business to run. More formally, "a firm's resources at a given time could be defined as those (tangible and intangible) assets which are tied semi-permanently to the firm" (Wernerfelt, 1984, p.172). Supporting this definition, Barney (1991) adds that "firm resources include all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc." (p.101). Furthermore, Barney (1991) classifies firms' resources into three resources. First, physical capital resources, including industrial machinery and tools used in the firm, the site and the geographic position of the firm, and the accessibility of raw material. The second classification, human capital resources, involves all capacities of individual personnel in a firm, including their educational attainment through training and experience, their intellectual attributes such as intelligence, judgement and insights, and their social relations (Barney, 1991).

The third classification of firm resources by Barney (1991) is organisational capital resources. He explained that organisational capital covers structures, systems, and relations applied in a firm. This capital includes the firm's formal reporting structure, controlling and coordinating system of formal and informal relations among groups within firms or between a firm and its environment. Further, Ludewig & Sadowski (2009) describe the organisational capital of a firm as a representation of "organizational practices, routines, and processes" (p.393) that can be associated with the firm itself or its personnel and their social relations. These resources enable a firm to seek improvement strategies to run the business more efficiently and effectively (Daft, 1983 as cited in Barney, 1991). Therefore, the RBV explains the resources that support the firm's sustained competitive advantage.

Firms' resources are heterogeneous, and the RBV attempts to draw a connection between "heterogeneous resources controlled by an organization, mobility of the resources within the particular industry and the strategic or competitive advantage enjoyed by an organization" (Joyce & Winch, 2004, p. 40). Therefore, the RBV focuses on firm resources in establishing a competitive advantage. As Barney (1991) emphasises, a firm is considered to hold a competitive advantage when its ongoing and prospective competitors do not apply the same strategy. Further, the RBV proposes that for a firm to have a sustained competitive advantage, the benefits of this strategy implementation cannot be duplicated by its competitors, both at present and in the future (Barney, 1991).

In essence, being at a competitive advantage requires a firm "to create a situation where its resource position directly or indirectly makes it more difficult for others to catch up" (Wernerfelt, 1984, p.173). The inclusion of potential competitors is essential for sustaining a competitive advantage since the firm's enjoyment of that advantage does not rely upon a certain period of calendar time. As Barney (1991) states, "a competitive advantage is sustained only if it continues to exist after efforts to duplicate that advantage have ceased" (p.102). For that reason, the RBV identifies some required attributes for firm resources to obtain a sustained competitive advantage.

The main attributes of a firm's resources to hold sustained competitive advantage are that the resources are valuable, rare, imperfectly imitable, and non-substitutable (Barney, 1991). Resources are valuable when they enable the firm to find and apply improvement strategies for effective and efficient performance. In other words, the resources should provide opportunities or neutralise threats in the firm's environment (Barney, 1991; Joyce & Winch, 2004). However, valuable resources cannot be a source of competitive advantage or sustained if they can be easily accessed and implemented by the firm's current and potential competitors (Barney, 1991; Joyce & Winch, 2004). For that reason, 'rare' is another attribute that should be possessed by firm resources to make the firm competitively advantaged. These two attributes of firm resources are strengthened to make the firm's competitive advantage possible and sustainable if competitors' effort to imitate and substitute the value-creating strategy is impossible or would be costly (Barney, 1991; Joyce & Winch, 2004). So, the resources should be imperfectly imitable and non-substitutable.

3.2 The Integration of Resources to Lead to Competitive Advantage

The key notion within the RBV is resources that are difficult for rivals to imitate. However, identifying which resources have this attribute is not easy because some resources are not prohibitively scarce for competitors to find and pursue. For example, physical capital resources, including machinery and tools, can be easily acquired by other firms. Thus, these tangible resources are less valuable for the firm than intangible ones (Teece, 2015).

Intangible resources are difficult to trade, and their value is dependent on their use in the context of firm resources and assets. An example of intangible resources is human capital resources, which are generally difficult to transfer to other firms because of their property rights and likely to have fuzzy boundaries (Teece, 2015). The RBV suggests entrepreneurship as one of the human capital resources that leads to competitive advantage. Having a unique mindset means a firm is likely to have strengths and weaknesses in various competitive environments (Alvarez & Busenitz, 2001). A unique mindset refers to simplifying the strategies used to make a strategic decision in a complex situation where less or uncertain information is available. The uniqueness in the entrepreneur's mindset is called 'heuristics' that are distinguished from managerial cognition in the process of decision making. Therefore, entrepreneurs with heuristics-based logic often make significant leaps of thinking to innovative ideas that are not always linear and factually based. Also, heuristics-based logic allows a faster decision and learning more quickly (Alvares & Busenitz, 2001).

Entrepreneurial heuristics-based logic thinking makes a firm open to technology changes and innovations (Oakey, 2015). These changes can be followed by inventions that bring economic growth and challenge the technological status quo through creative destruction. The creative destruction of the entrepreneur role-broke the status quo of large firms' domination (Oakey, 2015) by replacing existing technologies with better products and services for the benefit of consumers. In terms of invention, it needs to be noted that inventions can come from modifying or optimising the existing method or satisfying customers' needs more adequately (Schumpeter, 1983). Therefore, entrepreneurship capability leads to new opportunities recognition that enables organising firms' resources and creates heterogeneity of outputs superior to the market.

Entrepreneurs who can discover heterogeneous firm resources need to transform them into activities that can profitably be redeployed. The transformation depends on the competency of management to transform firms for competitive advantage. The competency encompasses a cognitive decision rule that determines how people transform resources into outcomes (Fiol, 1991). Hence, the competency often involves having different views between the owner and manager regarding the value of resources when converting the input to output (Alvarez & Busenitz, 2001). However, both owner and manager need to agree that transforming resources into action is a core competency leading to the competitive advantage and becoming part of the organisational identity (Barney, Ketchen Jr. & Wright, 2011; Fiol, 1991).

The organisational identity is central, distinctive, and enduring. Adopted from the definition by Albert and Whetten (1985), organisational identity can be understood as "those features of an organization that its members believe are central, distinctive, and enduring" (Barney, Ketchen Jr. & Wright, 2011, p. 1305). The firm's history as a determinant of competitive advantage influences organisational identity. This history affects the ability of firms to acquire and exploit resources and depends on their place in time and space (Barney, 1991). This journey in exploiting resources conveys how they arrive at where they are and is a source of advantage for firm capabilities (Rumelt, 1993).

The firm's capabilities refer to deploying and integrating different resources using a specific organisational process (Triguero & Córcoles, 2013). This meaning is similar to that for organisational capital resources, the third of Barney's RBV resources categories, which emphasises the firm's control and coordination system relations among groups within firms and between a firm and its environment (Barney, 1991; Ludewig & Sadowski, 2009). Hence, through the firm's capabilities, firms can integrate other capital resources, physical and human capital resources, to create and maintain revenues (Squicciarini & Mouel, 2012). This integration is represented in R&D activities that transform tangible resources or physical capital expenditure combined with intangible resources, represented in personnel skills (OECD, 2002) to increase absorptive capacity and exploit new technology (Triguero & Córcoles, 2013). Thus, R&D activities are represented as the organisation's capital resources that integrate a unique bundle of tangible and intangible resources to lead to a competitive advantage.

R&D activities are firm-specific information assets and a type of business knowledge that affects a firm's production possibility set. In other words, it is the knowledge embodied in firms that means "R&D investments may be seen as additions to the firm's stock of knowledge as it is an important resource both for creating innovation and developing knowledge" (Lome, Heggeseth & Moen, 2016, p. 66). Miyagawa and Kim (2008) agree that investment in R&D activities is associated with organisational capital. Furthermore, R&D activities improve the absorptive capacity of organisational learning (Lome, Heggeseth & Moen, 2016). Therefore, it can be concluded that R&D activities can lead to a sustained competitive advantage for firms.

3.3 Competitive Advantage

The explanation of competitive advantage is related to the competition's positioning and strategy, as proposed by Porter (1985). Competitive positioning represents a firm's decision in choosing the industry in which to operate. The decision about which industry firms choose depends on the different challenges and attractiveness industries possess. Some industries are attractive due to their long-term profitability, but firms need to discover what factors determine this profitability (Porter, 1985). Sometimes firms are in an attractive industry, but they may still not earn profits and vice versa. Therefore, firms need to discover their preferred positioning within the industry, and Porter (1985) addresses this as the firm's competitive position.

Industry attractiveness and firm competitive position are always dynamic and can change over time. Industries can become more or less attractive over time, whereas a competitive position is a never-ending competition among competitors (Porter, 1985). The determination of the industry's attractiveness can be analysed through Porter's (1985) "five forces", and this analysis also provides its underlying causes. Through this analysis, firms can identify their competitive position and strategise to gain a competitive advantage among competitors within industries. Competitive advantage is at the core of success or failure and contributes to firm performance (Porter, 1985).

Competitive advantage is not only about the products or services that firms sell or provide but includes the value of those products or services. Twin (2020) explained that value is what a customer is willing to pay. Porter (1985) argues that firms need to provide super value to customers to gain a competitive advantage. Super value means not only offering a lower price than competitors but providing a unique or equivalent benefit that more than offsets a higher price (Porter, 1985). This value-creating (Simpson, Taylor & Barker, 2004) distinguishes firms from competitors and recognises those with competitive advantages (Porter, 1985; Barney, 1991).

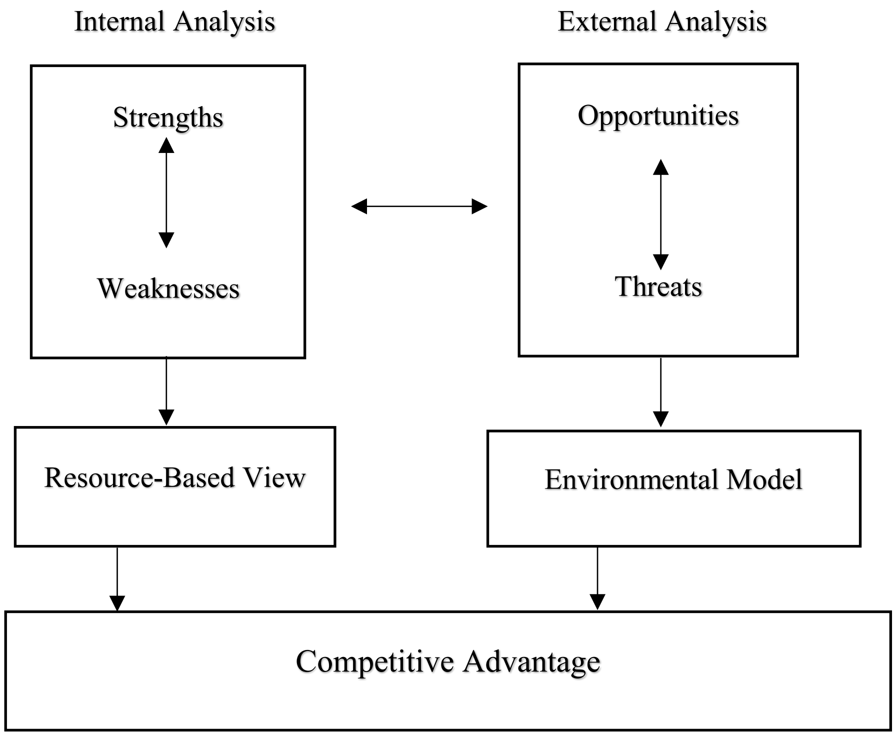
Porter (1980) proposes three generic strategies to maintain a firm's competitive advantage. The first is the cost leadership strategy, which leads to a lower cost of production or process. The second is the differentiation strategy used to distinguish products or services from competitors' products or services. Finally, the third is the focus strategy that allows the firm to focus on a particular market segment. According to Simpson, Taylor and Barker (2004), implementing these various strategies allows a firm to obtain a competitive advantage. However, Porter's proposed strategies are directed toward external forces of the environment in which the firm performs its activities and functions and focuses on its relationship with its suppliers and customers (Joyce & Winch, 2004; Wernerfelt, 1984). This approach is known as the environmental model of competitive advantage, often criticized as short-lived because industry competitors can easily obtain and access the same strategically relevant resources.

The environmental model criticism arises because most environmental models attempt to describe environmental conditions that favour a high level of firm performance and assume firms within any industry are identical in terms of strategic resources they control (Barney, 1991). This assumption contradicts the underlying RBV assumptions. First, firms within an industry may be heterogeneous in strategic resources, and these resources can be long-lasting. Second, the resources are not perfectly mobile. With these assumptions, Barney (1991) argues the merit of being a first mover within an industry to implement a strategy to obtain sustained competitive advantage over other firms. To be the first mover, firms must have the insight of opportunity, making it possible for better-informed firms to be associated with implementing a strategy. Through this strategy, firms can gain access, for example, to distribution channels and a positive reputation from customers before competitors implement the strategy. Therefore, first-moving firms may obtain a sustained competitive advantage (Barney, 1991).

Other criticisms of the environmental model are that it analyses firms' opportunities and threats in their competitive environment, assuming that opportunities are greater than threats (Barney, 1991). Thus, firms focus on the external perspective in analysing opportunities, such as the products or services offered to customers. On the other hand, firms' resources and products or services are two sides of a coin, where products require service from several resources and most resources can be used in several products (Wernerfelt, 1984). Therefore, even though the underlying assumptions are different, the RBV and environmental models represent complementary strategies and yield the same insight. The environmental model cannot be expected to improve a firm's expected performance more than other models without analysing the firm's unique skills and capabilities (Barney, 1986). The RBV exploits the internal strength of firms and identifies weaknesses by responding to environmental opportunities after neutralising the threats (Barney, 1991). The RBV and environmental models can be discrete or compound to gain a sustained competitive advantage (Ma, 2000).

The link between the RBV and environmental model using traditional SWOT (strength-weakness-opportunities-threats) analysis is shown in Figure 11.

Figure 11 Relationship between RBV and environmental model from SWOT analysis



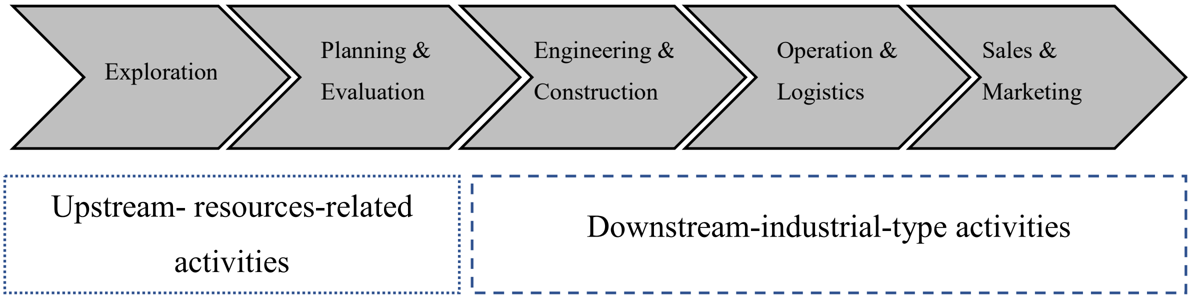
Source: Barney, J (1991), 'Firm Resources and Sustained Competitive Advantage

3.3.1 Competitive Advantage in the Mining Industry

As previously explained, the attractiveness of an industry depends on managers' views because each industry has its different challenges and attractiveness. The manager needs to discover the potential resources the firm has. Based on that, managers can choose which competitive position of their business to run (Porter, 1985). Resources and competitive positions direct managers to choose Porter's strategies to gain a competitive advantage. In terms of the mining industry, with a situation where the global market price sets the price, with no significant difference in products exists (Csiminga et al., 2015; Filippou & King, 2011), cost leadership strategies to lower the cost of mineral extraction are appropriate to apply.

In order to consider cost leadership as a determinant of competitive advantage in mining firms, it is necessary to use a value chain approach. The value chain approach is considered a basic tool for identifying a competitive advantage by arranging value-adding activities to satisfy customers' requirements in a sequential chain (Porter, 1985). Thus, value-adding activities and the linking of these activities are the sources of competitive advantage. Csiminga et al. (2015) added that the two value chains map upstream resources-related activities and downstream industrial activities for mining firms. The linking of these value chains is depicted in Figure 12.

Figure 12 Mining value evaluation



Source: Csiminga et al. (2015)

Some managers who focus on production are convinced that downstream activities are value creation activities that cause the creation of competitive advantage through cost minimisation (Csiminga et al., 2015). Lately, there is shifting support to upstream activities that create value in the mining activities that create a competitive advantage. Given an argument about a focus shift, mining firms need to answer a fundamental question about which activities bring added value and which add costs? From that point, mining firms can improve their operational performance to meet output targets and generate superior performance (Csiminga et al., 2015).

3.4 Competitive Advantage leads to Firm Performance

Firms compete in their industry to gain a competitive advantage because they count on it to bring superior performance. Even though some firms achieve superior performance without a competitive advantage, other external interventions or factors may be involved, such as government regulation or environmental shock. However, these external interventions are considered competitive advantages (Ma, 2000). Alexander & Ansari (n.d.) suggested that a strong regulatory regime can be a competitive advantage for the government as the policymaker or firms as the doers; hence mutual benefit can arise exclusively between them to increase economic growth.

Competitive advantage gives firms leverage over competitors. It should be emphasised that competitors, in this case, refer not only to current competitors but also to potential competitors poised to enter an industry in the future (Barney, 1991). The competitive advantage solidifies firms' position in the industry in the long run. Firms attain sustainable growth

(Simpson, Taylor & Barker, 2004) because competitive advantage helps create better value for customers, subsequently contributing to firm performance (Ma, 2000). Therefore, when competitors duplicate a competitive advantage, it affects firm performance in the long-term.

3.5 Hypotheses Development

As explained by the RBV, resources are one of the essential factors for understanding the origin of a firm's sustained competitive advantage (Barney, Ketchen Jr. & Wright, 2011). However, achieving a competitive advantage needs integration among the resources. R&D activities are represented as firm capabilities in integrating resources and between a firm and its environment that transforms them (OECD, 2002) to increase absorptive capacity and exploit new technology (Triguero & Córcoles, 2013). Subsequently, R&D activities influence firms in creating and maintaining revenues (Squicciarini & Mouel, 2012) and improving productivity and revenue (Rafiq, Salim & Smyth, 2016) and profit (Alarcón & Sánchez, 2013).

In terms of mining firms, R&D activities are value creation activities, either downstream or upstream that cause the creation of competitive advantage to improve their operational performance to meet output targets and generate superior performance (Csiminga et al., 2015). Using RBV to identify the unique resources of firms and the integration among resources through R&D activities lead to competitive advantage and subsequently improve their revenue and influence profit, this study develops two hypotheses to answer the first research question (RQ1) as follows:

RQ1: Does spending on R&D activities influence the profitability and revenue growth of mining firms in Australia?

Hypothesis 1: Spending on R&D activities significantly influence profitability for mining firms in Australia

Hypothesis 2: Spending on R&D activities significantly influence revenue growth for mining firms in Australia

R&D activities are considered an investment in intangible assets that contribute to the long-term growth of firms (Ehie & Olibe, 2010). Hence, many firm assets comprise less tangible assets to gain market competitiveness through knowledge of consumers' perceptions and branding their services to differentiate from other firms. Some literature suggests that R&D intensity is an important determinant of firm profitability. Even though the activities are generally a high-risk return, they are attractive to shareholders in anticipation of firms' better financial performance (see Coad, 2019; Ehie & Olibe, 2010; Griliches, 1981; Kim et al., 2018). Thus, R&D activities increase firms' innovative capabilities and may enhance performance in the capital market. This study develops Hypothesis 3 as follows:

RQ2: Does spending on R&D activities influence Tobin's q of mining firms in Australia?

Hypothesis 3: Spending on R&D activities significantly influences Tobin's q for mining firms in Australia

3.6 Summary

This chapter presents the theoretical framework used in this study to develop hypotheses to answer research questions. The theoretical concept used in this study is the RBV, which explains the usefulness of a firm's resources to gain a competitive advantage. The firm's resources comprise physical capital resources, human capital resources and organisational capital resources. However, these resources need to be valuable, rare, imperfectly imitable, and non-substitutable for firms to gain a competitive advantage.

Identifying which resources have the three attributes is not easy because some resources are not prohibitively scarce for competitors to find and pursue. Physical capital resources, including machinery and tools, can be easily acquired by other firms. Thus, these tangible resources are less valuable for the firm than intangible ones. Intangible resources, for example, human capital resources, are generally difficult to transfer to other firms because of their property rights and are likely to have fuzzy boundaries. These intangible resources are difficult to trade due to their value being dependent on their use in the context of firm resources and assets.

Organisational capital is a resource that integrates the two other capital resources. This capital comes from the journey of firms in exploiting resources, conveys how they arrive at where they are and is a source of advantage for firm capabilities. The firm's capabilities deploy and integrate different resources using a specific organisational process and are represented in

R&D activities that transform tangible resources, with support from intangible resources or personnel skills, to lead to a competitive advantage.

Competitive advantage is related to the value of products or services a customer is willing to pay for. Firms need to provide customers with super value that distinguishes them from competitors and prompts customers to recognise firms with competitive advantages. The three strategies to achieve a competitive advantage are differentiation, cost leadership and focus. However, in terms of the mining industry with a situation where the global market price sets the price, with no significant difference in products existing, cost leadership strategies to lower the cost of mineral extraction are appropriate to apply. As a determinant of competitive advantage in mining firms, a value chain approach is necessary to use by arranging value-adding activities to satisfy customers' requirements in a sequential chain that can be from downstream or upstream activities.

Competitive advantage gives firms leverage over competitors, referring not only to current competitors but also to potential competitors poised to enter an industry in the future. The competitive advantage solidifies firms' position in the industry, in the long run, to attain sustainable growth because competitive advantage helps create better value for customers, subsequently contributing to firm performance. Hence, this study develops three hypotheses positing that spending on R&D activities influences profitability, revenue growth and Tobin's q in mining firms in Australia.

Chapter 4 - Research Method

This study requires various forms of data to investigate the influence of spending on R&D activities on firm performance in Australian mining firms. Therefore, a mono-method archival study with longitudinal data is selected to develop a comprehensive understanding of the influence of spending on R&D activities on firm performance. This chapter presents the research design to draw inferences from testing the hypotheses developed from the two research questions in Chapter 2.

This chapter starts with a description of the research paradigm as a fundamental belief that affects the ways to conduct this study. The dominant paradigm underpinning this study, positivism, provides the rationalisation for using a quantitative research approach, with a mono-method archival study approach to comprehensively address the research questions. Section 4.2 develops the empirical model and is followed by identifying the variables used and the measures in this study, including the measures proxying for R&D activities and firm performance. This section also explains how the data are collected and the rationale for the analysis method and its application, including preliminary testing, descriptive analysis, and regression techniques. Finally, this chapter ends with a summary of the research methodology used in section 4.3.

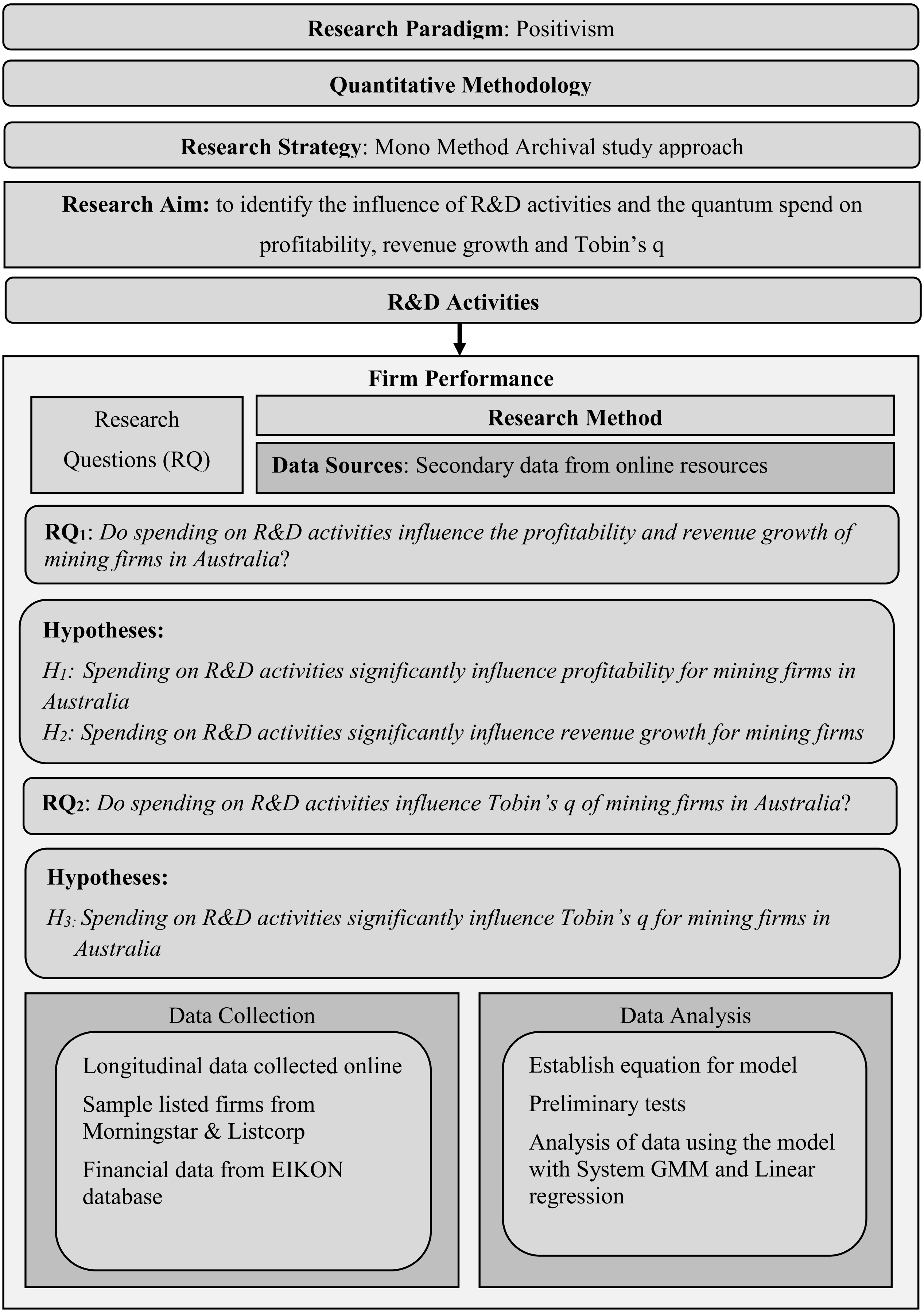
4.1 Research Design

To develop a research design, understanding the research objective and questions is the starting point to deciding the paradigm and approach, followed by the research strategy, data collection techniques and analysis procedures (Saunders, Lewis & Thornhill, 2015). The research paradigm in this study is positivism using an existing theory, the resource-based view (RBV), as a foundation to develop the hypotheses. According to Saunders, Lewis and Thornhill (2015), the positivism research paradigm helps to produce credible evidence through developing and testing whether the hypotheses are confirmed or refuted. They argue that results from hypotheses testing can lead to further development of theory, which then may be examined by further research.

A quantitative method that emphasises objective measurement and statistical data analysis is adopted to test the hypotheses. The data are collected using a single data collection technique called a mono-method (Saunders, Lewis & Thornhill, 2015). The principal data source is an online resource documented and administered by Refinitiv (formerly Thomson Reuters) Eikon database. Thus, this study is classified as archival, explaining the relationship between variables using numerical data (Bhandari, 2021).

A longitudinal approach is adopted, whereby data are collected from a population of firms for a period and summarised statistically. The population of mining firms listed on the ASX is collected from the Eikon database that provides financial and economic data. The research design for this study is summarised in Figure 13

Figure 13 The research design of the influence of spending on R&D on firm performance



4.2 Data and Methodology

4.2.1 Empirical Model

The selection of the empirical model included in this study comes after an extensive review of the literature concerning the influence of R&D on firm performance. R&D expenditure is the hypothesised explanatory variable, and firms' performance is the dependent variable.

Including two major indicators to identify mining firms' performance, profit and revenue growth represents a comprehensive test of R&D influence. While focusing on the influence of spending on R&D on profit and revenue growth, the firm-specific characteristics: firm size and leverage and macroeconomic fluctuations using year indicators are used as control variables.

Following the majority-view in the literature on the influence of R&D on firm performance (Alarcón & Sánchez, 2013; Coad & Rao, 2008; Ehie & Olibe, 2010; Kim et al., 2018; García-Manjón & Romero-Merino, 2012; Lome, Heggeseth & Moen, 2016; Shin, Kraemer & Dedrick, 2017), this study estimates the following equation.

To test Hypothesis 1, the influence of spending on R&D on profitability constructs, the following model is used:

Equation 1 Regression model to test Hypothesis 1

$$ROA_{it} = \alpha_0 + \alpha_1 ROA_{i(t-1)} + \alpha_2 RDI_{i(t-1)} + \alpha_3 Lev_{it} + \alpha_4 Size_{it} + \alpha_5 Year_{it} + \mu_{it} + \varepsilon_{it}$$

where: ROA_{it} denotes firm performance, $ROA_{i(t-1)}$ is lagged profitability (previous year profitability); and $RDI_{i(t-1)}$ represents lagged R&D intensity. This study controls for Lev_{it} and $Size_{it}$, leverage and firm size, respectively, over the period as firm-specific characteristics or business capabilities; $Year_{it}$ represents a dummy to capture the external changes not captured by firm data, for instance, economic inflation; μ_{it} is firm-specific fixed effects; and ε_{it} represents the error term.

To test Hypothesis 2, the influence of spending on R&D on revenue growth, the following model is used:

Equation 2 Regression model to test Hypothesis 2

$$Growth_{it} = \beta_0 + \beta_1 Growth_{i(t-1)} + \beta_2 RDI_{i(t-1)} + \beta_3 Lev_{it} + \beta_4 Size_{it} + \beta_5 Year_{it} + \mu_{it} + \varepsilon_{it}$$

Where variables are defined as previously and $Growth_{it}$ denotes revenue growth

To test Hypothesis 3, the influence of spending on R&D on Tobin's q. Following the majority-view in the literature on the influence of R&D on Tobin's q (see, for example, Connolly & Hirschey, 2005; Kim et al., 2018; Shin, Kraemer & Dedrick, 2017), three empirical models are developed. While controlling the firm size and financial strength, the first model is developed. According to Connolly and Hirschey (2005), profitability is a significant determinant of the market value of the firms as measured by Tobin's q. Hence, this study adds profitability as a control variable and develop the second model. Furthermore, the third model is developed to anticipate the existence of a non-linear relationship between R&D and Tobin's q (see Kim et al., 2018). The three models are developed as follows:

Equation 3 The Regression model to test Hypothesis 3

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 Lev_{it} + \gamma_3 Size_{it} + \gamma_4 Year_{it} + \varepsilon_{it} \quad (1)$$

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 RDI^2{}_{it} + \gamma_3 Lev_{it} + \gamma_4 Size_{it} + \gamma_5 Year_{it} + \varepsilon_{it} \quad (2)$$

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 ROA_{it} + \gamma_3 Lev_{it} + \gamma_4 Size_{it} + \gamma_5 Year_{it} + \varepsilon_{it} \quad (3)$$

Where variables are defined as previously and Q_{it} denotes Tobin's q as per the Q calculation, $RDI^2{}_{it}$ is the square of RDI_{it}, where RDI represents R&D intensity. The inclusion of the square of RDI_{it} in the regression anticipates the possibility that the influence of R&D is not linear following Kim et al. (2018).

4.2.2 Measures

The measures for the main and control variables are adopted from prior studies that have validated them. Each variable measure is discussed in the following section. Table 1 shows the measures adopted, and the studies that used them are referenced.

Table 1 Reference studies to construct variable dimensions and measures

Construct	Dimensions	Measurement	Reference
Firms' Performance	Accounting-based Dimension	Profitability	Busru & Shanmugasundaram (2017); Shin, Kraemer & Dedrick (2017); Alarcón & Sánchez (2013); Rafiq, Salim and Smyth (2016); Sun & Anwar (2015)
		Growth	Lome, Heggeseth & Moen (2016); García-Manjón & Romero-Merino (2012); Coad & Rao (2008); Coad & Rao (2010)
	Market-based Dimension	Tobin's q	Shin, Kraemer & Dedrick (2017); Hall & Oriani (2006); Bae, Park & Wang (2008); Chauvin & Hirschey (1993); Connolly & Hirschey (2005); Kim et al. (2018)
R&D Activities	R&D Expenditure	R&D Intensity	Shin, Kraemer & Dedrick (2017); García-Manjón & Romero-Merino (2012); Ehie & Olibe (2010); Kim et al. (2018); Alarcón & Sánchez (2013); Lome, Heggeseth & Moen (2016), Gui-long et al. (2017); Sun & Anwar (2015)
Control Variables	Firms Size	Total Assets	Kim et al. (2018); Bae, Park & Wang (2008); Han & Cheng-Min (2011); Tsai & Wang (2005)
		Total Revenue	Ehie & Olibe (2010); García-Manjón & Romero-Merino (2012); Chauvin & Hirschey, (1993)
	Financial Capability	Leverage ratio	Ehie & Olibe (2010); Kim et al. (2018)
	Year dummies	dummy	García-Manjón, & Romero-Merino (2012)

4.2.3 Dependent Variables

The outcome performance measures hypothesised as associated with the presence or absence of R&D activities, and for firms with R&D activities, comparatively higher R&D expenditure, are adapted from previous studies cited in Table 1. Several studies measure the outcome of R&D activities using different measures from different perspectives. However, most performance measures are related to expected economic outcomes, with the most common measures being profitability, revenue growth and market value.

These three performance measures are categorised as financial performance (Santos & Brito) as they can be drawn from internal financial data prepared by firms (Venkatraman & Ramanujam, 1986). However, the market value reflects shareholders' concern about the firm's future performance as is measured by combining internal financial data and the assumption used that shareholders predict the future of firms (Al-Matari, Al-Swidi & Hanim, 2014). Therefore, profitability and revenue growth represent accounting based measure drawn from the internal perspective, while market value is from an external perspective (Al-Matari, Al-Swidi & Hanim, 2014; Venkatraman & Ramanujam, 1986). These three performance measures are adopted in this study to assess the outcome of the influence of R&D. The measures of firm performance are explained in the next section.

4.2.3.1 Profitability

R&D activities will likely improve productivity and the production process (Rafiq, Salim & Smyth, 2016); hence they can reduce the cost of production and subsequently increase profitability. Profitability can be measured in many ways, for example, gross profit or net income (Rafiq, Salim & Smyth, 2016; Busru & Shanmugasundaram, 2017) or ratios such as profit margin (Shin, Kraemer & Dedrick, 2017; Sun & Anwar, 2015) or return on investment (Busru & Shanmugasundaram, 2017).

Among these profitability measures, Return on Assets (ROA) is the most common measure since it measures the ability of firms to effectively utilise investment in assets such as plants and equipment (Shin, Kraemer & Dedrick, 2017). However, in terms of return or earnings used as the nominator in the ratio, some scholars use different measures of return, such as revenue (Shin, Kraemer & Dedrick, 2017) or earnings before interest, taxes, depreciation and amortisation (EBITDA) (Alarcón & Sánchez, 2013).

The measurement of EBITDA excludes the effect of tax and the involvement of assets' usage through depreciation or amortisation. EBITDA excludes financing income or spending.

Thus, it reflects productive activity without the involvement of financing costs or depreciation and is close to measuring the real economic behaviour of firms (Alarcón & Sánchez, 2013).

Based on previous studies and R&D activities being risky, with a multi-stage time frame, long-lasting impact (Bakker, 2013) and long-term financial support needed, profitability is measured using ROA calculated as per Alarcón and Sánchez (2013) as the ratio of EBITDA to total assets. Since some R&D activities will be financed from equity-based resources without collateral or interest requirements (Alam, Uddin & Yazdifar, 2019; Brown, Fazzari & Petersen, 2009; Hall et al., 2016), using EBITDA minimises the impact of the type of financing.

In terms of EBITDA calculation, also added back is R&D expenditure, following Blass and Yosha (2003). As mentioned, spending on R&D activities is a voluntary disclosure (Percy, 2000). Firms can either expense or capitalise the spending on R&D activities based on generally accepted accounting standards. However, the Eikon database treats spending on R&D activities as an expensed portion of R&D costs for both disclosures, expensed or capitalised, which reduces profit. Therefore, adding back R&D expenditure to EBITDA avoids R&D activities being counted twice in profitability and the hypotheses variables. The formula of ROA_{it} is depicted as follows:

$$ROA_{it} = \frac{EBITDA_{it} + R\&D\ Expense_{it}}{Total\ Asset_{it}}$$

4.2.3.2 Revenue Growth

The time lag between the outlay of R&D expenditure and the resulting from completion to commercialisation of the R&D activities is often neglected in trying to estimate returns from R&D (Lome, Heggeseth & Moen, 2016). Even if constituting a step towards commercialisation, it takes time to convert R&D outcomes into revenue. The creation of knowledge through R&D activities is expected to influence the development of firms in terms of their growth.

There are two methods for measuring firm growth, aggregate growth and yearly growth. These measures have a common understanding that growth is related to revenue figures, and the calculation is based on a chosen year as the comparison. The first method, aggregate growth, was used by Lome, Heggeseth and Moen (2016) to measure the effect of R&D by choosing 2004 as the base year due to data collection starting in 2004. Another measure is yearly growth, measured as current revenue growth based on the previous year's revenue. Lome, Heggeseth and Moen (2016) used both measures to understand the influence of R&D

on firms' growth as they compare two event periods, before and after the global financial crisis (GFC). However, yearly growth fails to account for inflation, so it is biased. Coad and Rao (2008) address this issue by measuring growth using the difference in the logarithm of revenue, which removes common macroeconomic trends. Therefore, this study follows Coad and Rao (2008; 2010) and García-Manjón and Romero-Merino (2012) by using the difference in logarithms of current less prior year revenue. The formula for $Growth_{it}$ is depicted as follows:

$$Growth = \log(Revenue_{it}) - \log(Revenue_{i(t-1)})$$

4.2.3.3 Tobin's q

The market-based measure used in this study is Tobin's q (Q). Q represents a measure of firm value, consisting of tangible assets and intangible assets (Hung & Chou, 2013). Thus, Q can be a good proxy for firms' competitive advantage indicating a forward-looking measure of firms' performance (Hung & Chou, 2013) and is not affected by accounting conventions (Chakravarthy, 1986); however, Q is a complex calculation.

Q is calculated as the ratio of the market value of firms and the replacement cost of their assets (Chung & Pruitt, 1994). The complexity of calculating Q is due to the difficulty in measuring the replacement cost of firms' assets. The replacement cost of assets consists of the value of tangible and intangible assets. Tangible asset value can be drawn from financial reporting; however, intangible asset value is difficult to measure (Hall, Jaffe & Trajtenberg, 2005; Hung & Chou, 2013) because it is not captured by accounting conventions (Chakravarthy, 1986).

Due to this difficulty in determining the replacement cost, a simple approximation proposed by Chung and Pruitt (1994) with readily available data in the balance sheet is used. This simple Q calculation captures at least 96.6 per cent of the variability in the Q calculation (Chung & Pruitt, 1994). The simple measure of Q is the sum of the market value of common shares outstanding times price plus the book value of the total liabilities of firms, all divided by the book value of total assets. The formula for approximate Q, according to Chung and Pruitt (1994), is $approximate\ q = (MVE + PS + Debt)/TA$, which MVE is the number of common shares outstanding times the market price, while PS represents the liquidated value of the preferred stock, $Debt$ is the book value of total liabilities, and TA represents the book value of total assets.

4.2.4 Explanatory Variables

The main explanatory variable, spending on R&D activities, is measured as the ratio of R&D expenditure to revenue to measure innovativeness following García-Manjón and Romero-Merino, (2012). This ratio is called R&D intensity and represents firm innovative effort (Cohen & Klepper, 1992). In terms of R&D expenditure as the nominator, according to Fan, Yan and Sha (2017), it can be calculated as two categorised measures, innovation output and input. The measurement through innovation output comes from the number of patents or intellectual property (IP) registration (Fan, Yan & Sha, 2017). However, patent counts have a limitation since not all R&D activities can turn into patentable innovation, and the process of patent acquisition is expensive and slow, with most firms not intending to patent their innovation (Coad & Rao, 2008; Fan, Yan & Sha, 2017). The actual economic value of patents is highly skewed and concentrated in a small percentage of the total patentable innovation (Coad & Rao, 2008).

The reported R&D expenditure in the Eikon specifies that R&D expenditure is the portion directly expensed in the income statement, outside of the cost of goods sold. The definition of R&D expenditure in the Eikon database mentioned that R&D represents expenses for the research and development of new products or services by a company to obtain a competitive advantage. Moreover, Eikon gives examples of categorised R&D expenditures such as mineral exploration and evaluation, computer software and databases, the cost of collecting and analysing geophysical and seismic data in potential crude oil or natural gas exploration sites, and the cost of drilling wells[3]. The measure of R&D expenditure in Eikon is similar to the measure through innovation input, including internal resources such as material purchase, personnel cost of staff in the R&D department, engineering design, and the R&D budget (OECD/Eurostat, 2018).

There is a dispute about using R&D expenditure as a measure of R&D activities. It may be a good indicator for a firm with a technological position (Hall, 2004), but mining firms are not considered high-tech firms (Bartos, 2007). However, according to Oslo Manual (OECD/Eurostat, 2018), firms that perform R&D activities usually maintain a record of their R&D expenditure for a range of reporting requirements that includes five standard categories: R&D, personnel cost, external service disbursement, materials cost and capital goods. A manager has discretion regarding what information to disclose about R&D (Percy, 2000).

[3] The definition of R&D in the Eikon database is under COA code: ERAD with the Eikon for Office field TR.ResearchAndDevelopment. The office label for this definition is under Research and Development.

Using the Eikon database estimates R&D expenditure as the portion directly expensed in the income statement outside the cost of goods sold. In terms of firms disclosing the expensed and capitalised portions of R&D expenditure, the Eikon database provides estimates of the calculation applied to arrive at R&D rather than the combined value.

4.2.5 Control Variables

Firms' business capabilities potentially support managers' decisions about conducting R&D activities. Thus, business capability measures need to be included in the analysis of the influence of R&D on firm performance (OECD/Eurostat, 2018). However, internal capabilities or resources are crucial due to their ease of control (Lai, Lin & Lin, 2015). Also, they can distinguish among competitors for firms to gain a competitive advantage (Barney, 1991; Wernerfelt, 1984).

Internal resources included in this study are treated as control variables due to the possibility of autocorrelation and dependence of firm performance on the resource. The internal resources needing to be controlled come from firms' general resources. Based on Oslo Manual (OECD/Eurostat, 2018), these are firm size and financial strength. The measures for each control variable are explained in the following section.

4.2.5.1 Firm Size (SIZE)

Firm size is related to the propensity of firms to conduct R&D activities (Cohen & Klepper, 1996; OECD/Eurostat, 2018). However, several studies have inconclusive findings concerning whether large or small firms are advantaged in conducting R&D (Lee & Sung, 2005). One study indicates that larger firms earn higher returns on R&D due to cost spreading (Connolly & Hirschey, 2005; Legge, 2000). However, the theory of economic development through Schumpeter Mark-I argues that smaller firms challenge the status quo of larger firm domination through creative destruction with technology easing entry (Malerba & Orsenigo, 1996; Oakey, 2015). In addition, Revilla and Fernández (2012) argue that as firms grow, the lack of flexibility to conduct R&D activities increases due to complex bureaucracy. However, as highlighted by Oakey (2015), "both sizes always have an important contribution to make towards R&D effectiveness" (p. 394).

The measure for firm size (Size) is total assets at the end of a financial year, following Han and Chuang (2011) and Tsai and Wang (2005). Several studies use a different measure of firm size. For example, Connolly and Hirschey (2005) use market capitalisation and others use the number of employees (Kim, Lee & Marschke, 2009; Rafiq, Salim & Smyth, 2016; Revilla & Fernández, 2012) or revenue (Lome, Heggeseth & Moen, 2016). However, the data for total assets consistently exist in the data source.

4.2.5.2 Financial Strength – Leverage (LEV)

The financing ability plays an important role in conducting R&D activities (Ughetto, 2008) because of the inherent risk of the activities, which have a long time frame (Bakker, 2013) and uncertainty of success (Lai, Lin & Lin, 2015). Each step in R&D activities needs to be funded since returns from the activities cannot be predicted in advance (Bakker, 2013; Hall et al., 2016), and firms have various options to finance them. According to Hall et al. (2016), internal financing is a positive option because no collateral requirements are involved, and adverse selection problems are not created. Another option with the same characteristics as internal financing is external financing from equity, and additional equity does not magnify problems associated with financial distress (Brown, Fazzari & Petersen, 2009).

The option of financing R&D activities depends on decisions by firms, but some scholars agree that strategic investment, in this case in R&D activities, requires large capital expenditure (see Hall et al., 2016; Spescha, 2019; Wang & Thornhill, 2010). From a management perspective, debt is less intrusive because debt investors can take control only if the firm defaults on the contract (Vicente-Lorente, 2011). In addition, debt financing reduces overinvestment, which helps managers gain compensation and power but does not create value for shareholders (Wang & Thornhill, 2010). However, too much debt causes financial distress and increases default risk, reflected in risk-return preferences and strategic decisions. Therefore, financial strength in this study is measured as the leverage ratio, measured as the ratio of total debt to total assets, following Ehie & Olibe (2010) and Kim et al. (2018).

4.2.5.3 Years (YEAR)

Time is needed to convert valuable knowledge into firm economic performance, as Ehie and Olibe (2010) highlighted since there is a lag between discovery and commercialisation. Therefore, YEAR indicators are used to capture possible common economy-wide factors faced by firms over the study period.

4.2.6 Data Collection Method

Data collection occurred from three resources for three purposes. The first resource was the Listcorp website to collect the names of ASX listed firms in the metal and mining industry (GICS 151040). The second was the Morningstar DatAnalysis database to collect the names of firms delisted during the period of study (2006 - 2017). Morningstar also provides listed firm names specific to the metal and mining industry. Thus, Morningstar (list of listed and delisted firms) and Listcorp (list of listed firms) were reconciled to generate the names of all ASX metals and mining industry listed firms. The third database was the Eikon database for the collection of financial data. The Eikon database includes estimates of R&D expenditure since it is a voluntary disclosure. The definition of R&D expenditure in the Eikon database mentioned that R&D represents expenses for the research and development of new products or services by a company to obtain a competitive advantage.

From Listcorp, a population of 2216 firms was identified as listed on the Australian Securities Exchange (ASX) in 2017. Listcorp is a private Australian firm that focuses on research to help investors discover new investment opportunities in ASX and identifies industries based on the Global Industry Classification Standard (GICS) developed by MCSI in collaboration with S&P Dow Jones[4]. Under the GICS, the 2216 firms are categorised into 11 sectors and 24 industry groups. Each sector and industry group is identified by number and name. For instance, GICS number 15 represents the materials sector consisting of one industry group, materials (GICS 1510). The materials industry group consists of five industries: chemicals, construction materials, construction and packaging, metals and mining, and paper and forest products. The mining industry, as the focus of this study, is in the group of metals and mining industries with GICS number 151040, covering seven sub-industries: gold, steel, silver, copper, aluminium, precious metals, minerals and other diversified metals and mining firms.

Under GICS 151040, 525 firms were listed on the ASX for the year 2017, excluding delisted and suspended firms over the study period. The Morningstar database was used to retrieve names for delisted and suspended firms. Morningstar is a multinational firm that provides research and data as bridge information for investors and investing advice[5]. With

[4] According to Listcorp, the categorising firms in ASX is based on GICS method as mentioned in the websites of listcorp: https://www.listcorp.com/asx/sectors/ broken up into 11 sectors, 24 industries group, 69 industries and 158 sub-industries. GICS is developed to provide and efficient and detailed and flexible tools for use in the investment process as explained in the principle guidelines and methodology for GICS in https://www.msci.com/documents/1296102/11185224/GICS+Methodology+2020.pdf

[5] See website https://www.morningstar.com.au/About

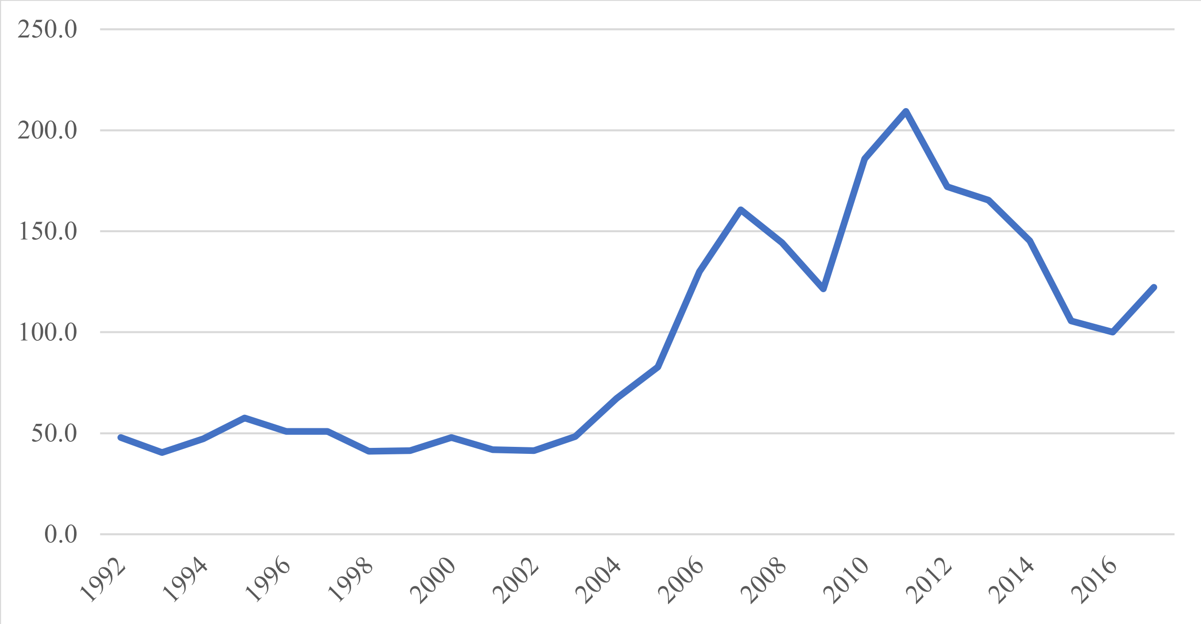
some adjustments for firms merged or acquired, 927 firms were listed in the metals and mining industry over the study period from 2006 - 2017.

The focus of this study is mining firms on the ASX that conducted R&D activities. Firms conducting R&D activities were identified through their annual financial reporting. However, firms are not mandated to report R&D expenditure in their financial statements or notes to the financial statements under accounting standards (Percy, 2000), which created a challenge for this study. The Eikon database includes an estimate of the amount expensed for R&D activities during the year, excluding the portion capitalised to tangible and intangible assets. This estimation made it possible to retrieve data on mining firms' spending on R&D activities. Of the 927 ASX listed mining firms, 538 (58 per cent) were identified in the Eikon database as spending on R&D within the period 2006 – 2017.

In this study, data are collected for the period 2006 – 2017. The Australian Financial Reporting Council (FRC) adopted International Financial Reporting Standards (IFRS) in June 2002, but full adoption was effective for annual periods commencing on or after 1 January 2005. Therefore, selecting the study period from 2006 means firms had adopted IFRS, and their reporting is comparable.

The mining cycle is also a consideration in the study period chosen. The mining boom in Australia started in 2003 and ended in 2008 with the GFC (Filippou & King, 2011). The GFC caused a decline in mineral prices, but the previous year's orders not yet delivered increased the volume of extracted minerals in 2009, so production capacity increased. This situation influenced the recovery of the mineral price above the previous years, with Deloitte (2017) arguing this situation caused the mining boom to continue until 2013. After 2013, most mineral prices, including copper, aluminium, iron ore, tin, nickel, zinc, lead and uranium, declined and continued dropping until 2017, when the mineral price index dropped to that in 2006. This pricing trend is shown in Figure 14.

Figure 14 Price movement in mineral commodities



Source: IMF (2021)

Data presented is the International Monetary Fund's (IMF) mineral price index which includes the prices of copper, aluminium, iron ore, tin, nickel, zinc, lead and uranium, with the reference year of 2016 = 100

4.2.7 Data Analysis Method

A panel data model close to actual economic behaviour is used as suggested by Fan, Yan and Sha (2017). The panel data model includes three dimensions of information, cross-section, time and variables.

Three stages are involved in conducting panel data analysis. The stage starts with a preliminary test to choose adequate regression analysis techniques by evaluating multicollinearity using variance inflation factors (VIF) and a Pearson Correlation Coefficient Matrix. The next preliminary test is an assessment of heteroskedasticity and endogeneity in the explanatory variables. This preliminary testing and its outcomes led to the regression techniques used. However, before applying appropriate regression techniques, the data were analysed using descriptive statistics to describe features from the data collection. Then it ends up with multiple regression analysis techniques, System GMM and Ordinary Least Squares (OLS), to examine the hypothesised relationship among variables. STATA 16 software is used for the data analyses.

4.2.7.1 Preliminary test

4.2.7.2 Multicollinearity test

This stage checks for multicollinearity amongst variable measures that could cause coefficient estimates to be unreliable (Coad & Rao, 2010). Pearson's correlation coefficients and VIFs are used to check for the presence of multicollinearity. The Pearson's correlation coefficient is a bivariate test between two variables, while the VIF is a multivariate test among variables used. The minimum VIF indicating the absence of multicollinearity is 1.0, revealing low collinearity between variables (Schroeder, Lander & Levine-Silverman, 1990). If the VIF value is over 1, the regressors could be moderately correlated, whereas between 5.0 and 10 is considered high and perhaps problematic (Akinwande, Dikko & Agboola, 2015). Values over 10 indicate that multicollinearity may unduly influence the estimators (Kutner et al., 1996).

4.2.7.3 Heteroskedasticity Test

This test checks the variance in the standard errors for all observations. When heteroskedasticity is present, it means that the variance of the error term is not constant but rather conditional on the regressors. However, this does not make the coefficient regression estimates inconsistent or invalid; instead, the standard error of the estimates is biased (Baltagi, 2005; Bascle, 2008; Baum, Schaffer & Stillman, 2003; Williams, 2020).

Two tests can be undertaken to check for the presence of heteroskedasticity. First, using a visual inspection by conducting a residual plot graph to illustrate the least-squares values against explanatory variables. Second, using two tests, the Breusch-Pagan/Godfrey/Cook–Weisberg and White/Koenker statistics, which are standard tests in an OLS regression (Baum, Schaffer & Stillman, 2003).

4.2.7.4 Endogeneity Test

The next stage is to check endogeneity, and failure to control for endogeneity could lead to spurious results (Schultz, Tan & Walsh, 2010). Endogeneity can come from errors-in-variables, omitted variables, or simultaneity causality (Bascle, 2008; Woolridge, 2010). Any of these might cause parameters to be imprecise and the error term to be underestimated in the model (Ullah, Akhtar & Zaefarian, 2018). Therefore, performing endogeneity tests is a serious concern (Lu et al., 2018).

The Durban-Wu-Hausman (DWH) test is commonly used to detect the endogeneity of individual regressors (Ullah, Akhtar & Zaefarian, 2018). The DWH is implemented by first testing whether each independent variable is endogenous or exogenous. For this, a regression was estimated on each independent variable with all control variables to predict the residuals. In the next step, the coefficient for the residual was estimated to test whether the residual is significant. A significant DWH test indicates that the variable is endogenous.

4.2.7.5 Descriptive Analysis

Descriptive statistics were used for organising, summarising, and describing the important characteristics of the set of data (Samuels, Witmer & Schaffer, 2012).

4.2.7.6 Regression Analysis

System general method of moments (GMM) and ordinary least squares (OLS) multiple regression techniques are applied to estimate the influence of R&D on firm performance. System GMM is applied when potentially endogenous variables are present in the regression (Ullah, Akhtar & Zaefarian, 2018) determined by at least one of the causes mentioned being present (Bascle, 2008). Instrumental variables (IV) techniques are often used to address endogeneity, with the most common IV estimator technique being 2SLS (Shepherd, 2009). However, 2SLS addresses endogeneity by one endogenous variable in a model needing one IV, two endogenous variables needing at least two and so forth (Shepherd, 2009).

The IV can be a valid instrument if there is a strong correlation with a potentially endogenous variable. Otherwise, the 2SLS estimator could produce a worse result than the OLS regression (Shepherd, 2009). The most common approach to addressing endogeneity bias is lagging the suspected endogenous variables by one or more periods (Shepherd, 2009). This lagging solution is based on the argument that although current values might be endogenous, past values are unlikely to be subject to the same problem (Shepherd, 2009). In this study, the lagging of the suspected endogenous variable is achieved by lagging R&D expenditure, which had been identified as a useful instrument in previous studies (Brundell, Griffith & Van Reenen 1999; Kleis et al., 2012). However, 2SLS cannot handle this approach because the number of endogenous variables needs to be the same as the number of IVs used. Also, 2SLS is often used for survey data (Ullah, Akhtar & Zaefarian, 2018). Therefore, this study used System GMM developed by Arrelano and Bond (1998) and applies IV and lagged variables.

4.3 Summary

This chapter presents the research method applied in this study. It starts with the research design for how this research is conducted to integrate the different components and address the research problem, measurement issues and data analysis. The research paradigm for this study is positivism, using the RBV as a foundation to test the hypotheses. The quantitative method is used to test the hypotheses. As an archival study that collects data from an online resource documented and administered by Refinitiv (formerly Thomson Reuters) Eikon database, this study identifies 538 mining firms listed on the ASX that conducted R&D activities between 2006 and 2017 as the time horizon for this study. The study period started in 2006 because this was the effective year of IFRS full adoption, after which financial reporting by mining firms can be comparable. Furthermore, the mining cycle period influences the chosen study period since most global mineral prices, including copper, aluminium, iron ore, tin, nickel, zinc, lead and uranium, surged to levels never reached before. This period is known as the mining boom, which peaked in 2013 and then declined and continued dropping until 2017, when the mineral price index dropped to that in 2006.

From an extensive literature review, variables are selected to include in a model to test the hypotheses. As the outcome variable is hypothesised to be associated with R&D activities, firm performance is measured using two accounting-based measures, profitability and revenue growth, and a market-based measure, Tobin's q. Profitability is calculated using ROA, whereas revenue growth is calculated as yearly growth measured by the difference in the logarithm of revenue between two consecutive years. Tobin's q is a complex construct because of the difficulty in measuring the replacement cost of assets. Due to this difficulty, this study uses a simple calculation of Tobin's q.

The main hypothesis variable for this study is spending on R&D activities, measured using R&D intensity (RDI). Some control variables are also included, such as firm size measured as the logarithm of total assets, financial strength measured using the ratio of total debt to total assets and year dummies to capture macroeconomic factors over the study period.

Some preliminary tests need to be conducted. These preliminary tests start with descriptive analysis, followed by tests for multicollinearity, heteroskedasticity and endogeneity. The results for these preliminary tests are used to justify the adopted approach to address them. The empirical models are also developed and discussed following the majority-view in the literature.

Chapter 5 -Data Analysis and Discussion

This chapter describes the data analysis, including the data descriptives, preliminary test results, and the analysis method and its application. This chapter starts with summary descriptives to explain the characteristics of the data set. This explanation includes adjustments made to the data and the frequency of firms that identifies spending on R&D per year. Section 5.2 explains the preliminary tests applied to provide information about the appropriate estimators to use. The results from the preliminary tests, followed by the statistical method adopted to test the hypotheses, are presented in section 5.3. Finally, the findings of hypotheses testing are presented in section 5.4, and a summary of the chapter appears in section 5.5.

5.1 Descriptive Analysis

5.1.1 Number of Observation

The Eikon database provides R&D expenditure as a proportion expensed in the income statement from charges of R&D activities disclosed as expensed and the expenses portion of capitalised R&D. The expense proportion of R&D expenditure is separate from reporting under the cost of goods sold category. In addition, the Eikon database provides the conversion of reporting currencies to a specific currency since the Australian Accounting Standards (AASB) do not specifically require reporting in Australian dollars (AUD). Thus, the data are made comparable for analysis purposes.

From 2216 listed firms on the ASX, 927 unique firms (42 per cent) are categorised in the metals and mining industry for the study period, 2006 - 2017. The choice of the study period was explained in Chapter 4. Of these firms, 538 unique firms (58 per cent) are identified that have R&D expenditure within the period of this study, with the number of firms spending on R&D varying every year.

In addition, a financial reporting period adjustment is required for firms that changed their fiscal reporting periods by more than one month. Table 2 shows firms making changes to their financial reporting year.

Table 2 Firms with changed financial year-end

Firms with Changed Financial Years

Firm names	Code	Financial year reporting		
		Previous	Change to	Started year
Tiger Resources Ltd	TGS	Jul - Jun	Jan - Dec	2010
Hillgrove Resources Ltd	HGO	Feb – Jan	Jan - Dec	2014
Austral Gold Ltd	AGD	Jul - Jun	Jan - Dec	2017
Kazakhstan Potash Corporation Ltd	KPC	Jul - Jun	Jan - Dec	2013
Mali Lithium Ltd	MLL	Jul - Jun	Jan - Dec	2017

Some firms were delisted, and others were listed on the ASX during the study period. This dynamic condition causes the data to be unbalanced, with each year having a different number of firm years available. Table 3 shows the number of firms identified as spending on R&D compared to the total number of firms listed each year. The number of observations in this study is 8478 firm years.

Table 3 Number of firms with R&D Expenditure during 2006-2017 collected from Morningstar and Eikon databases

Years	Unique firms spending on R&D	Percentage	Total number of firms
2006	156	26 %	600
2007	222	33 %	675
2008	266	38 %	695
2009	301	43 %	707
2010	330	45 %	728
2011	362	48 %	751
2012	369	49 %	751
2013	365	49 %	745
2014	360	49 %	737
2015	355	50 %	714
2016	333	48 %	697
2017	325	48 %	678
	Total observations		8478

5.1.2 Descriptive Statistics

Table 4 Summary statistics

Financial data/Variables	Obs	Mean	Median	Std.Dev.	Min	Max
Full panel						
Revenue	8478	256.00	0.12	3,030.00	- 55.10	76,700.00
EBITDA	8478	97.10	- 0.61	1,390.00	- 332.00	36,600.00
R&D Expenditure	8478	5.32	-	64.70	-	2,130.00
Total Asset	8478	581.00	10.00	6,710.00	-	162,000.00
Total Liabilities	8478	282.00	0.69	3,450.00	-	94,900.00
Market Capitalisation	8478	256.00	10.00	3,030.00	- 55.10	76,700.00
ROA	8478	-0.5	-0.06	15.83	-1,400.00	17.9
Growth	6154	0	-0.02	1.75	-14.84	10.78
RDI	8478	71.17	0	2,970.82	0	266,000.00
Leverage	8478	7.66	0.09	335.91	0	27,375.17
Size	8478	7.14	7.02	0.97	1.3	11.21
Q	8478	19.65	1.14	738.76	0	56,533.03
Firms with R&D						
Revenue	3744	467.00	0.18	4,480.00	0.00	76,700.00
EBITDA	3744	204.00	-0.75	2,090.00	-245.00	36,600.00
R&D Expenditure	3744	11.80	0.66	96.90	0.00	2,130.00
Total Asset	3744	1,050.00	9.60	9,810.00	0.00	162,000.00
Total Liabilities	3744	505.00	0.72	4,950.00	0.00	94,900.00
Market Capitalisation	3744	598.00	11.00	6,580.00	0.00	147,000.00
ROA	3744	-0.20	-0.09	0.92	-31.56	10.89
Growth	3362	0.00	-0.04	1.64	-9.25	10.36
RDI	3744	161.16	1.30	4,469.20	0.00	265,954.90
Leverage	3744	0.36	2.46	2.39	0.00	127.75
Size	3744	7.12	0.10	0.96	0.00	11.21
Q	3744	2.72	6.98	7.08	0.00	221.17
Firms without R&D						
Revenue	4,734	89.90	0.07	665.00	-233.00	10,600.00
EBITDA	4,734	12.70	-0.49	104.00	-332.00	2,970.00
R&D Expenditure	4,734	0.00	0.00	0.00	0.00	0.00
Total Asset	4,734	162.00	11.00	884.00	0.00	21,100.00
Total Liabilities	4,734	68.80	0.67	578.00	0.00	17,500.00
Market Capitalisation	4,734	198.00	9.80	1,470.00	0.00	40,700.00

ROA	4,734	-0.73	-0.04	21.16	-1,399.25	17.90
Growth	2,794	-0.01	0.01	1.87	-14.84	10.78
RDI	4,734	0.00	0.00	0.00	0.00	0.00
Leverage	4,734	12.41	0.00	432.50	0.00	27,375.17
Size	4,734	6.58	0.08	2.15	0.00	10.32
Q	4,734	31.36	7.05	964.70	0.00	56,533.03

This table presents the descriptive statistics for the full panel, panel data for firms with R&D and firms without R&D. Need to be noted that revenue, EBITDA, R&D expenditure, total assets, total liabilities, and market capitalisation are in millions (AUD)

The summary descriptive statistics for the data set are presented in Table 4. From the summary statistics, it can be observed that the average revenue metals and mining industry reported is A$256 million with a range of negative A$55.1 million to A$76,700 million. The negative revenue is related to derivative hedging activities to protect firms against adverse changes in mineral prices. This wide range of revenue is similar for EBITDA, where the range is high, from a loss of A$332 million to a mean profit of A$36,600 million. The EBITDA shows mining operations are a high-cost activity and reduce revenue by nearly 60 per cent.

The operational costs that reduce revenue by nearly 60 per cent are supported by mean total assets of A$581 million. In addition, to support R&D activities, financial strength is important and shows in the leverage ratio, measured as total debt deflated by total assets. The mean ratio is approximately 50 per cent and implies that total debt can be covered by half of the total assets. This condition shows how strong the financial position of mining firms is in supporting R&D activities.

Summary statistics show the average RDI (R&D expenditure deflated by revenue) is high at 71.17, and the maximum is A$266,000. This high R&D intensity is because some firms started spending on R&D when firms did not generate any revenue or loss. This early spending was due to firms benefiting from the mining boom when a sharp increase in mineral prices was followed by unprecedented investment in new mines, equipment, and infrastructure (Deloitte, 2017). In terms of the R&D intensity calculated as the ratio of mean R&D expenditure to mean revenue is approximately 2 per cent[6]. This percentage is higher than the concern expressed by Bryant (2015) and Filippou and King (2011) that mining firms underinvest in R&D with less than 1 per cent of revenue spent.

[6] In Table 4 the approximate 2 per cent for R&D intensity is calculated as the ratio of mean R&D expenditure deflated by revenue. Thus, the R&D intensity is 5.32/256, which is higher than expected by Bryant (2015) and Filippou and King (2011). R&D intensity measures the innovativeness of firms, or the industry, as argued by García-Manjón, and Romero-Merino (2012).

Focusing on the comparison between firms with and without spending on R&D, it can be observed that the average revenue and profit of firms conducting R&D activities are much higher than firms without R&D activities counterparts. While the maximum revenue and profit represented by EBITDA of firms with R&D are A$76,700million and A$36,600 million, the firms without R&D are A$10,600 million and A$2,970 million, respectively. In contrast, the average market capitalisation of firms spending on R&D activities is three times higher than firms without R&D activities, even though the firm size is slightly different between them. Interestingly, firms that spend on R&D have lower leverage, 0.36 on average, while their counterparts have leverage of 12.41.

In further analysis to understand whether differences exist between firms with and without spending on R&D in terms of firm performance, t-tests are conducted. The results show that for ROA among mining firms in Australia (N=927), there was no statistically significant difference between firms with spending on R&D activities (M=-0.2046, SD=0.923) and firms without spending on R&D activities (M= -0.7304, SD=21.164), t(8476) = -1.5190 $p \geq 0.05$. The same result for Growth is found, with no significant difference between firms with spending on R&D activities (M=-0.0006, SD=0.2827) and firms without spending on R&D activities (M= -0.0051, SD=0.3535), t(5602) = -0.0994 $p \geq 0.05$. Therefore, on a univariate basis, the null hypothesis of no difference in ROA and Growth between both firm categories cannot be rejected.

In terms of Tobin's q, the t-test found a similar result with no statistically significant difference t(8476) = 1.8168 $p \geq 0.05$, CI_{95} 3.3651, 34.0642 between firms with spending on R&D activities (M=2.7199, SD=7.0759) and firms without spending on R&D activities (M=31.3645, SD=964.6995). Table 5 shows the comparison of profitability, revenue growth and Tobin's q by firms with and without spending on R&D activities.

Table 5 Comparison of profitability, revenue growth, and Tobin's q by firms with and without spending on R&D activities

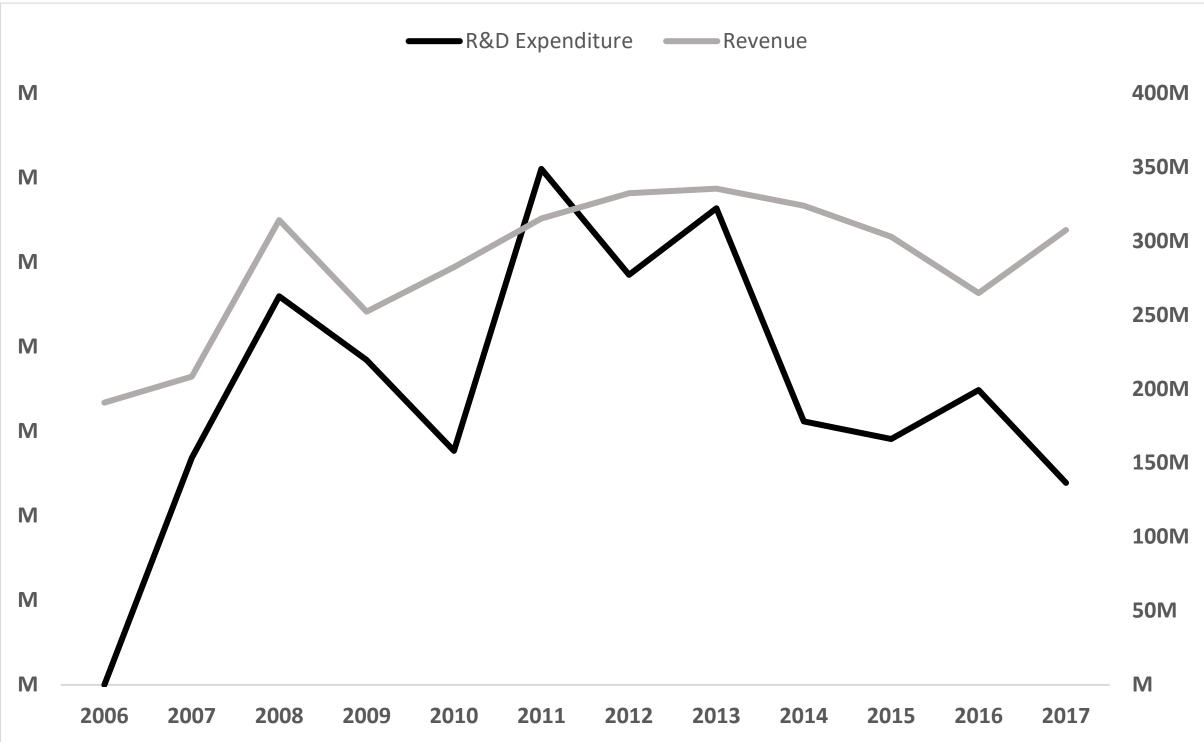
Firms	n	M	SD	t	df	p	95% confidence interval	
ROA								
Without spending on R&D	4734	-.7304434	21.16353					
With spending on R&D	3744	-.2046483	.922523					
Total	8,478	-.4982451	.1718991	-1.5190	8476	0.1288	-0.8352093	-0.1612809
Growth								
Without spending on R&D	2794	-.0051226	1.868748					
With spending on R&D	3362	-.0006247	1.639082					
Total	6156	-.0026662	.1718991	-0.1006	6154	0.9199	-0.0463135	0.0409812
Tobin's q								
Without spending on R&D	4734	31.36446	964.6995					
With spending on R&D	3744	2.719937	7.075944					
Total	8,478	18.71465	720.9962	1.8168	8476	0.0693	3.365073	34.06423

This table presents t-tests for differences in profitability, revenue growth and Tobin's q grouped by firms with and without spending on R&D activities. 'n' represents the number of observations, M is mean, and SD is the standard deviation. 't' is the result of t-value while df stands for degrees of freedom measured by the total number of observations minus 2. 'p' is the p-value to show the significance of the t-test where $p \geq 0.05$ represents a not significant result or failure to reject the null hypothesis.

5.1.3 R&D Spending Trends

Spending on R&D activities follows trends in the fluctuation of revenue, as shown in Figure 15. This situation confirms the findings of Gomory (1992) that the amount of R&D expenditure depends on sales. However, an exception occurred in 2012 when R&D expenditure increased significantly and did not follow the trend in revenue. This peak in the R&D expenditure boom was caused by an increase in productive capacity as a response to a sharp rise in accumulated global demand in the 2000s (Deloitte, 2017). The peak coincides with a decline in mineral prices over the years, so mining firms needed to seek cost reduction and productivity improvement to maintain profitability and cash flow. The price decline influenced spending on R&D activities, which dropped significantly in the following year. R&D expenditure in 2013, for example, was close to that of 2010, whereas after 2013, it steadily decreased to below the 2010 level.

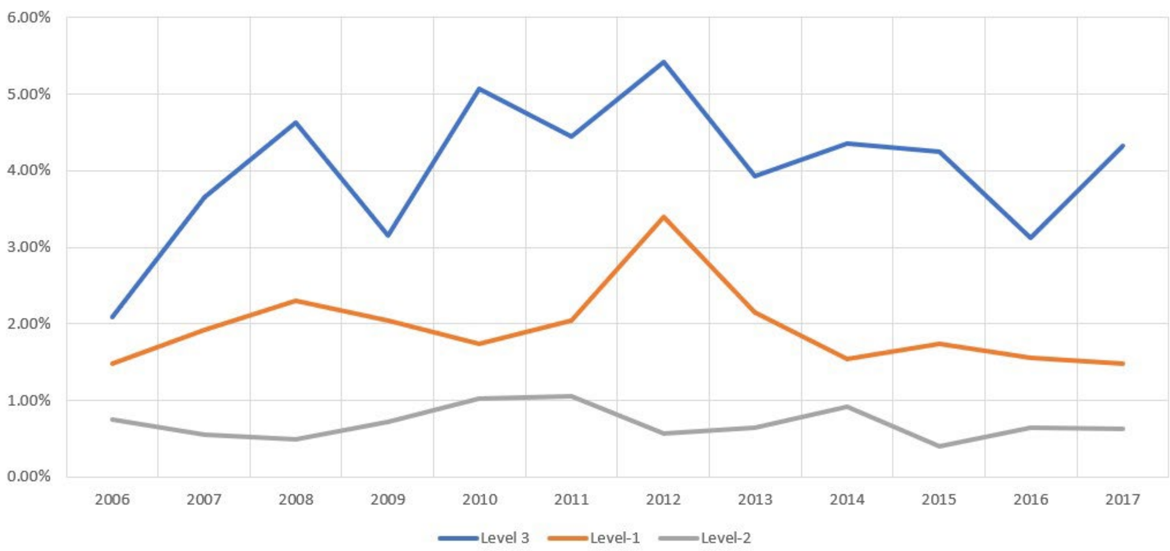
Figure 15 Consolidated R&D expenditure and revenue for the year 2006 – 2017



Focusing on firms with spending on R&D activities, the partition based on total assets followed a firm's size classification by Filippou and King (2011) and King (2005), are categorised into three sizes. Level 1 is for firms with total assets of more than A$40 billion, level 2 is between A$10 billion and A$40 billion, and level 3 is for mining firms with total assets less than 10 billion. Level 1 firms could elect to spend a significant amount on R&D. They spend on R&D expenditure deflated by revenue (R&D intensity), ranging from 1.5 to 3 per cent. This trend is opposite to the result reported by Filippou and King (2011) that level 1 firms spent below 0.6 per cent. However, the similarity of the summary in level 1 firms is that their R&D expenditure represents a very small percentage of their revenues. For level 2, the R&D intensity presents below level 1, ranging from 0.5 to 1 per cent. At level 2, firms are particularly those which focus on one metal and are more vertically integrated.

Firms categorised as level 3 show a higher percentage of R&D expenditure deflated by revenue (between 2.0 - 5.5 per cent) than other levels, and their expenditure is more volatile. It can be noted that level 3 firms are not adequately represented at this level since some firms do not generate revenues and mostly rely on mature technology purchased from outside (King, 2005). The comparison of R&D intensity amongst the three levels is depicted in Figure 16.

Figure 16 Consolidated R&D intensity classified based on total assets (levels 1 to 3)



5.2 Preliminary Test

STATA software is used to conduct preliminary tests before the statistical data analysis. STATA is a general statistics software package created by StataCorp that provides an integrated statistical software package for data science, including visualisations and statistics[7]. The following section explains the preliminary tests of data.

[7] More detail about STATA software is explained in website: https://www.stata.com/why-use-stata/

5.2.1 Multicollinearity Test

Checking for multicollinearity is necessary before analysing to anticipate unreliable coefficient estimates results from the model (Coad & Rao, 2010). The Pearson's correlation matrix is examined to check for multicollinearity at a concerning level among independent variables. The correlation between ROA and lagged R&D intensity is positive, strengthening the case for Hypothesis 1, which posits that spending on R&D activities increases profitability. This correlation is similar to the correlation between R&D intensity and revenue growth, which is positive. This positive correlation supports Hypothesis 2. In contrast, the correlation between Tobin's q (Q) and R&D intensity is negative, failing to support Hypothesis 3. However, these are bivariate correlations, and multivariate analysis is needed to test the hypotheses.

In summary, the correlation matrix shown in Table 6 reveals no correlations higher than 0.50 between any two independent variables. Thus, collinearity of a concerning nature was not found between two or more independent variables.

Table 6 Correlation matrix

Variables	ROA_{it}	$Growth_{it}$	Q_{it}	$RDI_{i(t-1)}$	Lev_{it}	$Size_{it}$	$Year_{it}$
ROA_{it}	1						
$Growth_{it}$	0.008	1					
Q_{it}	-0.1934***	-0.0285**	1				
$RDI_{i(t-1)}$	0.0014*	0.1040*	-0.0005*	1			
Lev_{it}	-0.2912***	-0.0352***	0.5863***	-0.0005	1		
$Size_{it}$	0.0423***	0.1306***	-0.0571***	-0.0173	-0.0476***	1	
$Year_{it}$	0.0037	-0.1329*	0.0084	0.0284**	0.0131	0.0434***	1

This table presents the correlation matrix of dependent and independent variables. ROA is a proxy for profitability. Revenue growth is proxied by Growth. $ROA_{i(t-1)}$ is the R&D previous year expenditure deflated by revenue of the previous year. ROA_{it} is the ratio of current EBITDA to current total assets. $Growth_{it}$ is the difference logarithm of current revenue and previous year revenue. Lev_{it} is the ratio of the total assets to total liabilities. $Size_{it}$ is the logarithm of the total assets. Year is a year dummy.

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

To further test the potential effect of multicollinearity, variance inflation factors (VIF) values for the independent variables are examined. The results in Table 7 show VIF values close to one for all independent variables, considered moderately correlated (Akinwande, Dikko & Agboola, 2015). Ehie and Olibe (2010) recommend checking the largest VIF value. None of the VIF values in the regression was greater than 1.5. Therefore, it can be concluded that multicollinearity is not an issue for the dataset.

Table 7 VIF result for dependent variables: ROA and Growth

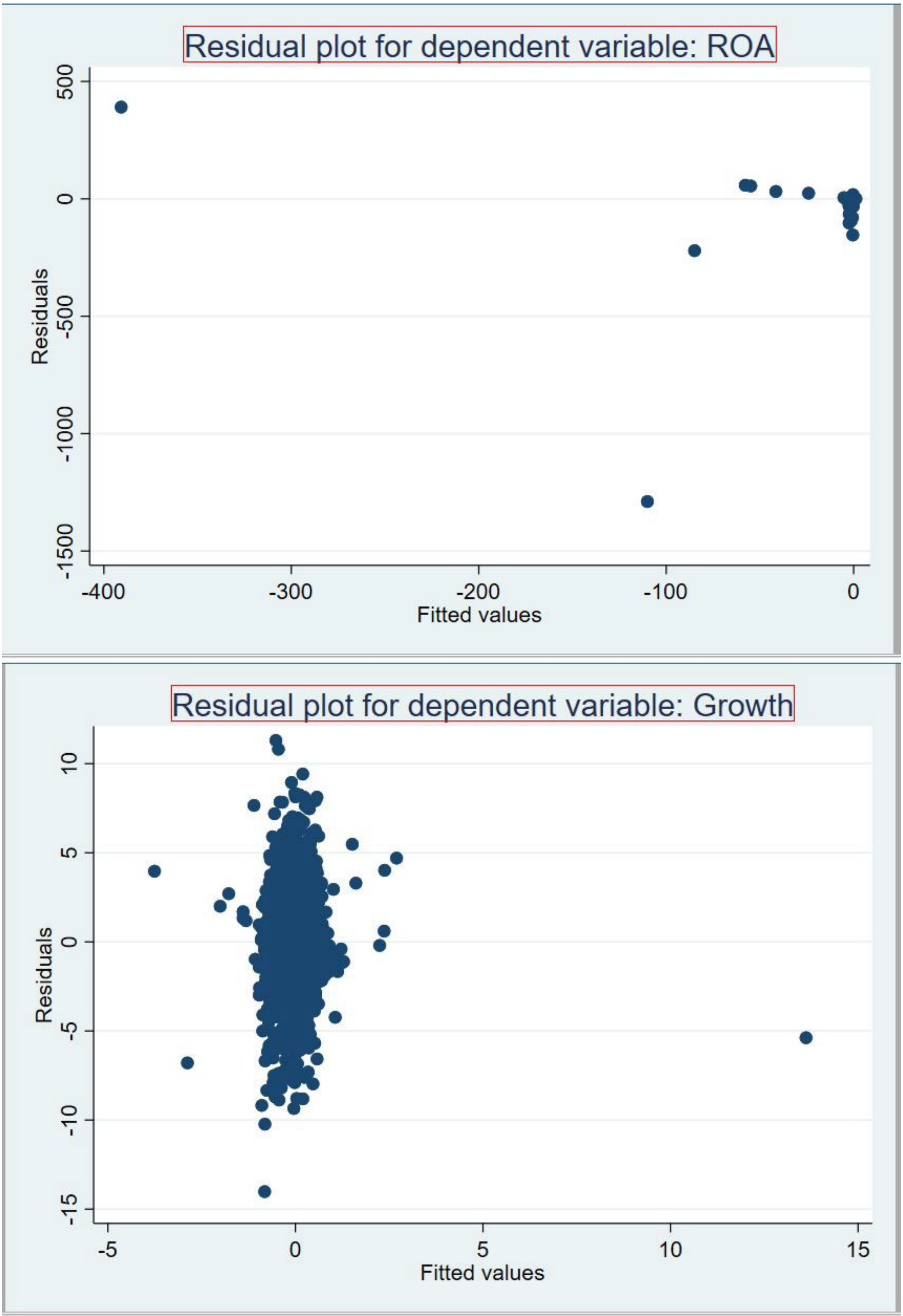
Variable	ROA		Growth	
	VIF	1/VIF	VIF	1/VIF
Lag R&D Intensity	1.00	0.9994	1.00	0.9959
Leverage	1.00	0.9997	1.01	0.9926
SIZE	1.00	0.9998	1.01	0.9893
Year	1.00	0.9993	1.00	0.9951
Mean VIF	**1.00**		**1.01**	

5.2.2 Heteroskedasticity test

Heteroskedasticity occurs when the variance of the error for all observations is not the same, causing the standard error of the estimates to be biased (Baltagi, 2005; Bascle, 2008; Baum, Schaffer & Stillman, 2003; Williams, 2020). Williams (2020) gives a simple example to understand the notion of heteroskedasticity. He provides a comparison between the sales variance for large and small firms, in which larger firms' sales might be more volatile than smaller firms. The error term of the larger firms has a larger variance than the smaller firms, and this is known as the presence of heteroskedasticity.

A visual inspection can be conducted using a residual plot to detect the presence of heteroskedasticity. Heteroskedasticity is not present when an 'envelope' of even width shape is not evident. "If the residuals [we]re roughly the same size for all values of X, it [wa]s generally safe to assume the heteroskedasticity [wa]s not severe enough to warrant concern" (Williams, 2020 p.3). The plot for visual detection is shown in Figure 17, and the shape is an uneven 'envelope' with the width for some values of X larger than others. This visual result concludes the presence of heteroskedasticity. However, visual detection needs to be confirmed with two other statistics tests (Williams, 2020).

Figure 17 Visual residual plot to detect the presence of heteroskedasticity



The two statistical tests, Breusch-Pagan/Godfrey/Cook–Weisberg and White/Koenker statistics are standard tests for an OLS regression (Baum, Schaffer, & Stillman, 2003). The Breusch-Pagan (BP) test is derived from a Lagrange multiplier (LM) test and is used to test Ho: $\sigma^2 = \sigma_\lambda^2 = 0$. The BP test investigates the null hypothesis (Ho), whether error variances are all equal or the alternative hypothesis of the error variances (H_a) shows one or more multiple functions. More specifically, when the variable is increasing, whether the variances increase and vice versa.

The null hypothesis (H_0) is constant variance or homoskedasticity, whereas the alternative hypothesis, H_a, is applied when the variance is not constant or heteroskedastic. The BP test generates Chi-squared test statistics with a corresponding p-value. When the p-value is below the common thresholds of 0.01, 0.05 and 0.10, it is sufficient to reject the null hypothesis H_0. The result of the BP test in this study shows the p-value is below the threshold; thus, it is sufficient to reject H_0 and accept H_a, confirming that heteroskedasticity is present in the data.

Breusch-Pagan / Cook–Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of ROA chi2(1) = 4.64e+06 Prob > chi2 = 0.0000	Breusch-Pagan / Cook–Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of Growth chi2(1) = 60.28 Prob > chi2 = 0.0000

The BP test is designed to detect heteroskedasticity in any linear form (Williams, 2020), which means that when the dependent variable increases, so do the error variance. The BP test is sensitive to the normality assumption, which does not work for non-normally distributed data, in contrast to White's test, proposed by the White/Koenker statistics test, which does not rely on the normality assumption and is easy to implement (Gujarati & Porter, 2009). In STATA, the command syntax to conduct the White test command is '*estat imtest, white'* and is applied after regression as a post-estimation test. Under the null hypothesis that there is no heteroscedasticity, it can be shown that the sample size (*n*) times R^2 obtained from the auxiliary regression asymptotically follows a chi-square distribution. If the Chi-square values exceed the critical chi-square value at the chosen level of significance, the conclusion is that there is heteroskedasticity. The result of White's test shows the resulting output, which suggests rejecting homoscedasticity for both ROA and Growth (p-values<0.001). The result confirms the BP test previously that heteroskedasticity is present.

5.2.3 Endogeneity test

An endogeneity test is essential for validity because failure to control all forms of endogeneity can lead to spurious results (Schultz, Tan & Walsh, 2010). In this regard, results of analysis without addressing endogeneity issues need to be interpreted with caution since they might cause parameters to be imprecise, and the effect of the error term tends to be underestimated in the model (Ullah, Akhtar & Zaefarian, 2018). Therefore, endogeneity is a serious concern that can threaten the validity of regression analysis results (Lu et al., 2018).

The presence of endogeneity bias is indicated when the explanatory variable(s) (X_{it}) is correlated with the error terms or disturbance terms (ε_{it}) in the model or $E(X_{it,}\varepsilon_{it}) \neq 0$. There is no direct way to statistically test the correlation between an endogenous variable and the error term. However, many indirect tests are available to guide the conclusion of the regression analysis result (Lu et al., 2018). One of the common indirect tests is the Durbin-Wu-Hausman (DWH) test (Ullah, Akhtar & Zaefarian, 2018).

The DWH test determines whether the error term (residuals) is correlated with the explanatory variable and uses OLS regression to detect the endogeneity. The procedure [8] to test for endogeneity in this study follows the procedure suggested by Ullah, Akhtar and Zaefarian (2018). The first step is to estimate a regression on each independent variable and control variable to predict the relevant residuals. The equation for the regression is shown in Equation 4.

Equation 4 Durban-Wu-Hausman test - first step model

$$RDI_{it} = Lev_{it} + Size_{it} + \varepsilon_{it} \qquad (1)$$

The second step is to test whether the coefficient for the residual or error term, ε_{it} is significant. The null hypothesis will be rejected if the two sets of coefficients are different (Lu et al., 2018) since that causes the null hypothesis (H_0) for the suspected explanatory variable is exogenous

[8] The procedures to carry out a Durbin-Wu-Hausman test in any version of STATA are explained at https://www.stata.com/support/faqs/statistics/durbin-wu-hausman-test/.

or not correlated with residual. For this step, the residual for R&D intensity (*RDI*) is included in the basic OLS model in Equation 5.

Equation 5 Durban-Wu-Hausman test - second step model

$$Performance_{it} = RDI_{i(t-1)} + Lev_{it} + Size_{it} + \varepsilon_{it} \quad (2)$$

As reported in Table 8, the significant statistic for DWH indicates that R&D intensity is endogenous for the performance measures of profitability and growth, but not for Tobin's q. However, the DWH test has a limitation since it depends on the quality of instrumental variables (Lu et al., 2018), and the endogeneity test cannot separate the choice of instrument variables from the real unobservable effect of endogeneity. Considering this limitation, the Sargan or Hansen test is also applied to check whether the instrumental variables used in the model are valid or not. The valid instrumental variable test is explained in the next section.

Table 8 The DWH test of endogeneity

Dependent variable	Test for Endogeneity	Result
Profitability measure ROA	(1) RD Intensity residual = 0 F(1, 10182) = 0.44 Prob > F = 0.5056	Fail to reject H_0: and the suspected endogenous variable is exogenous
Revenue growth measure, Growth	(1) RD Intensity residual = 0 F(1, 6141) = 16.77 Prob > F = 0.0000	Reject H_0: and the suspected endogenous variable is endogenous
Tobin's q with variable Q	(1) RD Intensity residual = 0 F(1, 5335) = 0.10 Prob > F = 0.7547	Fail to reject H_0: and the suspected endogenous variable is exogenous

In the statistical test of endogeneity, the relationship between R&D intensity and ROA is exogenous. However, as Ullah, Akhtar and Zaefarian (2018) suggest, endogeneity should be addressed theoretically first instead of empirically testing using statistical techniques. This theoretical approach requires extensively reviewing the literature and providing a comprehensive research design, and the statistical techniques ensure that data are rigorously investigated. Thus, even though the statistical result of R&D intensity and ROA is exogenous, the literature is extensively reviewed, and it is concluded that there is potential for R&D to be endogenous (see Demirel & Mazzucato, 2012; Spescha, 2019; Ullah, Akhtar & Zaefarian, 2018; Villalonga, 2004).

In contrast, for the relationship between R&D on Tobin's q, theoretically, some literature confirms a lack of endogeneity between R&D and Tobin's Q (see Connolly & Hirschey, 1990). This outcome means that statistical results support the theory of no presence of endogeneity bias between these variables.

5.3 Tests of Hypotheses

5.3.1 Analysis of R&D's Association with Profitability and Revenue Growth

From the results of the preliminary tests explained in the previous section, two conditions are applied. First, heteroskedasticity causes the standard errors of estimates to be biased, but the coefficients of regression estimates are valid and consistent (Baltagi, 2005; Bascle, 2008; Baum, Schaffer & Stillman, 2003; Williams, 2020). Second, endogenous bias is present when the explanatory variable is correlated with the error term and causes the inference of the test to be inconsistent, and the result is imprecise (Ullah, Akhtar & Zaefarian, 2018). It requires an estimation technique that provides consistent estimates instead of OLS to address these conditions.

The instrumental variable (IV) estimator is a recommended estimation technique to address these two conditions, and the common IV estimator is a two-stage least squares (2SLS) technique (Baltagi, 2005; Ullah, Akhtar & Zaefarian, 2018). The 2SLS distinguishes between regressors and instruments, even though it allows those two to overlap. However, a problem arising from 2SLS is that the number of instruments must equal the number of regressors to satisfy a moment condition where the coefficients on the regressors and the moment of the errors with the instruments are zero or uncorrelated (Roodman, 2009). If the instruments are outnumbered, the equation is unknown, and the system cannot be solved. However, according to Roodman (2009), outnumbered instruments can address the presence of endogenous bias.

Heteroskedasticity weighs the option to use 2SLS estimation to analyse the data. 2SLS assumes that heteroskedasticity is not present to prevent a valid inference (Bascle, 2008; Baum, Schaffer & Stillman, 2003). Thus, a 2SLS estimator with the presence of heteroskedasticity needs to be modified to draw a valid inference. Bascle (2008) recommends an upgrade of the IV estimation to the Generalised Method of Moments (GMM) procedure to generate a more efficient and consistent estimation. GMM makes use of the orthogonality condition that allows an efficient estimation in the presence of unobservable heteroskedasticity (Baum, Schaffer & Stillman, 2003) and simultaneously addresses the endogeneity sources (Schultz, Tan & Walsh, 2010).

"…the GMM can overcome the estimations problems introduced by unobservable heteroskedasticity, simultaneity, and dynamic endogeneity, and produce unbiased and consistent estimates by employing valid internal instruments during estimation." (p.146)

5.3.1.1 Applying Generalised Method of Moments (GMM)

The GMM estimator is designed for panel analysis with a situation of (i) few time periods (T) with many individuals, N (small T, large N); (ii) a linear functional relationship; (iii) a dynamic relationship in which current firm performance is influenced by its past realisations; (iv) some regressors not necessarily strictly exogenous; (v) fixed individual effects; and, (vi) heteroskedasticity and autocorrelation within individuals, but not across them (García-Manjón & Romero-Merino, 2012; Roodman, 2009; Ullah, Akhtar & Zaefarian, 2018). In GMM, the estimator optimally exploits all linear moment restrictions and covers the case of unbalanced panel data (García-Manjón & Romero-Merino, 2012).

The GMM estimator has two methods, *difference* and *System* GMM and both are used for dynamic panel data. The *difference* GMM was introduced by Arellano and Bond in 1991 (as cited in Arellano & Bond, 1998), which eliminates fixed effects from the equation by differencing. *System* GMM, developed by Arellano and Bover in 1995 and also by Blundell and Bond in 1998 (as cited in Arellano & Bond, 1998), uses the differences as a new set of instruments for levels of the lagged dependent variable. This new instrument exploits a new set of instruments within the *system* not available from the *difference* GMM estimator.

Previous studies using the *difference* GMM and *System* GMM have generated contradictory results. According to Blundell et al. (2000 cited in Baltagi, 2008),

"*a careful examination of the original series and consideration of the System GMM estimator can usefully overcome many of the disappointing features of the standard [difference] GMM estimator for dynamic panel model"* (p.161).

Therefore, to obtain robust results, this study uses the System GMM.

In analysing the data using System GMM, this study uses STATA with command syntax 'xtabond2' developed by Roodman (2009). The command syntax has more options such as ‘robust’ to compute robust variance estimators based on the ‘varlist’ of equation-level scores and a covariance matrix. The *‘small’* option in the command syntax requests a small-sample correction to the covariance matrix estimate and resulting t-test instead of a z-test. Another command syntax is ‘*twostep’* which requests two-step GMM in which the two-step estimator is efficient and robust to any patterns of heteroskedasticity and cross-correlation of the covariance estimator models (Roodman, 2009). The ‘*xtabond2’* has more syntax options that can be added; however, it also potentially creates a risk of misuse of the estimators. Thus, understanding the estimators’ purpose, design and limitations is a must before using the syntaxes (Roodman, 2009).

5.3.1.2 Transformation of R&D Intensity (RDI) Variable

System GMM is built into two equations, the original and the transformed equation and allows using more instruments to improve efficiency estimation. From the empirical model equation drawn from literature, an original equation is generated to test Hypotheses 1 (H_1) and 2 (H_2):

$$ROA_{it} = \alpha_0 + \alpha_1 ROA_{i(t-1)} + \alpha_2 RDI_{i(t-1)} + \alpha_3 Lev_{it} + \alpha_4 Size_{it} + \alpha_5 Year_{it} + v_{it} \quad (1)$$

$$Growth_{it} = \beta_0 + \beta_1 Growth_{i(t-1)} + \beta_2 RDI_{i(t-1)} + \beta_3 Lev_{it} + \beta_4 Size_{it} + \beta_5 Year_{it} + v_{it} \quad (2)$$

$$v_{it} = \mu_{it} + \varepsilon_{it} \quad (3)$$

This original equation uses RDI, which is indicated as an endogenous variable by lagging it. However, lagging RDI is not a solution to removing the presence of endogenous bias. It needs to be transformed to avoid further continued loss of information but minimised depending on the lagged observations of the original variables so that it remains available as an instrument (Roodman, 2009). The two common transformations are the first difference transform, which removes the fixed effects, but the lagged dependent variable is still potentially endogenous (Roodman, 2009). The reason is that the $\Delta y_{i(t-1)} = y_{i(t-1)} - y_{i(t-2)}$ is correlated with the $v_{i(t-1)}$ in $\Delta v_{it} = v_{it} - v_{i(t-1)}$. In summary, the endogenous variable, RDI and any predetermined variables that are not strictly exogenous, $Growth$ and ROA, become potentially endogenous biased because they might be correlated with $v_{i(t-1)}$, but not for longer lags of the regressor (Roodman, 2009).

The longer lags in the first-difference transformation magnified gaps in this study that the panel data was unbalanced, and Roodman (2009) identified as a weakness of this transformation. If some of the y_{it} are missing, then both Δy_{it} and $\Delta y_{i(t+1)}$ are missing in the transformed data. Therefore, orthogonal deviation as the second transformation is used to address this issue (Arellano & Bover, 1995) by using a moving-average serial correlation of residuals (Boumahdi & Thomas, 2008). Roodman (2009) explains this transformation by subtracting the average of all future available observations of a variable instead of subtracting the previous observation from the contemporaneous one. This transformation minimises data loss, and no matter how many gaps, it is still computable for all observations except the last for each individual (Roodman, 2009).

STATA facilitates the transformation of the '*xtabond2'* command syntax for GMM. The two transformations are in the '*equation ( )'* sub-option, *equation (diff)* is for first-difference transformation and *equation (level)* for orthogonal deviation. These transformations can be included in the command '*gmm( )'* for endogenous or predetermined variables and *'iv( )* for a strictly exogenous variable (Roodman, 2009) and if both need to be used, the transformations can be made using the command '*equation (both)'*.

The lag for the transformation in STATA, by default, generates lags of 1 and earlier of the instrumenting variable for the transformed equation. In contrast, System GMM by default puts a lag of 0 for the instrumenting variable in differences for the level equation. The command syntax of 'laglimit( )' sub-option overrides the default on lag ranges, for example, in the 'gmm()' include the command syntax of '*lag (2 .) equation (diff)'* after comma specifies lags of 2 and longer for a transformed equation that is equal to lag 1 for the level equation, '*lag (1 .) equation (level)'*. Roodman (2009) identifies the standard treatment of lag limit for an endogenous variable as lags of 2 and longer, while the predetermined variable is to use lags of 1 and longer. However, the lagged endogenous variable in the regressor is categorised as a predetermined variable (Gujarati & Porter, 2009). Thus, the transformation of the RDI variable can use lag limits of 1 and longer.

5.3.1.3 Transformation of Lagged Dependent Variables

Addressing the difficulty in finding instruments correlated with the original regressors but uncorrelated with errors, this study uses an internal instrument by lagging the dependent variable, $ROA_{i(t-1)}$and $Growth_{i(t-1)}$. These lagged dependent variables are categorised as predetermined variables independent of current disturbance but not strictly exogenous (Gujarati & Porter, 2009; Roodman, 2009). Therefore, Roodman (2009) suggested that if the variable is predetermined but not strictly exogenous, the standard treatment is to use lags of 1 or longer and put them into the instrument matrix command "*gmm ( )*".

The command syntax in STATA accommodates using a lag limit instrument for the transformation of a predetermined variable by including the "*gmm ( )*" command syntax. Combining the command syntax of transformation for the RDI variable as an endogenous variable and $ROA_{i_{(t-1)}}$and $Growth_{(t-1)}$ as lagged dependent variables is 'gmm(RDI, lag(1 2) equation(diff) collapse) gmm(ROA, lag(1 1) equation(level))' for profitability and 'gmm(RDI, lag(1 2) equation(diff) collapse) gmm(Growth, lag(1 1) equation(level))' for revenue growth. This syntax specifies the transformation of RDI with limited lagged 1 and 2 on the difference equation, whereas ROA or Growth is lagged 1 on the level equation.

The collapse sub-option of RDI in the STATA command syntax is used to limit instrument proliferation. Using the collapse sub-option creates one instrument for each variable and lags distance instead of one in each period. Thus, the collapse sub-option curtails computational demand by reducing the width of the instruments matrix. The proliferation of instruments can overfit an endogenous variable and cause failure to remove endogenous components (Roodman, 2009).

5.3.1.4 Instrument Variables test

Even though GMM is considered an appropriate estimation technique, the validity of instruments plays an important role. The instruments need to satisfy two conditions. First, the instruments must correlate to endogenous variables, and second, the instruments must be orthogonal to the unobserved error (Baum, Schaffer & Stillman, 2003; Wooldridge, 2012). The first condition requires that Z, representing instrument variables, must be correlated either positively or negatively, with endogenous variables, represented as X to satisfy the condition of an instrument relevance (Wooldridge, 2012). The correlation is formulated in Equation 6

Equation 6 The Correlation of Explanatory variable and Instrumental Variable

$$Cov(Z, X) \neq 0$$

The second condition, in which instrument variables are uncorrelated to unobserved standard errors, is formulated in Equation 7

Equation 7 The Uncorrelated Instrument Variable with Errors

$$Cov(Z, \varepsilon) = 0$$

These equations summarise Z as an exogenous instrument and not a partial effect of y and Z being correlated with the endogenous variable, X (Wooldridge, 2012).

To test the validity of instruments, the inequality number of instrumental variables and the number of endogenous variables need to be satisfied (Baum, Schaffer & Stillman, 2003; Shepherd, 2009). The inequality represents the overidentification of instrumental variables in which the number of instruments exceeds the number of endogenous variables. If the number of instruments equals or is less than the number of observations, the R^2in the first-stage regression is 1 and in the second stage, bias is present, and the result matches the OLS bias. (Roodman, 2009). If the model is exactly identified, it is when the number of instruments equals the number of endogenous regressors, the identification of invalid instruments is impossible to conduct even though $Cov(Z, \varepsilon) \neq 0$, the estimator chooses $\hat{\beta}$ and causes $Cov(Z, \varepsilon) = 0$ exactly. Furthermore, if the model is overidentified, the number of instruments exceed the number of endogenous variables and the corresponding moment condition of whether instruments are uncorrelated with the errors can be tested (Baum, Schaffer & Stillman, 2003).

This study uses two instrumental variables, Size and Lev, for the endogenous variable, RDI, which made the model overidentified, and the validity of the instrument could be tested. The validity test could use either Sargan or Hansen's J statistic test, but the Sargan's statistic test is inconsistent if there is suspected non-sphericity in the errors or the case of heteroscedastic errors (Baum, Schaffer & Stillman, 2003; Roodman, 2009). In STATA, Sargan and Hansen tests are a standard joint test of instrument validity in the post-estimation of GMM, but this study was concerned with the result of the Hansen J test.

The command syntax for the instrumental variable is in the command '*iv( )'* as assumed to be a strictly exogenous variable, and there is no need to use the 'laglimit' sub-option. The standard treatment for strictly exogenous variables is in '*iv( )'* and generates one column per variable with missing not replaced by 0 (Roodman, 2009). Moreover, the instrument uses *equation (level)* for orthogonal deviation.

5.3.1.5 Regression Analysis and Result

In summary, the influence of R&D expenditure on profitability and revenue growth is tested using a two-step System GMM that is consistent and asymptotically efficient in the presence of heteroskedasticity and error terms (Roodman, 2009). The command in STATA was 'xtabond2', specified with the 'twostep' syntax. Moreover, the 'robust' option should be applied in 'xtabond2' as equivalent to cluster(id) in most other estimation commands when requesting standard errors robust to heteroskedasticity, and an arbitrary pattern of autocorrelation within individuals exists (Roodman, 2009). The command syntax for the empirical model uses dynamic regression, where the lagged dependent variable is included as an independent variable, RDI as an endogenous variable, Lev and Size as control variables proxying for leverage and firm size, as shown in Table 9.

Table 9 The command syntax for profitability and revenue growth

Hypothesis one (H_1):	***R&D activities significantly influence profitability for mining firms in Australia***
'xtabond2 ROA L.RDI L.ROA Lev Size Year, gmm(RDI, lag(1 2) equation(diff) collapse) gmm(ROA, lag(1 1) equation(level)) iv(Lev Size Year*, equation (both)small twostep robust'*	
Hypothesis two (H_2):	***R&D activities significantly influence revenue growth for mining firms in Australia***
'xtabond2 Growth L.RDI L.Growth Lev Size Year, gmm(RDI, lag(1 2) equation(diff) collapse) gmm(Growth , lag(1 1) equation(level)) iv(Lev Size Year*, equation (level))small twostep robust'*	

The 'small' option was in place to request small-sample corrections to the covariance matrix estimate and result in t-test instead of z-test statistics for the coefficients. The $i.Year$ represented time-dummies and was included in the 'iv ( )" to hold the assumption of no correlation across individuals in the idiosyncratic disturbance (Roodman, 2009).

The statistical results generated from STATA are shown in Table 10. For each regression, this study indicates estimated coefficients, whether they are statistically different from zero (p-value), the first- and second-order correlation tests (AR_1 and AR_2), the Hansen test of instrument validity and the F-test of model statistical significance. The statistical tests do not reject the validity of the model and do confirm the validity of the instrument variables used to avoid the endogeneity problem, as indicated in the higher p-values of the Hansen test of overidentification for profitability (Prob > chi2 = 0.124) and revenue growth (Prob >chi2 = 0.153). The AR_1 of the regression of R&D intensity on profitability is failed to reject (p-value>0.05) but not on the regression of revenue growth (p-value<0.001). Even though this study expects some degree of AR_1, however, this correlation does not invalidate the result (de Andres & Vallelado, 2008). More importantly was the absence of AR_2 - second-order serial correlation in disturbances not rejected for profitability with AR_2 in first differences: z = 0.71 Pr > z = 0.478) and revenue growth (AR_2 in first differences: z = -0.81 Pr > z = 0.418). the presence of AR_2 does signal omitted variables (de Andres & Vallelado, 2008). The result of the test confirms the significant influence of spending on R&D on profitability and revenue growth (p<0.001) as hypothesised.

Table 10 Result of regression analysis with profitability and revenue growth as the dependent variable

Independent variables	ROA_{it}			$Growth_{it}$		
	Coef.	Std.Err.		Coef.	Std.Err.	
$RDI_{i(t-1)}$	0.0000	0.0000	***	0.0007	0.0003	***
$ROA_{i(t-1)}$	0.0108	0.0104				
$Growth_{i(t-1)}$				-0.1162	0.0331	***
Lev_{it}	0.0018	0.0107		0.0000	0.0002	
$Size_{it}$	0.3028	0.3126		0.3601	0.0374	***
Year 2007	0.1599	0.0846	*			
Year 2008	-0.6275	2.5130		0.9965	0.1058	***
Year 2009	-0.3567	0.2034	*	0.1039	0.1071	
Year 2010	0.0101	0.1237		0.4510	0.0895	***
Year 2011	0.0461	0.1498		0.9298	0.0955	***
Year 2012	0.0269	0.1721		0.5193	0.0952	***
Year 2013	-0.0656	0.1294		-0.0143	0.0908	
Year 2015	0.0156	0.6954		-0.0608	0.0925	
Year 2016	-0.7618	0.3873	**	0.1270	0.1072	
Year 2017	-0.0664	0.1525		0.4153	0.1068	***
Constant	-2.3193	2.0935		-3.0814	0.2779	***
Number of obs	7878			5266		
F-test	16.5031			36.2554		
Hansen test	0.124			0.153		
AR_1	0.256			0.000		
AR_2	0.478			0.418		

This table presents the coefficient and standard error of estimation for the regression of profitability, proxied by ROA_{it} and revenue growth, proxied by $Growth_{it}$ using the System GMM. $RDI_{i(t-1)}$ is the previous year of R&D expenditure deflated by previous year revenue. $ROA_{i(t-1)}$ is the ratio of previous year EBITDA to the previous year total assets. $Growth_{i(t-1)}$ is the difference logarithm of current revenue and previous year revenue. Lev_{it} is the ratio of the total asset to total liabilities. $Size_{it}$ is the logarithm of the total assets. YEAR is a year dummy

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

The use of dynamic regression by including the lag of the dependent variable ($ROA_{i(t-1)}$ and $Growth_{i(t-1)}$) and lag of R&D intensity ($RDI_{i(t-1)}$) reduce the number of observations to 7878 and 5266.

5.3.1.6 Robustness Test for Profitability and Revenue Growth

5.3.1.6.1 The Influence of Spending on R&D Activities During and After the Mining Boom

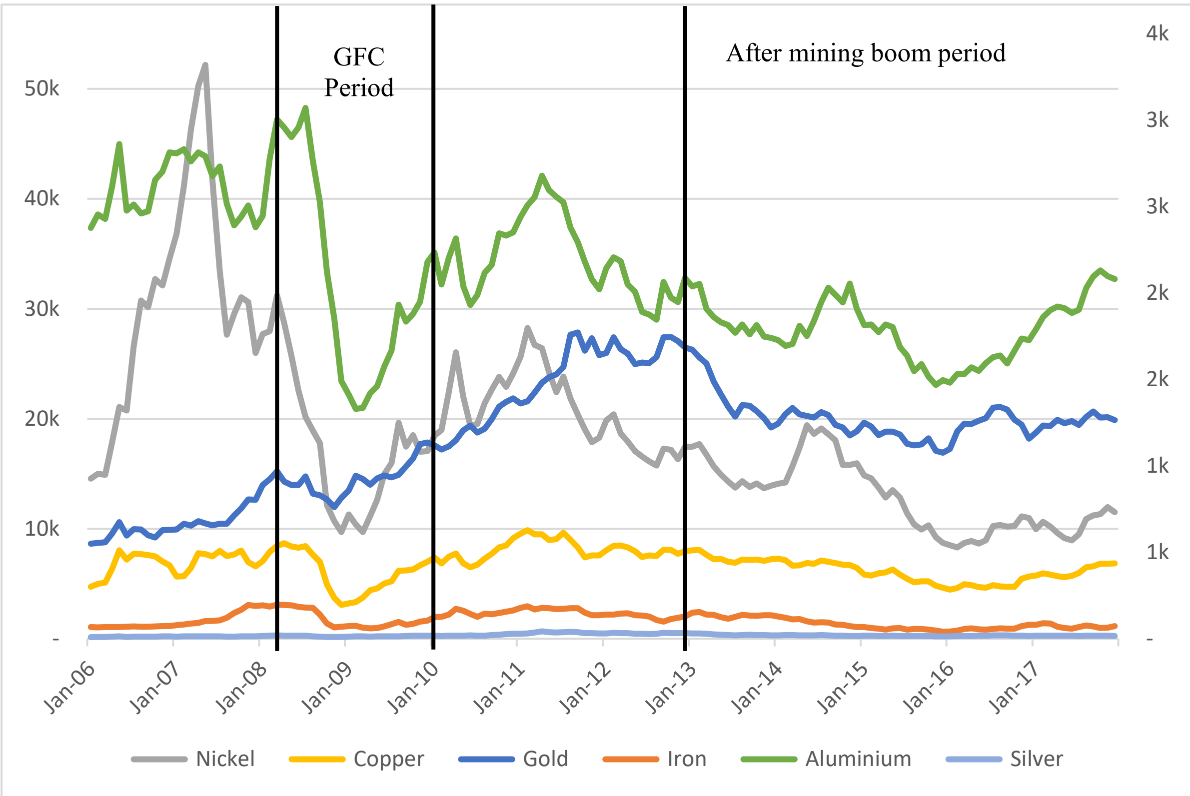
The period for this study includes the critical period of the global financial crisis (GFC). When the GFC happened, most industries, including the mining industry, which was pushed to adapt to changing and unpredictable conditions, were affected. These conditions made fluctuation in global mineral prices unpredictable, greatly influencing mining firms' revenue and profit as the global commodities market dictates minerals prices. However, based on a commodity report published by the Mineral Council of Australia (2020), except for silver, the global demand for minerals steadily increased during 2006 – 2017. Demand for silver has continuously declined from 2012/2013. Thus, fluctuation in revenue and profit for mining firms depends on mineral prices.

Mineral prices move up and down depending on the global economic situation, such as during the GFC. The GFC was a situation of extreme stress in the global financial market and banking system (RBA, np). In the context of Australia, an economic downturn occurred, with a decline in GDP growth in one quarter and increased unemployment to close to 6 per cent, with a sharp rise in the underemployment rate. The significant effect of the GFC in Australia occurred between 2008-2009, causing a collapse in mineral prices in the second half of 2008 (Humphreys, 2010). For example, iron ore, with the world's largest endowment in Australia, was at US$156 per metric ton in 2008 and dropped to around US$80 per metric ton in 2009.

The mineral price collapsed as the effect of the GFC did not take long to recover from, and the previous year's orders had not yet been not delivered, which increased the volume of extracted minerals and expedited price recovery (Deloitte, 2017). The increased extraction volume was due to the mining boom, driven by demand growth in the emerging economies and, in particular, China. The boom changed the key structures previously maintained by the supply side to the demand side (Humphreys, 2010). The persistence of the boom helped sustain this belief to recover the mineral price.

The collapsed mineral price during the GFC period and the recovery of belief in continued mining to help mineral price recovery are depicted in Figure 18. In the GFC period, mineral prices dropped significantly in the second half of 2008; however, at the end of 2008 and the beginning of 2009, they recovered and continued to increase. The graph shows historical mineral prices of minerals that Australian mining firms mostly focused on.

Figure 18 Drastic changes in iron ore price



Notes: Gold, Iron, Aluminium, and Silver prices are on the secondary axis (right side), Nickel and Copper are on the first axis for the price (left axis)

Source: World bank & Eikon Datastream (2021)

The recovery after the GFC period continued, and mineral price increases caused Deloitte (2017) to argue the mining boom continued until the end of 2012. In addition, the period of mining booms was between 2003 – 2012 (Deloitte, 2017) starting from when mineral prices surged to a level never reached before (Deloitte, 2017; Humphreys, 2010) which led to a massive injection of capital investment in the mining industry (Deloitte, 2017). Hence, to check the robustness of the findings of the influence of spending on R&D activities on profitability and revenue growth, the GFC period between 2008 and 2009 is omitted, and the period after the mining boom between 2013 and 2017 is analysed using the same two-step System GMM technique, with results reported in Table 11

Table 11 Result of regression analysis with changing the year of observation by omitting the GFC period and after the mining boom period only

Independent variables	ROA_{it}		$Growth_{it}$	
	Omitted GFC period+	After the mining boom Period++	Omitted GFC period+	After the mining boom Period++
$RDI_{i(t-1)}$	0.0000***	0.0000***	0.0005***	0.0003**
	(0.0000)	(0.0000)	(0.0002)	(0.0001)
$ROA_{i(t-1)}$	0.0624***	0.0632***		
	(0.0164)	(0.0177)		
$Growth_{i(t-1)}$			-0.4216	-0.6936**
			(0.3086)	(0.3364)
Lev_{it}	-0.0004	-0.0006	-0.0249	-0.0160
	(0.0018)	(0.0023)	(0.0197)	(0.0227)
$Size_{it}$	0.1416***	0.1909***	0.3030***	0.3854***
	(0.0351)	(0.0593)	(0.0594)	(0.0685)
Year 2007	-0.0494			
	(0.0436)			
Year 2009	-54.2811		-5.6734	
	(37.4119)		(25.3104)	
Year 2010	-0.0870**		0.5692***	
	(0.0374)		(0.0950)	
Year 2011			1.1495***	
			(0.1823)	
Year 2012	-0.0444	-20.1583	0.9325***	-6.1369
	(0.0338)	(19.5105)	(0.3323)	(9.3220)
Year 2013	-0.1660**		0.2598	
	(0.0655)		(0.1955)	
Year 2014	-0.0729*	0.0906		-0.4149*
	(0.0389)	(0.0668)		(0.2138)
Year 2015	-0.3419***	-0.1654	0.0983	-0.2955
	(0.1102)	(0.1223)	(0.0909)	(0.2022)
Year 2016	-0.3712**	-0.1698	0.2789**	-0.1265
	(0.1608)	(0.1765)	(0.1133)	(0.2208)
Year 2017	-0.1868	-0.0119	0.6032***	0.2441
	(0.1365)	(0.1462)	(0.1465)	(0.1691)
Constant	-1.0703***	-1.5803***	-2.8739***	-3.1708***
	(0.2590)	(0.4386)	(0.5503)	(0.4575)
AR-2	-1.67	-1.43	-1.03	-1.59
(p-value)	0.095	0.153	0.301	0.112
Hansen Test	4.28	2.99	12.41	7.01
(p-value)	0.747	0.559	0.088	0.136
Obs.	6476	3571	4364	2722
Pseudo R^2	.z	.z	.z	.z

This table presents the coefficient and standard errors (in parenthesis) of the result of System GMM of ROA_{it} as proxied by profitability and $Growth_{it}$ as a proxy for revenue growth. The years of data analysed omitting the GFC period (2008-2009) are reported in parentheses + (the years of data analysed are 2006-2007 and 2010-2017). The parentheses ++ are the years of the data analysed after the mining boom (between 2013 and 2017).

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

Omitting the GFC period in the analysis does not change the significant influence of spending on R&D on profitability and revenue growth in mining firms. This could be because mining firms benefited from the mining boom period's increased prices. Indeed, the downturn in mineral prices greatly influenced profit and revenue growth, which decreased by 17 per cent and 10 per cent, respectively[9]. However, the influence of spending on R&D activities on profitability and revenue growth in the downturn period (after the mining boom between 2013-2017) remains significant, as shown in Table 11. These findings accentuate the importance of R&D activities and the positive relationship of these activities on profitability and revenue growth in unpredictable conditions faced by firms (Lome, Heggeseth & Moen, 2016). Thus, it can be concluded that R&D activities allow firms to be better equipped to handle change through increased absorptive capacity because they increase the ability of firms to adapt to changing environments (Lome, Heggeseth & Moen, 2016).

5.3.1.6.2 Distribution of the Influence of Spending on R&D on Profitability and Revenue Growth

To obtain a complete picture, quantile regression can help examine the underlying relationship between spending on R&D activities and firm performance: profit and revenue growth. Quantile regression can obtain a more complete picture if important features of the underlying relationship are hidden (Coad & Rao, 2008). Quantile regression as an alternative tool for analysis is considered a better technique to study the influence on firm performance because it enables the researcher to analyse the entire distribution compared to OLS, which considers the mean distribution only (García-Manjón & Romero-Merino, 2012). This technique provides a more complete story focusing on the relationship between R&D activities and profitability and R&D activities and revenue growth.

Using the command '*qregpd'* in STATA to execute the quantile regression estimator for panel data (QRPD), the results are shown in Table 12 and Table 13. QRPD can estimate the impact of exogenous or endogenous treatment variables on the outcome distribution using 'within' variation in the instruments for identification purposes (Powell, 2020).

[9] The measurement use year 2008 as the base of profit and revenue to be compared to profit or revenue in 2013. The use of 2008 is to indicate the peak of mineral price before the GFC hit the prices globally. Year 2013 is used to indicate the starting point of the ending of mining boom as argued by Deloitte (2017)

Table 12 Quantile regression to estimate the influence of spending on R&D activities on Profitability

Independent variables	ROA_{it} Quantile regression (in percentage)				
	10	25	50	75	90
$RDI_{i(t-1)}$	-0.0000***	-0.0000***	0.0000***	0.0000***	0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$ROA_{i(t-1)}$	0.1846***	0.0338***	0.0030***	0.0005	0.0014***
	(0.0003)	(0.0004)	(0.0000)	(0.0011)	(0.0003)
Lev_{it}	-0.1821***	-0.0513	0.0000***	0.0001**	-0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$Size_{it}$	-0.0280***	-0.0138***	-0.0085***	0.0239**	0.0437*
	(0.0020)	(0.0045)	(0.0000)	(0.0100)	(0.0243)
Year	0.0135*	-0.0112	0.0000	0.0496**	0.0062
	(0.0080)	(0.0075)	(0.0001)	(0.0207)	(0.0054)
Obs.	10197	10197	10197	10197	10197
Pseudo R^2	.z	.z	.z	.z	.z

The table presents the coefficient and standard errors (in parenthesis) of the estimation by using quantile regression. $ROA_{i(t-1)}$ is the ratio of previous year EBITDA to previous year total assets. $RDI_{i(t-1)}$ is the R&D previous year expenditure deflated by the revenue of the previous year. Lev_{it} is the ratio of the total assets to total liabilities. $Size_{it}$is the logarithm of the current total assets. YEAR is the proxy for indicators to capture possible common economy-wide factors measured using a dummy

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

Table 13 Quantile regression to estimate the influence of spending on R&D activities on revenue growth

Independent variables	Growth $_{it}$ Quantile regression (in percentage)				
	10	25	50	75	90
RDI $_{i(t-1)}$	0.0002***	0.0003***	0.0003***	0.0015***	0.0009***
	(0.0001)	(0.0000)	(0.0000)	(0.0002)	(0.0002)
Growth $_{i(t-1)}$	-0.3380***	-0.2237***	-0.1644***	-0.1826***	-0.2592***
	(0.0138)	(0.0113)	(0.0117)	(0.0124)	(0.0166)
Lev $_{it}$	-0.0010*	0.0003***	0.0002***	0.0007***	0.0005
	(0.0006)	(0.0000)	(0.0000)	(0.0003)	(0.0004)
Size $_{it}$	0.9995***	0.7592***	0.5025***	0.5513***	0.5086***
	(0.1009)	(0.0250)	(0.0710)	(0.0352)	(0.1407)
Year	-0.1108***	-0.0929***	-0.0204***	-0.0143	-0.3658***
	(0.0227)	(0.0209)	(0.0063)	(0.0273)	(0.1175)
Obs.	5266	5266	5266	5266	5266
Pseudo R^2	.z	.z	.z	.z	.z

This table presents the coefficient and standard errors (in parenthesis) of the estimation by using quantile regression. RDI $_{i(t-1)}$ is the R&D expenditure for the previous year divided by revenue for the previous year. Growth $_{it}$ is the difference logarithm of current revenue and previous year revenue. Lev $_{it}$ is the ratio of total assets to total liabilities. Size $_{it}$ is proxied by firm size measured as the logarithm of total assets. Year is the proxy of indicators to capture possible common economy-wide factors measured using a dummy.

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

As observed in the quantile regression estimations, spending on R&D activities significantly influences the profitability and revenue growth of mining firms in any distribution of profit and revenue growth. However, the significant influence on profitability is negative when mining firms have lower profits, represented in the below quantile 25 result. This negative influence could be due to the time between the outlay of an R&D dollar and the resulting revenue stream. Spending on R&D increases operational costs and indirectly influences profitability. Lome, Heggeseth and Moen (2016) argue that two-time lags exist: the time between projection and completion and the time to commercialisation. These lags imply that when spending on R&D occurs, the benefit of higher profit is delayed, suggesting that mining firms with lower profits strive to attain a competitive advantage through R&D activities.

In terms of the observation on revenue growth, the influence of R&D activities is significant for all quantiles and much larger at higher quantiles. These results suggest that spending on R&D activities makes a larger contribution to the growth rates of high-growth compared with low-growth mining firms.

Overall, the results presented in Table 11 and Table 12 suggest that the influence of R&D activities on profitability and revenue growth is significant. R&D activities can be viewed as contributing to the knowledge production process, which improves firm performance (Sun & Anwar, 2015). However, the small increase in profitability and revenue growth reveals that the nature of R&D activities in the mining industry does not emphasise the notion of 'newness' in innovation as defined by Schumpeter (1947) but focuses on optimising and automating existing mining methods (Bryant, 2011; Filippou & King, 2011). This nature of the activities is related to the competitive advantage of mining firms as price takers instead of price-makers.

Being a price taker allows mining firms to choose a cost leadership source that focuses on cost reduction to achieve cost efficiency in upstream and downstream processes. Cost reduction is a mechanism to improve mining firms' business and gain competitiveness (Bryant, 2011). Therefore, a cost leadership strategy allows mining firms to maintain their sustainability by decreasing production costs and managing profitability and positive cash flow (Deloitte, 2017). Here, conducting R&D activities is one strategy in the mining industry to reduce production costs and improve existing processes to achieve Porter's operational effectiveness (Filippou & King, 2011).

The R&D activities in mining firms have had no breakthrough changed productivity or reducuction in operating costs (Bryant, 2011). Most R&D activities have been driven by incremental improvement in existing methods, or what Peters (2008) calls incremental innovation, which is improvement in the existing product or process to achieve the pinnacle of efficiency and cost-effectiveness. R&D activities conducted in mining firms are related to larger, longer-lived equipment and better chemistry to improve processing recoveries; for example, increasing the size of a shovel, truck and port infrastructures or expansion of plant capacity that follows best practices. However, these activities represent short-term cost reductions rather than improving longer-term value creation (Bryant, 2011). This outcome is not enough to reduce costs and improve business performance. The findings of this study confirm this insignificant influence. Therefore, competition among mining firms is tight and implies a thin margin in both firm performance measures.

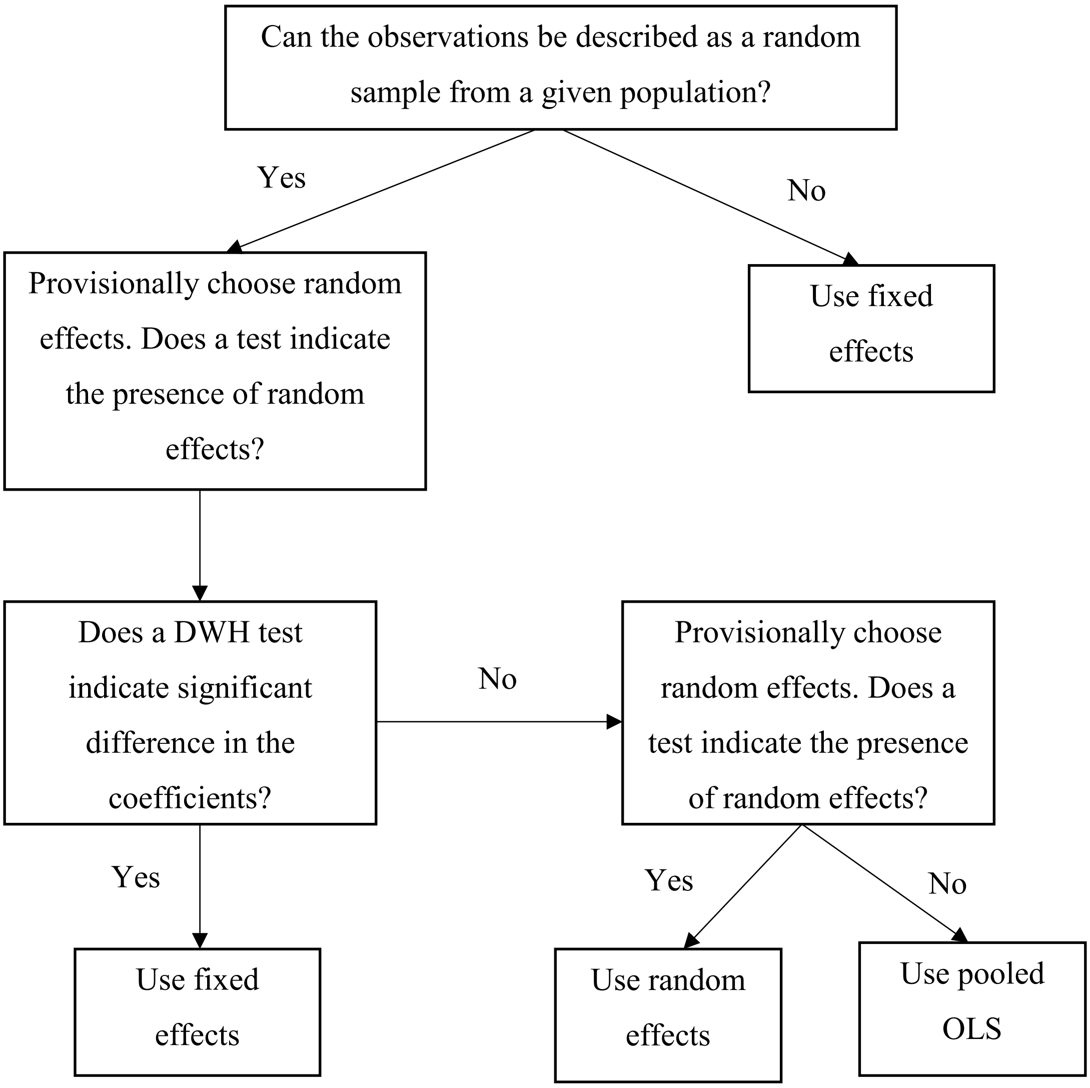
Transformational approaches in R&D activities can become an alternative for mining firms to improve business performance and reduce extraction costs. The transformation encompasses all major phases of operations, from mine development to the extraction process and transportation, including the provision of utilities. These approaches are used because mining firms generally do not have all resources necessary to design, construct and implement a new production platform (Bryant, 2011). Hence, collaboration with external expertise or third parties with relevant knowledge and capabilities is needed. The collaboration or alliance can be with a commercial mining technology or an academic research institution and is considered an effective way to drive results.

5.3.2 Analysing the influence of R&D on Tobin's q

In analysing the influence of R&D expenditure on Tobin's q (Q), linear regression is used as there is no endogenous bias of R&D on Tobin's Q based on the preliminary test, consistent with Connolly and Hirschey (1990). However, to explore the possibility of firm-specific effects, some tests are conducted to check the statistical validity of the model.

The tests follow guidance by Dougherty (2011) to choose between pooled, fixed, or random effects. To check for any significant difference in the coefficients, the Hausman test is performed to choose between fixed and random effect regressions. If a significant difference is identified, the analysis needs to use fixed effects (*fe*), and conversely, if there is no significant difference, the random effects (re) model needs to be used. However, the choice of using '*re'* needs to be tested to choose between '*re'* or pooled OLS. The test to indicate is the Breusch-Pagan test, and the flowchart of testing is depicted in Figure 19.

Figure 19 Flowchart of regression model



Source: Dougherty (2011, p.527)

In STATA, the command syntax for the Hausman test is by regressing both *fe* and *re* then storing them in the system. To regress using '*fe*' and '*re*', the command syntax is *"xtreg ( )"* and is followed by putting the command syntax of '*fe*' or '*re*' for fixed effect and random effects after it, respectively. The result of the Hausman test confirms the rejection of the null hypothesis (H*o*) (p-value >0.05), which indicates choosing random effects (as shown in Table 14).

Table 14 Hausman test result

Test: Ho: difference in coefficients not systematic	chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 2.57 Prob>chi2 = 0.9979

When the random effects model was selected, the Breusch-Pagan Lagrange multiplier (BP) test was used to identify whether using a random effect or pooled OLS was recommended. As shown in Table 15, the result indicates the significant presence of a random effect. It simultaneously implies rejecting the pooled OLS model and accepting the use of random effects to analyse the influence of R&D expenditure on Tobin's Q to test Hypothesis 3.

Table 15 The BP test result

Breusch and Pagan Lagrangian multiplier test for random effects

TobinsQ[ASX_ID,t] = Xb + u[ASX_ID] + e[ASX_ID,t]

Estimated results:

	Var	sd=sqrt(Var)
TobinsQ	38642.55	196.5771
e	30726.72	175.2904
u	1244.57	35.27847

Test: Var(u) = 0

chibar2(01) = 47.13

Prob > chibar2 = 0.0000

5.3.2.1 Applying the Model

Using the selected regression model, random effects as a result of the Hausman and Breusch-Pagan Lagrange multiplier tests, the first regression model is applied:

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 Lev_{it} + \gamma_3 Size_{it} + \gamma_4 Year_{it} + \varepsilon_{it} \quad (1)$$

The results from applying a random effects model are reported in Table 16.

Table 16 Results of regression analysis with Tobin's q as the dependent variable

Independent Variables	Q_{it}		
	Coef.	Std.Err.	Sig
RDI_{it}	-0.0002	0.0001	
Lev_{it}	1.3045	0.3418	***
$Size_{it}$	-13.0588	9.6085	
Year 2006	0.0000	.	
Year 2007	9.9032	6.7232	
Year 2008	14.0401	7.3895	*
Year 2009	10.2844	7.4984	
Year 2010	12.8701	9.3445	
Year 2011	17.1585	11.0787	
Year 2012	98.0587	78.1316	
Year 2013	11.9022	9.0618	
Year 2014	10.1110	6.7723	
Year 2015	0.2236	4.2812	
Year 2016	13.2290	6.1045	**
Year 2017	12.6718	8.0859	
Constant	80.3977	58.0027	
Number of obs	8478		
Overall r-squared	0.3459		
Chi-square	4475.1858		
R-squared within	0.3446		
R-squared between	0.3519		

This table presents the results for the random effects regression. Q_{it} is proxied by the approximate Tobin's q measured using Chung and Pruitt's (1994) calculation. RDI_{it} is the R&D expenditure deflated by revenue. Lev_{it} is the ratio of the total assets to total liabilities. $Size_{it}$ is the logarithm of the total assets. Year is the year dummy as a proxy of indicators to capture possible common economy-wide factors

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

Controlling Lev_{it} and $Size_{it}$, this study does not detect a significant influence of spending on R&D activities on Tobin's q (p-value>0.05).

The insignificant influence of spending on R&D activities using the first model could be because of a non-linear correlation between R&D and Tobin's q (Ehie & Olibe, 2010; Kim et al., 2018). Thus, squared RDI (RDI^2) is included in the second regression model as shown in Equation 8.

Equation 8 The non-linear regression model (second regression model) with Tobin's q as dependent variable

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 RDI^2{}_{it} + \gamma_3 Lev_{it} + \gamma_4 Size_{it} + \gamma_5 Year_{it} + \varepsilon_{it} \quad (2)$$

Using random effects regression and generated in STATA by adding 'robust' command syntax in 'xtreg', the result shows that both RDI and squared RDI show no significant relationship with Tobin's q, as found by Ehie and Olibe (2010) and Kim et al. (2018). Table 17 reports the comparison results using pooled, random, and fixed effects models.

Table 17 Result of regression analysis with non-linear correlation

Independent Variables	Pooled	Q_{it} Fixed effects	Random Effects
RDI_{it}	-0.001	-0.000	-0.001
	(0.001)	(0.001)	(0.001)
RDI^2_{it}	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)
Lev_{it}	1.304***	1.305***	1.304***
	(0.342)	(0.345)	(0.342)
$Size_{it}$	-13.063	-18.723	-13.063
	(9.613)	(13.374)	(9.613)
Year 2006	-19.028	-25.317	-19.028
	(53.282)	(51.459)	(53.282)
Year 2007	-8.550	-10.919	-8.550
	(52.230)	(51.546)	(52.230)
Year 2008	-3.841	-4.274	-3.841
	(44.857)	(44.894)	(44.857)
Year 2009	-7.009	-7.636	-7.009
	(42.022)	(42.019)	(42.022)
Year 2010	-3.862	-2.700	-3.862
	(38.071)	(38.823)	(38.071)
Year 2011	0.992	4.500	0.992
	(33.427)	(35.484)	(33.427)
Year 2012	82.491	86.590	82.491
	(91.318)	(94.181)	(91.318)
Year 2013	-3.119	-0.448	-3.119
	(22.023)	(23.529)	(22.023)
Year 2014	-4.289	-2.707	-4.289
	(14.641)	(15.547)	(14.641)
Year 2015	-13.600	-13.584	-13.600
	(9.295)	(9.357)	(9.295)
Constant	1243.582	1747.441	1243.582
	(10638.147)	(10463.493)	(10638.169)
Obs.	8478	8478	8478
Pseudo R^2	.z	.z	.z

This table presents the coefficient and standard errors (in parenthesis) of the estimation result from the Pooled, fixed effect and random effect regression of the possible non-linear relationship between spending on R&D activities on Tobin's q as found by Ehie and Olibe (2010) or Kim et al. (2018). Q_{it} is proxied by the approximate Tobin's q. RDI^2_{it} is squared of RDI to show the non-linear regression. Lev_{it} is the ratio of the total assets to total liabilities. $Size_{it}$ is the logarithm of the total assets. Year is a year dummy

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

The third regression model follows a study by Connolly and Hirschey (2005) that finds profitability is a significant determinant of the market value of firms as measured by Tobin's q. Hence, profitability is added to the regression model (as explained in Chapter 4 for the third empirical model). The regression model is shown in Equation 9:

Equation 9 The third regression model with Tobin's q as dependent variable and adding ROA as control variable

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{\mathrm{it}} + \gamma_2 ROA_{it} + \gamma_3 Lev_{it} + \gamma_4 Size_{it} + \gamma_5 Year_{it} + \varepsilon_{it} \qquad (3)$$

Using three different statistical methods (pooled, fixed effects and random effects), comparison results are shown in Table 18. The results from the fixed and random effects models show that spending on R&D activities significantly influences Tobin's q, and the only notable contrast is the degree of significance, which is 5 per cent and 10 per cent for fixed and random effects, respectively. In contrast, the pooled regression does not show a significant influence of spending on R&D activities on Tobin's q.

Table 18 Result of regression analysis of Tobin's q as the dependent variable and adding ROA as a control variable

Independent Variables	Q_{it}		
	Pooled OLS	Fixed Effects	Random Effects
ROA_{it}	-1.0981***	-1.1031	-1.0981
	(0.4190)	(2.2015)	(2.1966)
RDI_{it}	-0.0002	-0.0002**	-0.0002*
	(0.0021)	(0.0001)	(0.0001)
Lev_{it}	1.2889***	1.2897***	1.2889***
	(0.0205)	(0.3668)	(0.3632)
$Size_{it}$	-12.7665***	-18.2897	-12.7665
	(3.6726)	(13.9154)	(9.9858)
Year 2007	9.7082	13.3676	9.7082
	(32.8319)	(9.4392)	(6.9716)
Year 2008	11.7199	17.0409	11.7199
	(32.6890)	(12.9147)	(9.3337)
Year 2009	9.5669	14.5305	9.5669
	(32.5115)	(11.7403)	(8.4362)
Year 2010	12.5860	19.1388	12.5860
	(32.3695)	(13.9832)	(9.7055)
Year 2011	16.9756	25.6450	16.9756
	(32.1475)	(17.0672)	(11.2828)
Year 2012	98.0047***	107.0820	98.0047
	(32.1755)	(84.3217)	(78.2910)
Year 2013	11.5568	18.9852	11.5568
	(32.1916)	(14.3208)	(9.5056)
Year 2014	9.8391	16.0335	9.8391
	(32.1936)	(11.0254)	(7.0625)
Year 2015	0.2362	4.6895	0.2362
	(32.4048)	(3.8570)	(4.2291)
Year 2016	12.3430	16.5773*	12.3430**
	(32.6203)	(8.5042)	(6.1084)
Year 2017	12.3021	16.2874	12.3021
	(32.8491)	(10.7826)	(8.5387)
Constant	78.4362**	110.5903	78.4362
	(32.5408)	(77.5297)	(60.5253)
Obs.	8478	8478	8478
Pseudo R^2	.z	.z	.z

This table presents the coefficient and standard errors (in parenthesis) of the comparison result for the Pooled, fixed effect and random effect regressions by adding ROA_{it} in the control variable. Q_{it} is proxied by the approximate Tobin's q. ROA_{it} is the ratio of EBITDA to total assets. RDI_{it} is the R&D current expenditure deflated by current revenue. Lev_{it} is the ratio of total assets to total liabilities. $Size_{it}$is the logarithm of total assets. YEAR is year dummy to capture possible common economy-wide factors.

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

5.3.2.2 Robustness Test for Tobin's q

Conolly and Hirschey (2005) suggest that instead of profitability as a significant determinant of the market value of the firm measured by Tobin's q, there is another factor with predictable influence on the current market value of firms. This factor is revenue growth. Growth has a positive effect on market value if future spending is expected to earn above-normal rates of return (Connolly & Hirschey, 2005). Thus, to check the robustness of the finding of a significant influence of spending on R&D activities on Tobin's q, this study includes controls for revenue growth following the Connolly and Hirschey (2005) suggestion. The empirical model for this robustness test is established in Equation 10 as follows:

Equation 10 represents a regression model for a robustness test, including profitability and revenue growth as control variables

$$Q_{it} = \gamma_0 + \gamma_1 RDI_{it} + \gamma_2 ROA_{it} + \gamma_3 Growth_{it} + \gamma_4 Lev_{it} + \gamma_5 Size_{it} + \gamma_6 Year_{it} + \varepsilon_{it}$$

Including profitability and revenue growth in the regression model results in strong significance for the influence of spending on R&D activities on Tobin's q (p-value<0.001). When only including ROA as a control variable, the significance level is below the 5 per cent level. In addition, a strong result is shown in three regression analyses (pool, fixed and random effects), which report the same result of a significant influence of spending on R&D activities on Tobin's q. Overall, the results are consistent with the earlier findings (third regression model) and confirm that the empirical findings of the influence of R&D activities on Tobin's q are robust. The results for the robustness check to add ROA and revenue growth as control variables are shown in Table 19. The decreased number of observations to 6156 is due to including revenue growth as a control variable, which is measured using annual growth calculated by the difference logarithm of current and previous year revenue.

Table 19 Results of regression analysis of Tobin's q as dependent variable and adding ROA and revenue growth as control variables

Independent Variables	Q_{it}		
	Pooled OLS	Fixed Effects	Random Effects
ROA_{it}	-2.516***	-2.460***	-2.516***
	(0.038)	(0.038)	(0.038)
$Growth_{it}$	-0.008	0.078	-0.008
	(0.092)	(0.123)	(0.092)
RDI_{it}	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Lev_{it}	1.016***	1.027***	1.016***
	(0.008)	(0.008)	(0.008)
$Size_{it}$	-1.209**	-2.476**	-1.209**
	(0.485)	(1.026)	(0.485)
Year 2007	2.811	4.394	2.811
	(3.290)	(3.672)	(3.290)
Year 2008	1.411	2.878	1.411
	(2.910)	(3.259)	(2.910)
Year 2009	-0.153	1.215	-0.153
	(2.661)	(2.934)	(2.661)
Year 2010	0.844	2.147	0.844
	(2.235)	(2.517)	(2.235)
Year 2011	1.146	2.391	1.146
	(1.902)	(2.186)	(1.902)
Year 2012	0.051	1.194	0.051
	(1.552)	(1.790)	(1.552)
Year 2013	-0.531	0.447	-0.531
	(1.221)	(1.405)	(1.221)
Year 2014	-0.409	0.150	-0.409
	(0.872)	(0.949)	(0.872)
Year 2015	1.433	1.468	1.433
	(1.425)	(1.371)	(1.425)
Constant	-447.658	-958.702	-447.657
	(698.891)	(769.161)	(698.890)
Obs.	6156	6156	6156
Pseudo R^2	.z	.z	.z

This table presents the coefficient and standard errors (in parenthesis) of the comparison results for the Pooled fixed effect and random effect regressions by including ROA and Growth as control variables. Q_{it} is proxied by the approximate Tobin's q. ROA_{it} is the ratio of EBITDA to total assets, whereas $Growth_{it}$ is a proxy for revenue growth measured as the difference logarithm of current and previous year revenue. RDI_{it} is the R&D expenditure deflated by revenue. Lev_{it} is the ratio of total assets to total liabilities. $Size_{it}$ is the logarithm of total assets. YEAR is year dummy

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

5.4 Findings

The previous sections presented the results of GMM and OLS estimations to test the influence of R&D expenditure on profitability, revenue growth and Tobin's q. The results of the hypotheses testing are presented in Table 20 and discussed below.

Hypothesis one (H_1): spending on R&D activities significantly influences the profitability of mining firms in Australia.

Hypothesis one investigates the influence of R&D activities on profitability measured using ROA. The finding shows a significant influence of the activities on profitability with $p < 0.01$.

Hypothesis two (H_2): spending on R&D activities significantly influences the revenue growth of mining firms in Australia.

Hypothesis two predicts a significant influence of R&D activities on revenue growth. The result of the analysis indicates that the activities significantly influence revenue growth with $p < 0.01$.

Hypothesis three (H_3): spending on R&D activities significantly influences Tobin's q for mining firms in Australia.

Hypothesis three predicts a significant influence of spending on R&D activities on Tobin's q; the analysis finds a significant influence of spending on R&D activities on Tobin's q. This significant influence occurs when including profitability as a control variable. However, a non-linear correlation between spending on R&D activities and Tobin's q is not found.

Table 20 Summary of the hypotheses and test results

	Hypothesis	Result
H_1	Spending on R&D activities significantly influences profitability for mining firms in Australia	Significant
H_2	Spending on R&D activities significantly influences the revenue growth for mining firms in Australia	Significant
H_3	Spending on R&D activities significantly influences Tobins's q for mining firms in Australia	Significant

5.5 Summary

This chapter presents the results of descriptive data analysis, consisting of descriptions of panel data and preliminary tests to understand the data and choose the relevant analysis methods. The data shows that R&D expenditures follow fluctuations in revenue, but the volatility of R&D intensity is higher for firms with total assets below A$10billion.

Preliminary testing found no concerning multicollinearity among included variables, but the presence of heteroskedasticity and endogeneity bias was detected in RDI for profitability and revenue growth. The presence of endogeneity made using OLS as an analysis methodology not consistent and biased. This preliminary testing resulted in System GMM being used to address endogeneity and heteroskedasticity when testing the first two hypotheses. A random-effects model was used in testing the relationship between R&D intensity and Tobin's q after conducting Hausman and Breusch-Pagan Lagrange multiplier tests since endogeneity bias was not present.

The results show a significant influence of R&D activities on three firm performance measures: profitability, revenue growth and Tobin's q. In terms of Tobin's q, the significant influence occurs after including profitability as a control variable. Furthermore, previous studies found a non-linear correlation between R&D intensity and Tobin's q. For robustness, the square of R&D intensity is used to check for a possible non-linear correlation. However, the result did not find a significant influence of R&D activities on Tobin's q.

Chapter 6 - Discussion of Findings

This chapter presents an overall discussion of the findings of this study, which were presented in Chapter 5. The discussion provided in this chapter addresses the relevant literature and previous research findings. This chapter is structured based on the research findings, addressing two research questions raised in Chapter 2 that mainly aim to investigate the influence of R&D activities on the financial performance of mining firms in Australia, measured as profitability, revenue growth and Tobin's q. The findings are generated using System GMM analysis to address the presence of heteroskedasticity and endogeneity and random effects analysis, which assumes unobserved variables are uncorrelated with observed variables. In addition, a section on other relationships is provided.

Overall, the findings suggest that spending on R&D activities significantly influences firms' business performance, as measured by the influence of R&D intensity on profitability and revenue growth. The influence of R&D spending on Tobin's q is also significant after controlling profitability, implying that firms' strategic decisions in conducting R&D activities influence share market value.

Detailed discussions for each research question are presented in this chapter, starting with a discussion of the firm's capabilities to integrate internal resources to conduct R&D activities. Section 6.2 discusses findings for the influence of spending on R&D activities on profitability and revenue growth. The next section, 6.3, discusses spending on R&D activities influences Tobin's q. Concluding remarks on the influence of R&D activities on business performance are presented in the last section, section 6.4.

6.1 Background

The resources owned by a firm are essential for the business to run, including all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. (Barney, 1991). These resources enable a firm to seek improvement strategies to run the business more efficiently and effectively; however, firms' resources are heterogeneous. RBV, through the connection of heterogeneous resources, attempts to establish resources that support a firm's sustained competitive advantage. In essence, being at a competitive advantage requires a firm "to create a situation where its resource position directly or indirectly makes it more difficult for others to catch up" (Wernerfelt 1984, p.173). Valuable, rare, imperfectly imitable and non-substitutable are the main attributes of resources needed to hold sustained competitive advantage (Barney, 1991).

The first two attributes strengthen firms to make a firm's competitive advantage possible and sustainable if competitors' efforts to imitate and substitute the value-creating strategy is impossible or costly (Barney, 1991; Joyce & Winch, 2004). Hence, the resources should be imperfectly imitable and non-substitutable. However, when firms find these resources, they must integrate them. Firms' capabilities to deploy and integrate the resources using specific organisational processes (Triguero & Córcoles, 2013) are important. This integration, represented in R&D activities that transform tangible resources or physical capital expenditure combined with intangible resources, represented in personnel skills (OECD, 2002), increases absorptive capacity and exploits new technology (Triguero & Córcoles, 2013).

Using firm size and leverage level as control variables in examining the influence of spending on R&D activities, this study finds a positive and statistically significant relationship with both profitability and revenue growth. This finding confirms the results of previous studies suggesting that firm size influences profitability (Rafiq, Salim & Smyth, 2016) and revenue growth (Nunes, Serrasqueiro & Leitão, 2012). Schumpeter Mark-II also emphasises the key role of firm size in technological change and innovation. This role indicates the possibility of large firms diversifying their activities as a consequence of the characteristics of R&D activities (Del Canto & González,1999; Nunes, Serrasqueiro & Leitão, 2012) to spread costs and earn higher returns on R&D (Connolly & Hirschey, 2005; Legge, 2000). However, in the context of Tobin's q, firm size is not statistically significant when modelled as a linear relationship but is significant when modelled as a non-linear relationship.

Previous year profitability or revenue growth are other non-imitable resources. Finding a significant relationship between profitability in the previous and current periods suggests that the decision to spend on R&D activities is based on the position of the previous year's profit and revenue growth. However, a significant influence between profitability and Tobin's q cannot be established.

Regarding the importance of financing for profitability, revenue growth and Tobin's q, this study finds that (i) a greater level of debt incurred in the business restricts profitability and diminishes revenue growth and (ii) debt has a positive influence on Tobin's q. The various findings of this study corroborate previous studies (Ughetto, 2008; Wang & Thornhill 2010) that show R&D activities are resource-consuming, so firms need to consider the consequences of R&D expenditures on financing choices. Firms have an optimal point of R&D expenditure to access debt, and at the optimal point, firms can raise the highest level of debt to support R&D activities. However, firms at a high level of R&D expenditure, as Wang and Thornhill (2010) suggest, should utilise common equity financing.

Hashi and Stojčić (2013) list factors that firms need to consider before conducting R&D activities, including firm size, export intensity, the existence of public support for innovation, the culture of the country and the availability of working capital or financing. Furthermore, the education level of employees is also a factor to consider (Kemp et al., 2003). All internal supporting resources and capabilities to integrate these resources through R&D activities create and maintain revenues (Squicciarini & Mouel, 2012). The discussion of these findings is in the next section, and a summary of the influence of R&D intensity on firm performance and other factors is presented in Table 21.

Table 21 Summary of findings

Variables	**Profitability**	**Revenue Growth**	**Tobin's q**
R&D Intensity	√***	√***	-/-/√***
Squared R&D Intensity	-	-	ni/-/ni
Control Variables:			
Previous Year Profitability	√***		ni/ni/√***
Previous Year Revenue Growth		√***	ni/ni/-
Firm Size	√**	√***	-/-/√**
Financial Strength	√*	/	√***/√***/√***

This table presents a summary of findings from Chapter 5. In the last column (Tobin's q), there is a sign ' / ' which indicates 'or' because there are three regression models to analyse. For example: -/-/√*** on the row of R&D intensity, which means the first and second models are not significant, while the third is significantly influenced with a significance level at 1 per cent. Furthermore, in the same column, the result is taken from the result of the random effects analysis.

*** Denotes significance at 1% level
** Denotes significance at 5% level
* Denotes significance at 10% level

√	Significantly influence	-	Insignificantly influence
ni	Not included in the regression model		Significant for the sample after the mining boom or excluded the GFC period

6.2 The Influence of Spending on R&D Activities on Profitability and Revenue Growth

The relationship between R&D activities and firm performance is a research topic that raises a lot of interest and has been discussed for a long time. The perspective of RBV suggests that firms need to focus on resources that contribute to strategies that competitors cannot duplicate, both at present and in the future, hence giving the firm a sustained competitive advantage (Barney, 1991). Organisational capital resources, as one of the resource categories under the RBV, represented as R&D activities, are an important resource for creating innovation and developing knowledge that leads to a competitive advantage (Lome, Heggeseth & Moen, 2016). This advantage is gained because firms can transform their unique skills and capabilities into action, consequently creating and maintaining firm performance (Squicciarini & Mouel, 2012). Thus, maintaining a competitive advantage is crucial for firms to survive, as found in the mining industry, through reducing operational costs and improving a firm's competitive advantage. R&D activities significantly influence profitability, as evidenced for mining firms in the findings of this study.

This study shows that R&D activities significantly influence profitability and revenue growth, a result generated from System GMM estimation. The result indicates that the coefficient on RDI in influencing profitability and revenue growth is positive and statistically significant, 0.000049 (p-value<0.01) and 0.000681 (p-value<0.01), respectively. This positive and significant influence on profitability and revenue growth indicates that R&D activities allow firms to increase financial performance. Hence, firms that conduct and spend on R&D activities are more profitable than firms that do not (Alarcón & Sánchez, 2013; Busru & Shanmugasundaran, 2017). In addition, this result confirms the importance of R&D activities for mining firms in Australia, as emphasised by the CSIRO (2015). Miller (2012) suggested that Australia has an opportunity to seize the initiative and become a world leader in mining innovation through R&D activities.

Having established that spending on R&D activities influences profitability and revenue growth of mining firms in Australia, the significant influence of R&D activities is also involved in normal (shown after omitting the GFC period) and downturn growth (shown after the mining boom) periods. This finding implies that R&D activities might make the mining firms better equipped to handle change by increasing a firm's absorptive capacity (Lome, Heggeseth & Moen, 2016; Triguero & Córcoles, 2013). The higher absorptive capacity involves being better at identifying, assimilating, and exploiting intangible assets formation (Alarcón & Sánchez, 2013), thus making the firm better able to handle external turbulence (Lome, Heggeseth &

Moen, 2016). Several studies (see Cohen & Levinthal, 1990; Lazzarotti, Manzini & Pellegrini, 2011; Alarcón & Sánchez, 2013) show that R&D activities positively influence a firm's absorptive capacity and increase absorptive capacity contributes to increasing the firm's ability to adapt to changing environments. Thus, absorptive capacity, as one of the positive effects of R&D, places firms in a more favourable position.

Every period of firm business, downturn, upturn, or financial turbulence, generates opportunities, as pointed out by Lome, Heggeseth and Moen (2016). Of course, the opportunities present differently in each period, making them more challenging for firms to grasp. A firm with R&D activities may be better equipped to exploit these challenges as the presence of R&D activities make them better at identifying and exploiting new opportunities (Lome, Heggeseth & Moen, 2016). R&D activities that represent firms' capabilities to integrate their internal tangible and intangible resources (OECD, 2002) and the relation between a firm and its environment (Barney, 1991) lead firm capabilities to be adaptive to a changing environment. Thus, R&D activities are essential for the survival of firms that face any dilemmas and could be expected to increase the adaptive capabilities of firms as accentuated by the positive influence of R&D in a period of downturn.

For all distributions of profit and revenue growth, the influence of spending on R&D activities is significant. This is consistent with the Schumpeterian economic theory that firms gain market share by innovating (Coad & Rao, 2008, García-Manjón & Romero-Merino, 2012). However, this study observes that the significant influence of spending on R&D activities is especially attributable to firms with higher profit (represented in quantiles 50 per cent and above). It is acknowledged that profit measures using ROA might be biased by earnings management; however, shrinking firms do not benefit from spending on R&D (quantile 10 per cent and 25 per cent of profit) as for these firms, this spending is significantly negatively associated with profit. In contrast, increased spending on R&D activities positively influences the growth of revenue in all cases. Thus, these results suggest that spending on knowledge generation and innovation contribute to a higher rate of revenue growth.

6.3 The Influence of spending on R&D Activities on Tobin's q

This section focuses on the findings concerning the second research question about how spending on R&D activities influences the market-based measure, calculated using Tobin's q. Spending on R&D activities can create intangible capital for firms, as revealed in their valuation by the market. Any spending on a firm's intangible assets can be expected to increase market value (Bosworth & Rogers, 2001; Min & Smyth, 2016). The notion of the influence of R&D activities on a firm's market value was initiated by the seminal contribution of Griliches (1981). He argues that a firm's market value represents a bundle of tangible and intangible assets, can reflect the present value of expected returns from R&D activities and does not need to occur after a long lag of converting the invention into actual sales (Griliches, 1981).

The finding of no significant influence of spending on R&D activities on Tobin's q without controlling profitability and revenue growth shows that a linear relationship between R&D activities and market values cannot be established in the context of mining firms in Australia. This study does not confirm the Connolly and Hirschey (2005) expectation that R&D activities as part of the wide range of firm investment decisions drive a positive market response that gives a premium to an innovative leader and leads to a higher Tobin's q. Even though the possibility exists of a non-linear correlation between R&D activities and Tobin's q (see Ehie & Olibe, 2010; Kim et al., 2018), the findings do not confirm this possibility. Thus, in the situation of the mining industry in Australia, the linearity and non-linearity relationship between spending on R&D activities and Tobin's q does not occur.

Interestingly, after controlling profitability and revenue growth, the result changes so that the influence of spending on R&D on Tobin's q is significant. From this result, several possible reasons can be conjectured, principally stemming from the different measures of R&D intensity and Tobin's q, as applied in this study. First, shareholders suffer from a form of myopia in which managers sacrifice long-run profit to maximise shareholders' wealth by favouring short-term benefits. This market myopia affects spending on R&D activities as a long-term investment with a long-run payoff that will not be reflected in the current stock price (Connolly & Hirschey, 2005; Parcharidis & Varsakelis, 2010). If market myopia occurs, a negative reaction to the announcement of R&D activities can be expected, as predicted by Parcharidis and Varsakelis (2010). This study finds a negative coefficient for R&D intensity, and it becomes significant after including profitability as a control variable (the coefficient is -0.0002 with a p-value<0.01). Thus, the possibility of market myopia is present.

Second, shareholders are not concerned with strategic decisions, including R&D activities, that managers make (as per the result without including profitability as a control variable). The underlying reason for this attitude is that market valuation reflects shareholders' perceptions but not a firm's fundamental value (Gentry & Shen, 2010). Moreover, spending on R&D activities is expected to drive an immediate positive market response giving a premium to innovative firms, leading to a higher Tobin's q (Parcharidis & Varsakelis, 2010). Tobin's, representing an assessment of market returns on tangible and intangible assets, is expected to reflect how firms' strategies and actions influence shareholders' perceptions. The strategic decision to spend on R&D activities is expected to generate a profit stream and increase the value of a firm's intangible assets (Connolly & Hirschey, 2005). However, using R&D intensity (without a lag), this study could not detect shareholder reaction through share prices to the decision to conduct R&D activities.

In contrast to the second reason above, shareholders are more concerned about the financial strength to ease of accessing financing resources. R&D activities are considered resource-consuming; consequently, access to financing choices is needed. Firms with good financial strength have an optimal point to access debt and can raise the highest level of debt to support R&D activities. On the other hand, the ease of accessing finance resources is an advantage of being a large firm (Cockburn & Henderson, 2001) and ease to access capital or labour to gain market power to prevent other firms from entering the market (Revilla & Fernández, 2012). Large firms have higher financial strength and vice versa, but this shows that being a large firm or having good financial strength enables them to control the mining market. Hence, this study finds a positive relationship between financial strength and the market valuation of Tobin's q.

Alternatively, mining firms may not be reacting to market valuation. Instead of having outside structural challenges of corporate social responsibility (CSR), such as environmental issues that continue to mount and geopolitical and community pressures, mining firms focus on sustained rises in operating expenses and capital development. This internal focus seizes mining firms on sustaining their businesses despite the long-run price decline in mined products. Therefore, some mining firms focus their spending on R&D activities to reduce energy consumption in production by inventing better equipment to enhance production efficiency with minimal energy consumption, while others choose mergers and acquisitions.

R&D activities in mining firms do not move forward the key role of reducing environmental impact, such as production speed, without meeting the demand for increased energy or deployment of improved clean energy. While these key roles are forward-looking for shareholders in terms of future community and environment, the mining industry in Australia is known as the largest per capita polluter in the world, contributing 1.5 per cent of global greenhouse emissions (Nguyen, Agbola & Choi, 2021; Pellegrino & Lodhia, 2012). Shareholders are concerned with the environmental issues and social impacts not addressed seriously by mining firms. Hence, several studies confirm a positive influence of CSR activities on the market value of mining firms (see Nguyen, Agbola & Choi, 2021; Yu-Chun, 2017).

6.4 Summary

This chapter presents a discussion of findings that starts with explaining the unique capabilities of firm resources developed through R&D activities to establish a competitive advantage, leading to superior performance, as guided by the RBV perspective. The R&D activities integrate a firm's unique capital resources to increase a firm's absorptive capacity and create and maintain a firm's performance. This study confirms that spending on R&D activities significantly influences profitability and revenue growth for mining firms. Even after the mining boom period (period 2013 – 2017), the results still show significant influence on both profitability and revenue growth. This significant influence accentuates the importance of R&D activities and the positive influence of activities on profitability and revenue growth in unpredicted conditions faced by firms. Thus, R&D activities allow firms to be better equipped to handle change through increased absorptive capacity because they increase the ability of firms to adapt to changing environments.

The small increase in profitability and revenue growth from R&D activity influence is related to the nature of the competitive advantage of mining firms, which are price takers. Being a price taker allows mining firms to focus R&D activities on reducing costs and achieving cost efficiency in upstream and downstream processes. However, the activities are more concerned with incremental innovation, such as optimisation and improvement of existing methods, instead of emphasising the notion of 'newness' in innovation. These activities represent short-term cost reductions rather than improving longer-term value creation. Thus, mining firms need transformational approaches in R&D activities to improve business performance and reduce costs in the whole process. In addition, collaboration with external expertise or third parties with relevant knowledge and capabilities can effectively drive results. The collaboration can be with a commercial mining technology or an academic research institution.

In terms of market-based measures such as Tobin's q, spending on R&D activities has a significant influence after controlling profitability but is not significant without it. This finding has some possible explanations. First, a myopic market occurs when shareholders focus on short-term benefits while managers sacrifice profit to maximise shareholders' wealth by favouring their short-term benefits. Spending on R&D activities is considered a long-term investment with a long run payoff and will not be reflected in the current stock price

Second, shareholders are not concerned with strategic decisions, in this case, R&D activities, as shown in the result for Tobin's q without including profitability as a control variable. Third, it could be that mining firms are not concerned about market valuation because they strive to sustain their businesses despite operating expenses increasing and external issues continuing to mount. On the other hand, shareholders focus on the inherent risk involved in the mining firms from environmental issues and social impact arising from their operational activities. Some literature (see Nguyen, Agbola & Choi, 2021; Yu-Chun, 2017) focusing on environmental action by mining firms confirms that these actions influence their market valuation, but this is not the case for the strategic decision to engage with R&D activities, as found in this study.

Chapter 7 - Conclusion and Implications

This final chapter concludes this study by reflecting on what has been carried out and making some recommendations for further studies based on the limitations of this study. The first section presents the conclusions, elaborating on the answers to the research questions. Section 7.2 highlights the implications of this study and its contribution to the academic literature, policymakers and business practitioners. Section 7.3 identifies potential weaknesses in this study. Finally, this chapter ends by paving the way for future research to advance our understanding of the influence of spending on R&D activities on firm performance in other industries.

7.1 Conclusion

In conclusion, two main points which address the two research questions need to be made. In general, firms' potential internal resources are significant factors in the decision to conduct R&D activities. This confirms the RBV's focus on internal resources or anything owned by a firm to run the business. Two of the internal factors focused on are the financial strength and size of firms. Both factors are significant for firms in deciding on R&D activities in mining firms where there is an understanding of the importance of conducting R&D activities to address the unpredictable global mineral market. The importance of R&D activities can be seen in the increasing number of firms conducting R&D activities over the years. With inherent pressure in the mining industry due to a lack of control over global mineral prices, R&D activities are conducted to decrease production costs and manage profitability and positive cash flow (Deloitte, 2017) while the mineral resource is depleted (Mitra, 2019), causing a decline in productivity (Bryant, 2015).

This study finds that firms spending on R&D activities significantly influences their profitability, growth in revenue and market value measured using Tobin's q. However, when facing any negative economic conditions, such as the GFC, recessions or a downturn in mining, firms face many dilemmas concerning whether to proceed with R&D activities or wait for a better time (García-Manjón, & Romero-Merino, 2012) as R&D activities are highly uncertain of success (Lai, Lin & Lin, 2015) although they may increase the probability of superior performance (Coad & Rao, 2008). This study provides evidence of the benefits of R&D

activities in mining firms, especially firms with higher profit distribution, but for all cases of revenue growth distribution.

In terms of the market value of firms, shareholders are not concerned about the R&D activities conducted by firms. However, shareholders are more concerned about the profitability and revenue growth of firms. This is in line with the previous findings that whether firms conduct R&D activities or not, there is no significant effect on profit. Therefore, if R&D activities influence profitability and revenue growth, market value will be affected.

7.2 Practical Implications of this Research

7.2.1 Implications for the Academic Literature

The implications of this study for the academic literature are as suggested by Rafiq, Salim and Smyth (2016), who study the effect of R&D expenditure on firm performance in the US and Chinese mining industries. They suggest studying the R&D effect on firm performance using Australian mining firm data because Australia is a country in which the importance of R&D investment in mining has been emphasised. The results of this study show that R&D activities in mining firms have a significant influence on profitability, and revenue growth and receive positive responses from shareholders, measured using Tobin's q. However, instead of facing internal challenges within mining firms in terms of earnings or growth of revenue, firms face external pressures and emphasise R&D activities to tackle these issues, for example, the environmental impact of exploiting mining resources. Mining firms are transforming mining processes to be more environmentally friendly with lower carbon emissions.

7.2.2 Implications for Policymakers

Other implications relate to policymakers who advocate for or implement support by providing R&D tax incentives. Since most firms with R&D activities benefit from those R&D activities, reviewing existing R&D tax incentives is a reasonable policy objective. However, potential concerns are raised for companies at the lower range of the profit distribution as there is a lack of any significant relationship between R&D intensity and profit. There is no concern about firm growth, as R&D activities benefit their growth of revenue. To enhance firm growth, the priority of R&D incentives programs could be to target firms located in half of the distribution of the conditional profit and growth distribution. However, it is difficult for R&D incentives to target this particular group.

Even though R&D activities benefit firms' performance in the future, the trend in mining firms is the sustained rise of operational expenses and capital development costs. Supporting the mining industry through giving R&D tax incentives is not enough for mining firms to sustain themselves in the future. R&D activities in mining firms are mostly related to larger, longer-lived equipment and better chemistry to improve processing recoveries (Bryant, 2015) and reduce operational costs or operate the mining process efficiently. This could be because mining firms do not have the knowledge or resources to implement technological solutions. Therefore, providing support for the mining industry to sustain it in Australia is needed. Collaboration and alliance with other partners, such as universities and research firms, are needed to achieve rapid and effective changes (Bryant, 2015).

7.2.3 Implications for Business Practitioners

The findings in this study have some important implications for managers. The findings reveal that spending on R&D activities has a profound influence on profit and revenue growth. Moreover, R&D activities are important activities as accentuated during the mining downturn period. Hence, increased spending on R&D activities is an important factor for managers to sustain their firms for any future crisis, as this empirical study shows the significant relationship between spending on R&D activities and firm performance after the mining boom period. That is, R&D is essential for the growth and survival of firms.

Another implication to managers is related to the option of short-term versus long-term solutions. Managers often face pressure from shareholders and owners to cut the operating expenditure during a downturn period. According to Lome, Heggeseth and Moen (2016), 'short-term fixes are favoured over long-term solutions, and possibly profitable R&D spending are shelved' (p. 75). These findings could show that managers should carefully consider before cutting R&D spending. Firms that do not cut spending on R&D may gain an important competitive advantage when economic conditions start to recover and take a larger part after a downturn economic. At the same time, competitors are struggling to get back to a level before the downturn period.

7.3 Limitations of the Study

This study has several limitations that provide direction for future studies. First, the reporting of R&D expense or expenditure in the financial statements is not compulsory. Firms prefer not to report the total amount of their R&D activities clearly in the financial statements because it is related to competition in the industry. Firms report on R&D activities in the information section of financial reports but with little information on the total amount they spend. This voluntary reporting of R&D expenditure leads to drastically reducing the number of observations available for research.

Second, and related to voluntary reporting of R&D expenditure, the R&D expenditure reported in the financial statements is embedded with firms' tax planning of firms. Instead of reporting as an asset by capitalising the expense, firms report R&D activities as an expense to reduce the tax to be paid. Moreover, firms do not report spending on R&D activities specifically under R&D accounts but expense it through many different ledger accounts.

Third, assets or equipment used to support R&D activities are used for normal operations. Due to these shared assets, R&D expenditure does not cover the cost of R&D activities that consist of multiple activities. Firms do not allocate specifically the assets or equipment used for R&D activities. Therefore, R&D expenditure does not cover the total cost of R&D activities conducted by firms. Moreover, firms do not reveal the underlying purpose of R&D activities.

In terms of profit and revenue growth as influenced by spending on R&D activities, this study has another limitation. Profit or revenue growth is related to the earning management motivated by managers. In the mining industry, earnings management is prevalent and considered to engage in income-decreasing earnings management behaviour (Rath & Sun, 2008). In addition, Rath and Sun (2008) argue that earnings management by managers is an attempt to influence short-term stock performance by using discretionary accruals that are positively associated with future stock returns. Thus, measuring the influence of spending on R&D activities using profit or revenue growth consider debatable and consequently influences the performance of stock price in the capital market.

7.4 Future Research Recommendation

Future study is needed in the area of innovation in the mining industry to influence firm performance. This study uses R&D as the proxy for innovation, in which use spending on R&D activities is the only one of the inputs that can drive innovation. Hence, for future research, this study recommends the use of more complete measures of innovation to overcome the biases of a single variable such as R&D expenditure. For example study by Coad and Rao (2008) proposed using a common variance of R&D and patent intensity, whereas Lanjouw and Schanjerman (2004) measure innovation with multiple characteristics of patents.

Delving deeper into the nature of R&D activities in the mining firms is needed, for example, investigating the difference between process and business model innovation on firm performance. However, R&D activities in mining firms are mostly related to optimizing and automation the current mining process and no transformation approach and new process (Bryant, 2011). While this study using the current R&D process finds the significant influence of R&D on firm performance and CSIRO saw the importance of R&D activities in the mining firms; hence, further research is recommended to investigate the relationship between the new approaches or process and firm performance in mining firms.

R&D activities are viewed as determinants of the growth and productivity of firms. However, measuring the influence of R&D activities on firm performance has become a critical issue in which quantitative indicators such as profit and revenue or net sales are considered determinants of earnings management (Rath & Sun, 2008). At the same time, managers have other concerns that not all indicators, such as financial performance, have the same share in the overall measuring of the influence of R&D activities. Thus, further research needs to consider measuring the influence of R&D activities using different assigned levels of importance to different perspectives and different indicators for each perspective. For example, quantitative indicators for measuring the influence of R&D activities on customers' perspectives (such as customer satisfaction) or internal business indicators (such as efficiency and quality of outputs) could be used.

The role of the control variables has received little attention across ranges of relationships in the management literature. This has not been addressed for the presence of endogeneity in the model. The list of control variables is related to managers' considerations in deciding to conduct R&D activities. This study uses firm size and leverage level as control variables in the model. However, as suggested by Hashi and Stojčić (2013), some other factors need to be considered, such as export intensity, the existence of public support for innovation, the culture of the country and the availability of working capital or financing. The education level of employees also needs to be considered in conducting R&D activities (Kemp et al., 2003).

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