THREE PERSPECTIVES ON CANADIAN MINING: EVOLUTIONARY, RESOURCE-BASED, AND STRATEGIC

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

Under Special Arrangements
in the
Faculty of Business Administration

SIMON FRASER UNIVERSITY

Spring 2006

APPROVAL

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Degree: Doctor of Philosophy

Title of Thesis: Three Perspectives on Canadian Mining: Evolutionary, Resource-Based, and Strategic

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ABSTRACT

This research, comprised of three essays, considered the evolution of Canada's population of mining firms over much of the 20th century, the resource characteristics of the firms that survived the industry shakeout, and the strategic positioning of the firms that ranked among the largest mining firms in the world.

In the first essay, the forces responsible for the change in the number of Canadian mining firms between 1929 and 1999 were explored using a set of mathematical models designed to identify the underlying dynamic. Density, or the number of mining firms in the population, was found to be responsible for the industry's evolutionary profile.

Organizational populations typically experience a significant decrease in membership at one point in their history. This phenomenon, known as a 'shakeout', occurred in the 1980s for the population of Canadian mining firms. In the second essay, the survival of a cohort of 741 firms that were active in 1969 was tracked over a thirty year period. The firms that survived were not only the older firms and the firms with more financial resources but also those firms in possession of a portfolio of resource-based assets in the form of deposits and mines.

In the third essay, the strategic positioning of twenty-six of the world's largest mining firms, seven of which were Canadian, was examined. In an industry where little competitive or corporate strategic variety would be expected, the few firms that chose to position themselves somewhat differently than their competitors were found to outperform those who aligned themselves with the majority of firms.

Keywords: strategy, population, resource-based, Canada, mining

DEDICATION

To

Dr. Paul John Russell

Hilary Margaret Russell

Bronwen Elizabeth Russell

ACKNOWLEDGEMENTS

My Ph.D. research has been a journey, and I am indebted to the many people who have helped me along the way. Dr. Daniel Shapiro was my guide, always ready to read and comment on yet another piece of my work. Dr. Aidan Vining sharpened my thinking, and Dr. Elicia Maine persuaded me that there were other technologies just as interesting as mining. Dr. Hemant Merchant introduced me to the resource-based view of the firm, and Dr. Steven Globerman, to foreign direct investment. Dr. Mary Lesperance helped me interpret my data. Cindy Lister made sure all the paperwork was in place. Vivian Blaker made me feel connected to the University with her frequent email communications, and Penny Simpson helped me format my finished thesis. Chris Gay provided me with work so I could remain close to the resources I needed to finish my thesis. Dr. J.V.P Chatwin and Elizabeth Chatwin were there, as always, to support me in my learning.

In addition, to those that were a part of my journey, I would like to thank my examiners, Dr. Anthony Boardman and Dr. Carolyne Smart, for their rigorous questioning at my defence.

And to the company that inspired my research, the former Consolidated Mining and Smelting Company, I wish it continued success. Working for this Company, introduced me to Dr. Mark Selman. I am grateful to him for showing me where the journey could begin.

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THREE PERSPECTIVES ON CANADIAN MINING: AN INTRODUCTION

The aim of this thesis was to explain the evolution and success of Canada's mining industry over the 20th century and the strategic position of its major firms at the start of the 21st century. The thesis (a) applies the theories of industrial evolution to a population of Canadian mining firms, (b) considers the survival of a cohort of firms from the perspective of the resource-based view of firm, and (c) explores the corporate strategies of the world's largest mining firms using the theories of strategic variability.

The thesis is comprised of three essays: the first identifies the dynamic responsible for the evolution of Canada's population of mining firms over much of the 20th century; the second, the resource characteristics of the firms that survived the industry shakeout; and the third, the strategic positioning of the firms that rank among the largest mining firms in the world. For the first essay, the population of mining firms was drawn from the Canadian Mines Handbook, a handbook that has been continuously published since 1934. The 1969/70 edition of this handbook was also the data source for the second essay. Both essays considered changes in firms over time: the first essay, the change in the number of firms over a 70 year period; the second essay, the number of firms that survived over a 30 thirty year period. The third essay, which used firm specific data drawn from company sources, presents a cross-sectional view of a group of global mining firms at one point in time, 2003.

Definition of the Industry

Mining is a difficult industry to define. The two most common methods of defining an industry are based on the use of national boundaries and a standard industrial classification (Thomas and Venkatraman, 1988). Defining the mining industry based on national boundaries is relatively easy, but this is not the case with respect to a standard industrial classification system. The most common industrial classification standard for grouping establishments is the North American Industry Classification System (NAICS). The NAICS distinguishes between those establishments engaged in mine operation and those engaged in mining support activities, such as exploration. However, MacDonald (2002) has argued that separating the producing firms from the exploration firms creates artificial boundaries that ignore (a) the relationships which exist between the member firms and (b) the ways in which risk is managed by the member firms. The high levels of discovery risk, coupled with the long lead times on mining projects, have fostered a set of relationships between the members that are unique, and over the lifetime of a mining asset, effective control and ownership of an asset can change many times. The NAICS further differentiates establishments engaged in mine operation with respect to the natural resource that is mined. This distinction is also problematic for several reasons. First, certain of the natural resources are often found together in nature, for example, silver with lead and copper with gold, a characteristic that puts a firm mining these ores in more than one commodity group. Second, the technologies associated with mining are readily transferable from one commodity to another. The technologies associated with open pit coal mining, for example, are the same as those used for mining oil sands, which also channels a firm into more than one commodity group. And third, many of the firms are vertically integrated, which makes it difficult to segment the industry by the stage of production. Even junior firms can be producers under certain circumstances.[1] Given the limitations imposed by a standard industrial classification, a broader definition of the industry, one based on a definition suggested by MacDonald (2002), was chosen for this research; namely, mining is that population of firms whose industrial focus is on all aspects of the mine life cycle from exploration through to reclamation.

The Essays

The first essay sought to identify the evolutionary force responsible for the change in Canadian mining firm numbers over the 20th century. There is a persistent tendency for organizational populations to concentrate over time, a phenomenon for which explanations have been drawn from organizational ecology, evolutionary economics, and technology management (Agarwal, Sarkar, and Echambadi, (2002). Typically, a population starts out with few members, increases in number fairly rapidly, and then the number of members begins to decline. This pattern, which has been observed for a wide variety of populations (Carroll & Hannan, 1989), is thought to be a consequence of a significant change in entry barriers, that is, scarcity of resources, a change from product to process focus, or market acceptance of a dominant design that irrevocably alters the competitive environment.

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1 Junior gold exploration firms can produce gold on-site using a heap-leach process.

A plot of the number of Canadian mining firms reveals an evolutionary profile that does not violate the stylized facts of industry evolution as set out in the literature: entry and exit occur throughout the history of an industry; the early structure of an industry differs from the mature structure; and the distribution of the number of firms when plotted over time is skewed (Winter, Kaniovski, & Dosi, 2003). The distribution of mining firms is, however, negatively skewed as opposed to the more usual positively skewed distribution. This unexpected variant in evolutionary trajectory provided the focus for the first essay.

Geroski and Mazzucatto (2001) developed a set of relatively simple models that could be used to identify the dynamic responsible for an industry's evolutionary pattern. Based on these models and a count of the number of active Canadian mining firms in each year between 1929 and 1999, density (i.e., the number of firms in the population) was found to be responsible for the change in the number of firms over the 70 years in the time series.

The population of Canadian mining firms reached its peak number of members in the 1980s. In the years that followed the shakeout (a period marked by a sharp increase in the number of exits), the number of firms continued to decline, and the industry itself underwent a major structural change. At the beginning of the time series (1929), mining firms internalized most of the activities associated with the mine life cycle, from exploration through to reclamation. By the end of the time series (1999), few mining firms were engaged in all aspects of the mine life cycle. The industry is now comprised of senior firms (vertically integrated firms with a number of large mining operations around the globe), intermediate firms (firms with one or more medium-to-large size mining operations in one or two regions of the world), expansionary junior firms (firms with a sizable mineable deposit that is being using to finance further growth), and junior firms (exploration firms with few mining assets). With the expectation that there would be fewer firms in the future now that the industry has passed its peak, coupled with the fact that the industry was undergoing a restructuring, the question became which of the firms that were active at the time of the shakeout would survive?

The second essay approached this question from the perspective of the resource-based view of the firm. This perspective was chosen for three reasons. First, the resource based view has become the dominant explanation for intra-industry performance differences. Firms in possession of assets which fit the criteria for resource-based assets, that is, valuable, rare, inimitable, and non-substitutable, have a sustained competitive advantage that has been found to generate superior returns (Barney, 1991). Second, while much of the research on the resource-based view of the firm has focused on the relationship between the intangible assets of the firm and financial performance, physical assets have recently been found to contribute to the success of the firm (Galbreath & Galvin, 2004), (Ray, Barney, & Muhanna, 2004). And third, survival, profitability, and the growth of the firm have all been suggested as appropriate performance measures in applications of the resource-based view (Thornhill & Amit, 2003).

The phases of mining produce a limited set of physical assets, namely, prospects, deposits, and mines, which have both tangible and intangible characteristics. Mining assets are durable; they do not deteriorate; and they can be bought and sold – all characteristics of tangible assets. Mining assets are also difficult to find, require considerable skill to bring into production, and are not easily substituted – all characteristics of intangible assets. And certain of these assets, meet the criteria for resource-based assets.

Two techniques were used to explore the relationship between the assets of the mining firms which were active in 1969 and survival over the period between 1969 and 1999: the Cox proportional hazards regression technique and the Kaplan-Meier procedure. These two procedures revealed that survival is linked to size, age, number of deposits, and number of mines. The results confirmed the findings of other researchers that age and size matter when it comes to survival; they also revealed that owning a number of deposits and mines reduces the chances of failure. But not all mining firms own deposits and/or mines. Exploration firms typically have no deposits or mines, and some mining firms choose not to be operators, preferring instead to hold shares in other mining firms.

Of the 741 firms in the original cohort of mining firms, only 36 survived the 30 year period of the study. Almost half of the firms that survived had few financial assets and many were recent entrants in 1969, suggesting that size and age are not the only determinants of survival in mining. Also significant is the ability to develop a portfolio of deposits and mines. Mining assets can be depleted so they must be replaced if the firm is to survive. Doing so is a demanding task as discovery risk is quite high. It has been estimated that for every 1,000 prospects with possible or probable mineralization, 100 may warrant further investigation, 10 may justify a drilling program, and one may eventually become a mine (MacDonald, 2002). The process of transforming a deposit into an operating mine is a costly process that can take 10 years or more. For example, Redfern Resources Ltd. has been working on its Tulsequah Chief project since 1981 and has yet to open the mine (Redfern Resources Ltd., 2006).

Having established in the first two essays that Canada's mining industry was evolving much like any other industry, albeit at a slower rate, and that firms in possession of a portfolio of physical mining assets have a survival advantage, the third essay considered the strategic positioning of the industry's major mining firms with respect to their global competitors. In an industry where the technology is stable, where prices are generally beyond the control of the producer, where the geology dictates the location, and where the products themselves are homogenous, there is little within the control of the firm besides cost. Under these conditions, corporate strategy becomes important; that is, mining firms have more options in terms of the lines of business they choose to engage in, the markets they choose to enter, and the mining activities they choose to internalize. How much variety to expect, given the possibilities for differing strategic positioning, was the focus for the third essay.

There are two schools of thought on how much strategic heterogeneity to expect among firms within the same industry. The first posits that strategy is generic and largely determined by the environment (Aharoni, 1993). Based on the theoretical arguments in support of this position, it might be expected that the industry should demonstrate little strategic heterogeneity for a number of reasons. First, mining is a mature industry, and variety has been found to decline as an industry matures (Miles, Snow, & Sharfman, 1993). Second, the top ranking mining firms sell similar products in many of the same markets as their competitors, suggesting there ought not to be significant differences in the strategies and behaviours of similar firms in different countries (Lindell &

Karagozoglu, 1997). Third, while mining assets can be depleted, the core activities of mining (drilling, blasting, mucking, hauling, crushing, milling, and refining) are stable. And fourth, industries, like mining, with relatively simple group structures and high concentration are characterized by relatively homogenous firms (Seth and Thomas, 1994). The second school of thought posits that strategy is unique and emanates from the skills or activities in which the firm excels (Aharoni, 1993). Based on the theoretical arguments in support of this position, it might be expected that the mining industry should demonstrate some degree of heterogeneity because the resource characteristics of each of the firms are different.

Cluster analysis was used to identify homogeneous subgroups among the 26 largest mining firms in the world, an analysis based on four measures of strategic variability: country geographic scope, product scope, exploration/research and development intensity, and capital intensity. Three clusters were identified – that is, one dominant cluster and two non-dominant clusters. The dominant cluster of 15 firms can be characterized as firms with moderate to high geographic and product scope, as well as average capital and exploration/research and development intensity; the first non-dominant cluster of 5 firms, as firms with low product and/or low country geographic scope, average exploration/research and development intensity, and average to below average capital intensity; and the second non-dominant cluster of 2 firms, as firms with high country geographic scope, low product scope, average capital intensity, and high exploration/research and development intensity. Strategy is about performance, and the average operating profitability of each of the firm clusters was found to be different: roughly 8% on average for the dominant cluster, 20% for the first non-dominant cluster, and 4 % for the second non-dominant cluster. These results suggest that even within an industry where little strategic variety would be expected, a certain degree of strategic heterogeneity can be observed, and these differences in strategic choice appear to be associated with differences in performance. In the main, firms that adopted the dominant strategy generated returns that were less than the mean.

A Concluding Theme

Although the three essays present different images of Canada's mining industry, taken together they provide a coherent explanation for the evolution and the success of the industry in the 20th century, as well as for the positioning of the industry's major firms at the start of the 21st century. Until the time of the industry shakeout in the late 1980s, a favourable environment for mining fostered the growth of the industry. Factors such as the change in the tax regime for mining, the introduction of substantive environmental legislation, and the price of gold changed the cost structure and increased competition. The change in dynamic from growth to competition, revealed in the evolutionary profile of the industry, was also present in the 1969-1999 survival plots. The firms that were most likely to survive the post shakeout period were not just the large firms or the older firms. Firms with few financial assets or young firms having a portfolio of physical mining assets also survived. And finally, firms that choose a corporate strategy that differed from that of the majority of firms appeared to do better than those that did not.

This research contributes to the literature in three ways. First, it demonstrates that there are other evolutionary industry profiles besides the more usual positively skewed distribution of firms. The evolutionary profile for Canada's mining industry reveals a long period of slow growth followed by a sharp decline in the number of firms later in the industry's history. Second, the research adds to the limited number of empirical studies of survival that span more than 20 years. It is not just old firms or firms with more financial assets that are less likely to fail. Firms in possession of a portfolio of physical mining assets in the form of deposits and mines are also less likely to fail. And third, the research demonstrates that in an industry expected to demonstrate little strategic variety, a certain degree of strategic heterogeneity can be discerned, and this strategic differentiation appears to be linked to performance.

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CANADA'S MINING INDUSTRY – THE EVOLUTIONARY PERSPECTIVE

Abstract

The underlying dynamic for the evolutionary pattern observed among a number of Canadian mining firms over the period 1929 to 1999 was examined. Trading firm data from the Canadian Mines Handbook and the evolutionary models derived by P. Geroski and M. Mazzucato (2001) suggest density is the evolutionary dynamic consistent with mining firm data. Unlike the positively skewed distribution observed in other industry populations, the population of Canadian mining firms is negatively skewed. This finding challenges the stylized view of industry evolution and provides an example of an industry that may be subject to other legitimating forces besides legitimacy of the organizational form.

Introduction

Researchers have found that when the number of firms within an industry or organizational population is graphed over time, a common pattern emerges (positive skew): the number of firms or organizations within the population starts out small, increases fairly rapidly, and then decreases, a pattern that has been observed for a wide variety of organizations (Carroll & Hannan, 1989). This evolutionary profile has been noted, for example, among newspaper, automobile, tire, brewing, telephone, semiconductor, wine, cement, worker co-operatives, and voluntary social services organizations (Carroll & Hannan, 1989; Singh & Lumsden, 1990). To illustrate, a graph of the number of tire producers based on Jovanovic and Macdonald's (1994) data reveals the typical profile (see Figure 1.1). But unlike the pattern observed for these U.S. tire producers, the profile for Canadian mining firms is notably different (negative skew), resembling a reflection of the tire producer pattern (see Figure 1.2). That is, the number of firms starts fairly small, as in other populations, but then increases slowly over an extended period of time before the firm numbers begin to decline, with the peak number being reached late in the evolution of the population, in this case 1988. Certain stylized facts have emerged from the research on industry evolution: entry and exit occur throughout the history of an industry; the early structure of an industry differs from the mature structure; and the distribution of the number of firms when plotted over time is skewed (Winter, Kaniovski, & Dosi, 2003). Although the mining industry data do not violate any of these stylized facts, the distribution is not positively skewed as it is in the other industry examples.

The next section of this essay provides a description of the theoretical explanations for the observed evolutionary patterns. Then, a section is allocated to each of the following: (a) the models developed by Geroski and Mazzucato (2001), data and the methodology, (c) empirical results, (d) interpretation of the results, and (e) concluding comments.

The Theoretical Explanations

Three theories have been advanced to explain the persistent tendency of organizational populations to concentrate over time (Barnett, 1997), namely, the organizational ecology, evolutionary economics, and technological change theories (Agarwal, Sarkar, & Echambadi, 2002). The underlying premise of each of these perspectives is that changes to entry barriers at one point in time irrevocably alter the competitive environment such that there is a sharp decrease in net entry rates (Agarwal et al., 2002).

Organizational Ecology Explanation

Organizational ecologists apply the biological principles that characterize living organisms to social organizations in an attempt to understand why the number of organizations of a particular form varies over time. The principal tenet of their theory is that once an organization has been founded, the forces of inertia are such that subsequent changes to the population are demographic, that is, the result of foundings and dissolutions (Singh & Lumsden, 1990). According to the theory, first articulated by Hannan in 1977 (Barnett, 1997), when there are a limited number of organizations within a given population, increases in the number of organizations lends legitimacy to the emerging organizational form, leading to further increases in number or density; as density continues to increase, competition for resources begins to affect the number of organizations and density begins to decline (Barnett, 1997). The long term evolution of an organizational population is thus governed by the dual processes of legitimation and competition. In short, legitimacy, or taken-for-grantedness (Baum & Powell, 1995), increases organizational foundings and decreases mortality; competition decreases organizational foundings and increases mortality (Barron, 2001).

Singh and Lumsden (1990) suggest that the evidence in support of the density dependence theory of organizational ecology is strong. Agarwal et al. (2002) suggest several studies that demonstrate the effect of foundings and mortality rates on organizational populations: for example, Carroll and Swaminathan (1991), Carroll and Hannan (1989), Tucker, Singh, and Meinhard (1990), and Hannan and Freeman (1987). Carroll and Swaminathan (1991) tested the density dependent model using U.S. brewing industry data for the years 1633 to 1988 and found that the rates of organizational founding and mortality were related to organizational density as predicted by the model. Similarly, Carroll and Hannan (1989) in their study of nine newspaper populations spanning the years 1800 to 1975 found that both the founding rate and the mortality rate were a function of population density. Singh et al. (1990) found in their study of voluntary social service organizations operating during the period 1970 to 1982 that population dynamics effects were related to both density and changes in density levels. Hannan and Freeman's 1987 study demonstrated that the founding rate of national labour unions was influenced by variations in the number of unions; their 1988 study indicated that the mortality rate was also influenced by the number of unions in the population.

Compelling as these results are, the evidence in support of the theory is in the opinion of Barron "far from unequivocal" (2001,547). Baum and Powell's (1995) review of the studies published between 1990 and 1994 that examined the density dependence model found 74% of the founding studies and 55% of the failure studies supported the theory. One of the difficulties researchers have with the density explanation lies in its assumption that all organizations experience the effects of legitimacy and competition similarly. In the low-density conditions of the early stages in the evolution of a population, this may well be the case as new entrants and incumbents are typically very similar in organizational form; in the low-density conditions of the late stages of the evolution of a population, this may not be the case as new entrants and incumbent organizations tend to differ in size and strategy, and a few large organizations often dominate (Baum & Powell, 1995). Several researchers have also noted that the density dependence model cannot explain a shakeout (Barron, 2001), nor can it account for the long decline in firm numbers associated with the maturing of an industry (Agarwal et al., 2002), (Lomi, Larsen, & Freeman, 2001). The utility of the density dependence theory thus appears to derive from its ability to account for the evolution of a population until the population reaches peak size.

Evolutionary Economics Explanation

The evolutionary economics explanation for the pattern of an increasing number of firms followed by a decreasing number of firms is attributed to Gort and Klepper (1982), who determined that time was a critical determinant of the ultimate structure of the market (Agarwal, 1998). According to the theory, in the early stages of the evolution of an industry, there is sufficient external knowledge to make entry attractive; firms enter rapidly to exploit this information, firm numbers increase, prices fall, and output increases until incumbent knowledge exceeds external industry knowledge. At this point, net entry declines, turns negative, and inefficient firms exit the industry (Agarwal, 1998). The resulting pattern is more of an S-shaped curve than the skewed distribution characteristic of the density-dependent model, and it is not restricted to number of producers of a new product[2].

Researchers have determined that there are two distinct phases to this pattern, namely, an entrepreneurial or product innovative phase and a routinized or process innovation phase (Agarwal et al., 2002). In the words of Nelson, "an entrepreneurial regime is one that is favourable to innovative entry and unfavourable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way round" (Winter, 1984,297). During the entrepreneurial phase, critical information related to innovation resides outside established routines and industry sources, giving new entrants an advantage over incumbents because product innovation is more important during this phase than process innovation, the latter being a strength of the incumbents (Agarwal et al., 2002). During the routinized phase, critical information

[2] Product and process innovations, as well as the use of a new technology, have also been found to produce an S-shaped curve when plotted over time (Jovanovic & Lach, 1989)

derived from market-based experience resides inside established routines and industry sources, giving incumbents an advantage over new entrants because process innovation and cost-based competition are more important than product innovations in this evolutionary phase (Agarwal et al., 2002).

Agarwal et al. (2002) indicate that the research of Gort and Klepper (1982), Acs and Audretsch (1988), Audretsch (1991), Jovanovic and MacDonald (1994), and Agarwal (1998) supports the evolutionary economics explanation. Gort and Klepper (1982) traced the histories of 46 new products and concluded that the number of producers was determined by "... discrete events such as technical change and the flow of information among existing and potential producers" (1982,651). Acs and Audretsch's (1988) analysis of the innovative activity of large and small firms supported Winter's (1984) prediction that innovation is driven by different technological and economic considerations. Audretsch (1991) concluded from his study of 11,154 manufacturing firms that one of the factors that contributed to the 10 year survival rates was the underlying technological regime: new firm survival rates were found to be positively related to innovative activity. Jovanovic and MacDonald (1994) found that firm numbers in the U.S. automobile tire industry were driven by major exogenous changes in technology: innovation fostered entry, and failure to innovate prompted exit. Agarwal (1998) updated Gort and Klepper's earlier work (1982) and reconfirmed that the time trend in number of firms followed the expected pattern.

The recent work of Filson (2001), however, challenges the premise that innovation is characteristic of the early history of an industry, followed by cost innovation, or process improvement, as the industry continues to evolve. Filson (2001) found in his examination of four micro-electronic industries (personal computers, rigid disk drives, computer monitors, and computer printers) that the rate of quality improvements did not diminish over time as predicted by the theory, suggesting that "the opportunities for innovation in modern high-tech industries evolve in systematically different ways from previous ones [e.g., the automotive industry]" (2001,464).

The technological underpinnings of the evolutionary economics theoretical explanation make the model more applicable to certain industrial populations than to others (Agarwal et al., 2002). This tends to limit the utility of the theoretical explanation to industries that compete on the basis of their ability to improve and innovate (Rumelt, Schendel, & Teece, 1991).

Technological Change Explanation

The third explanation for the evolutionary pattern of firm concentration, an explanation which can be considered a variant of the evolutionary economics theoretical explanation, is that of technological change. Technology tends to evolve through a long period of incremental change followed by a period of radical change (Agarwal et al., 2002). During the latter period, new firms enter and compete for dominance; once the dominant design emerges, barriers to entry rise, incumbent firms assume the advantage relative to the new entrants, and the disadvantaged firms exit (Agarwal et al., 2002). The period of radical change (or era of ferment) is characterized by multiple variants of both the new and the existing technology; the period of the dominant design (or era of incremental change), by the emergence of a particular variant that best captures the requirements of the market (Agarwal et al., 2002). The entry and exit of firms within the industry parallels the change in technology; that is, the number of firms is dramatically reduced following the appearance of the dominant design (Utterback, 1994). During the *shakeout* (a period in which there is a dramatic decline in the number of firms), the number of producers (at least among manufacturing firms) can be reduced by as much as a half (Klepper & Simons, 1996).

According to Agarwal et al. (2002), the principal works in the technological change tradition are those of Abernathy and Utterback (1978), Tushman and Anderson (1986), Anderson and Tushman (1990), Baum, Korn, and Kotha (1995), and Suarez and Utterback (1995). Abernathy and Utterback (1978) determined that major innovations undergo countless improvements over time; whereas, incremental innovation results in a highly specialized system that depends on economies of scale and mass marketing for continued success. Using data from the minicomputer, cement, and airline industries, Tushman and Anderson (1986) demonstrated that technology evolves through periods of incremental change followed by periods of rapid technological change. These researchers also noted that entries dominated during periods of rapid technological change; exits, during periods of incremental change. Anderson and Tushman's (1990) study of the cement, glass, and minicomputer industries revealed that when patents are not a significant factor, technological discontinuities (i.e., innovations that dramatically reduce cost while increasing performance) were generally followed by a single standard, or dominant design.

Further support for the technological change explanation has been provided by Baum et al. (1995) who examined the link between dominant designs and the pattern of foundings and failures in telecommunication service industries and concluded that there was "… clear evidence of the link between dominant designs and ecological processes in an evolving population" (1995,129). Suarez and Utterback (1995) in their analysis of the automobile, typewriter, transistor, electronic calculator, television, and picture tube industries found that firm survival was strongly influenced by the evolution of the technology of the industry. These researchers were able to establish that the probability of firm survival was greater for firms entering the industry before the emergence of a dominant design than for firms entering after the dominate design had emerged.

In spite of the links that other researchers have found between the emergence of the dominant design and the entry/exit of firms, Klepper and Simons (1996) found in their analysis of the shakeouts among automotive, tires, television, and penicillin firms that the emergence of a dominant design was not the underlying cause but rather a consequence of a "broader evolutionary process in which early entrants became leaders in product and process innovation and eventually dominated their industries" (1996,87). Suarez and Utterback (1995) found that only one of the six industries they examined supported their prediction that the risk of failure would be higher for those firms entering a market a number of years after the dominant design had been established.

Like the evolutionary economics theoretical explanation, the technological change explanation is limited in its applicability by its focus on the role of technology in altering entry barriers. The theory may also not apply if the technology is process based rather than product based (Utterback, 1994).

In Summary

The central concern of the three theoretical perspectives outlined above has been to understand how changes linked to the passage of time affect the survival of a population of organizations. Supporters of the density dependence theory of organizational evolution argue that the long term evolution of organizational populations is governed by the processes of legitimacy and competition and that density, or the number of organizations in the population, is linked to organizational founding and organizational mortality through these two processes (Carroll & Swaminathan, 1991). Proponents of the evolutionary economic theory argue that the pattern of entry and exit is determined by the source of information (internal versus external) and the advantage that accrues (a) to new entrants when the information source is external and (b) to incumbents when the information source is internal. And for those who favour the technological change explanation, innovation and competition increase firm numbers; market acceptance of the dominant design decreases firm numbers.

Density, the knowledge regime, and dominant design explanations are not necessarily in competition with each other. According to Geroski and Mazzucato (2001; 2001), depending on where the industry is in its evolution, certain of the explanations may be more appropriate than others. For instance, as noted earlier, organization ecology theory may have more explanatory power in the early stages of the evolution of a population. In addition, the theoretical explanations are similar in several respects. The two phases of the technological change explanation, for example, mirror those of the evolutionary economics explanation in that the period of radical change is much like the entrepreneurial regime, and the post-dominant design period is similar to the routinized phase (Agarwal et al., 2002). Similarly, the standards setting process itself has been likened to the population ecologists process of legitimation (Geroski, 2001). In general terms, all three explanations support the notion that a structural change occurs at one point in the life cycle of an industry, and this change has a profound effect on (a) organizational foundings and failure rates and (b) the basis of competition.

The Geroski and Mazzucato Models

Geroski and Mazzucato (2001) developed a set of models that (a) link to the three theoretical explanations described above and (b) can be used to account for industry population dynamics. The present paper applies three of the Geroski and Mazzucato (2001) entry and exit models (density dependence, negative feedback, and contagion), two of which are linked to the theoretical explanations described above, to Canadian mining firm population data. The Geroski/Mazzucato models were considered appropriate for use with mining firm data, even though the industry evolutionary profile for mining firms differed from that of other industrial populations, because mining firm data do not violate any of the stylized facts with respect to industry evolution noted earlier.

The three hypotheses suggested by the models are as follows:

Hypothesis 1: There is a relationship between population size and population density.

Hypothesis 2: There is a relationship between population size and market feedback.

Hypothesis 3: There is a relationship between population size and rational market behaviour.

The density dependence model tests the organizational ecology explanation; the negative feedback model, the evolutionary economics and technological change explanations. The contagion model, which is not linked to the theoretical explanations described above, is included to test the possibility that entries and exits associated with either a transitory surprise event or a follow-the-leader type herd reaction are responsible for the observed decline in the number of Canadian mining firms, for as Bikchandani, Hirschleifer, and Welch (1998) have observed, there are many examples of convergent behaviour that cannot be explained using traditional economic models. The speculative e-commerce bubble of the late 1990s is an example of this type of phenomenon that cannot be readily explained on the basis of the business fundamentals. The contagion model was also the model Geroski and Mazzucato (2001) found to be consistent with their data. A brief description of each of these models follows.

Density Dependence Model

As noted earlier, the density dependent model is founded on the principles of legitimacy and competition. In the early stages of the evolution of an industry, establishing the legitimacy of the organizational form is the key dynamic. As the market becomes established, entry becomes easier and the number of enterprises increases. At some point, resources and customers become scarce, competition replaces legitimacy as the key dynamic, and the number of enterprises in the industrial population declines. As there are no direct measures of legitimacy or competition, the model is a test of density and the relationship of density to population growth rates.

The model specified by Geroski and Mazzucato (2001) in its simplified form[3] is expressed as:

$$\Delta N(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \varepsilon(t) \qquad \text{Equation 1}$$

$$\rho_1 > 0, \rho_2 < 0$$

In this equation, N is the number of firms at time t. $\rho_1 N(t-1)$ is the founding rate times the number of firms in year t minus 1. $\rho_2 N(t-1)^2$ is the exiting rate times the square of the number of firms in year t minus 1. The founding rate is used as a proxy for legitimacy; the exiting rate, for competition. ρ_0 is a constant and ε is the error term. The model is estimated using $\Delta N(t)$, which is the first difference (the number of firms in year t minus the number of firms in year t minus 1). Geroski and Mazzucato (2001) used the first difference because in their view it was unreasonable to assume that all of the observed data were equilibrium observations. This model tests for the possibility that the change in the number of mining firms is affected by the density of the population.

Negative Feedback Model

The negative feedback model of entry and exit predicts that excess profits attract entrants, and the absence of excess profits encourages exit. For new entrants, it is an expectation of post-entry profits that is the attraction, and should this expectation not be realized, firms will exit the industry. Over time, the industry will reach an equilibrium state where there are no excess profits, and the number of firms in the industry stabilizes. Feedback on innovation or technological progress could presumably produce similar

[3] The model is derived from simplifying the following two equations:

$$\Delta N(t) = \rho_0 + \rho N(t-1) + \varepsilon(t)$$
$$\rho = \rho_1 + \rho_2 N(t-1)$$

results, a presumption that was also made by Geroski and Mazzucato (2001). In this case, the new entrants would have expectations about their innovative capabilities or the dominance of their technology, and again, should these expectations not be realized, firms will exit. Based on this reasoning, the negative feedback model was used to test the evolutionary economics and the technological change theoretical explanations.

The model specified by Geroski and Mazzucato (2001) in its simplified form[4] is as follows:

$$\Delta N(t) = \alpha_0 + \alpha_1 N(t-1) + \varepsilon(t) \qquad \text{Equation 2}$$

$$\alpha_0 > 0, \alpha_1 < 0$$

In this equation, ΔN_t is the first difference in the number of firms. $\alpha_1 N(t-1)$ is the feedback term on expectations, which is used here to test for expectations with respect to innovation and technology, rather than profits. α_0 is the constant and ε is the error term. The inclusion of this model provides a test of the possibility that expectations with respect to innovation or technology are responsible for the evolutionary trajectory.

Contagion Model

As noted earlier, it is possible that the evolutionary trajectory does not model rational firm behaviour, which is why the contagion model is included in the set of models under consideration. The contagion model of entry and exit is predicated on the premise that firms follow the actions of others without doing a full evaluation of their

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[4] The model is derived from simplifying the following two equations:

$$\Delta N(t) = \alpha\{\pi^e(t) - F\} + \mu^1(t)$$

$$\pi(t) = \pi^* - \beta N(t-1)$$

In the first equation, the number of firms is dependent on expectations at time t (π^e) minus feedback on post entry profits (F); in the second, realized profits (π) are dependent on cumulative past entry/exit where ($\pi^*-\beta$) is the level of monopoly profits.

own before proceeding with a business action. It is another form of feedback model; in this case, the actual entry/exit is above or below the expected entry/exit based on the fundamentals. Geroski and Mazzucato (2001) specified the model as:

$$\Delta N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \varepsilon(t) \qquad \text{Equation 3}$$

$$\psi_0 > 0, \psi_1 < 0, \psi_2 > 0$$

In this model, ΔN_t is the first difference in the number of firms. $\psi_1 N(t-1)$ is the expected number of entries and exits based on the business fundamentals; $\psi_2 \Delta N(t-1)$ is the actual number of entries and exits. ψ_0 is the constant and ε is the error term. If ψ_2 should equal zero, the model reduces to the negative feedback model described above. Also, the effect of the initial unexpected rise in firm numbers diminishes over time such that the contagion event will have no long term effect on firm numbers. This model tests for the possibility that the change in the number of mining firms is affected by unfounded optimism about post-entry conditions.

The Data and the Methodology

The Canadian Mines Handbook (Handbook) was used to obtain the count data needed to model the population of Canadian mining firms over the 20th century.[5] The Handbook has been published annually since 1934, and as such, it represents the only continuous listing of what consecutive editors considered Canada's active mining

[5] When data are collected on sets of firms, there is a presumption that the firms are comparable. The practice of examining sets of firms that have been conventionally group together is considered an acceptable practice (Frech III, 2002)

companies. For this study, a count of the number of firms whose stocks were included in the Trading Range section of the Handbook was made for the years 1929 to 1999[6].

The dependent variable used by Geroski and Mazzucato (2001) was net entry or the first difference in the number of firms between time 0 and time 1, for as noted earlier, these researchers assumed their observations were not equilibrium observations. Net entry is considered to be a response or an adjustment mechanism to a state of disequilibrium (Carree & Thurik, 1999).

The regression analysis of Geroski and Mazzucato (2001) was replicated using mining firm data; that is, $\Delta N(t)$ was regressed (a) on N(t-1) for the negative feedback model, (b) on N(t-1) and $N(t-1)^2$ for the density dependence model, and (c) on N(t-1) and $\Delta N(t-1)$ for the contagion model. Geroski and Mazzucato (2001) added time trends and quadratic terms to their basic regression equations in order to find a model that was consistent with their data, and these additional terms were also used with mining firm data. (See Regression Equations.)

[6] For each new edition, the list of companies included in each of the years covered by the Trading Range section of the Handbook is revised. Overlooked companies are added, and inactive, delisted, or merged companies are dropped from the listing, making it difficult to determine the precise number of active mining companies in any given year. To ensure an accurate count, the number of firms reported in each of the years covered by the Trading Range was tallied, and the highest count of firms for any given year was selected for the data set.

Results

The results of the standard least squares regression analysis[7] for the three Geroski/Mazzucato models using the first difference as the dependent variable are detailed in Table 1.1. For the density dependence model (Equation 1) to be consistent with the data, a positive coefficient for the N(t-1) term and a negative coefficient for the $N(t-1)^2$ term were required. The sign of the coefficient for both the N(t-1) term and the $N(t-1)^2$ term were correct. The N(t-1) term was statistically significant at the < 0.10 level of significance[8], the $N(t-1)^2$ at the < 0.05 level. The *F* test statistic confirmed the existence of a regression relation between the dependent variable and the set of independent variables (F^* 2.6136 > F 2.39), although only 4% of the variability in firm numbers was explained by the model. Adding an $N(t-1)^3$ term (Equation 1b) to test for non-linear density dependence in the data did not change the results.

For the negative feedback model (Equation 2) to be consistent with the data, a positive coefficient for the intercept and a negative coefficient for the N(t-1) term were required. The sign of the coefficient for both the intercept and the N(t-1) term were correct, but the N(t-1) term was not significant. Adding a quadratic time trend to the model (Equation 2a) to allow expectations regarding post-entry profits (innovation or technology) to move deterministically over time did not change the results.

For the contagion model (Equation 3) to be consistent with the data, a positive coefficient for the intercept, a negative coefficient for the N(t-1) term, and a positive coefficient for the ΔN(t-1) term were required. The signs for the coefficients for the

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[7] Poisson regression analysis is useful when the outcome is a count and large outcomes are rare events (Neter, Kutner, et al., 1996). The Poisson regression was not used here because of the large outcomes associated with the count of mining firms.

[8] With observational data, a probability > $|t|$ < 0.10 can be considered significant.

intercept and the N(t-1) and ΔN(t-1) terms were correct, and both the N(t-1) term and the ΔN(t-1) were significant at the < 0.05 and < 0.01 levels of significance, respectively. The *F* test statistic confirmed the existence of a regression relation between the dependent variable and the set of independent variables (F^* 4.4667 > F 3.15), although only 9% of the variability in firm numbers was explained by the model. Adding a time trend (Equation 3a) increased the adjusted *R Square* value from 0.09 to 0.12. Substituting an N(t-2) term for the ΔN(t-1) provided a further test of the contagion model (Equation 3b).[9] The regression results for this additional test were consistent with the contagion model in that the coefficient of the N(t-1) term was positive, significant, and equal in size, but opposite in sign, to that of the coefficient of the N(t-2) term, which was also significant.

The results of the regression analysis to this point suggest that (a) both the density dependence and the contagion model are consistent with mining firm data, albeit at different levels of significance, and that (b) less than 10% of the variability in firm numbers can be explained by either model. When Geroski and Mazzucato (2001) applied these models to U.S. domestic car producer data, they were able to find a model that (a) was consistent with their data, that is, one capable of explaining an early rise in firm numbers followed by a sharp rise in exits and a long decline and (b) explained 37% of the variability in firm numbers. Based on the regression results obtained with mining firm data, their models do not appear to fit well when the distribution of firm numbers reflects a long period of steady growth followed by a sharp rise in exits. In an attempt to find a model more consistent with mining firm data, additional variables specific to the mining

[9] Geroski and Mazzucato (2001) added an N(t-2) term to their negative feedback model as a further test of the contagion model.

industry were added to these two models, and the models were changed to allow for equilibrium firm numbers.

The use of industry specific information in evolutionary models was advocated by Carree and Thurik (2000) who argued that such information played an important role in explaining why some industries are slow to experience a shakeout, a feature characteristic of the Canadian mining industry. Five variables specific to mining were considered. Three of the variables were drawn from two 20th century events identified in the literature as having had an impact on Canada's mining industry. The first such event, which suggested two variables, was a change in the tax regime for mining. Prior to 1972, expenses could be expensed against current income; mining taxation allowances for the development and production phases of mineral investment could be taken on an individual basis or on an integrated company basis; new mines could qualify for a three-year tax exemption; and capital gains were not taxable (DeYoung, 1977). The 1972 Income Tax Act changed the federal tax rules for Canada's mining companies, and beginning in 1974, the provinces also changed their tax rules. DeYoung (1977) examined the effect of the tax law changes, which basically removed and/or reduced many of the tax concessions of the pre-1972 era, and found that both exploration expenditures and investment in the Canadian mining industry steadily declined in the years immediately following the changes.

The second event (suggesting one variable) was the passing into law of the Canadian Environment Protection Act (CEPA). The CEPA was introduced in 1988 in response to growing public concern about the presence of toxic substances in the environment (Douglas & Hebert, 1999). It consolidated existing federal environmental statutes and provided the authority to establish environmental guidelines for federal departments and agencies (Organization for Economic Co-operation and Development, 1994). The CEPA was subsequently renewed in 1999 and remains Canada's principal piece of federal environmental protection legislation (Douglas & Hebert, 1999). As with the changes in taxation, the introduction of federal environmental legislation was followed by the enactment of provincial environmental legislation (Chambers & Winfield, 2000). According to Jeffery (1981), the introduction of the new federal and provincial legislation related to environmental issues was one of the factors that changed the competitive environment for mining in the last quarter of the 20th century.

To examine the influence of these two events, dummy variables were used for the 1972 federal tax changes (1972 Tax Change), the 1974 provincial tax changes (1974 Tax Change), and the 1988 Canadian Environmental Protection Act (CEPA 1988). These variables were coded 0 for all years prior to the introduction of the regulatory change, and coded 1 for all years after the change. To differentiate between the short-term effects of the regulatory change and longer term effects, a linear time trend variable was created for each of these dummy variables using a method specified by Barron, West, and Hannan (1994).[10]

The two remaining variables considered were the U.S. price of gold (Au) and the Bank of Canada rate (Bank Rate). The U.S. price of gold was used to model the effect of commodity price changes on the number of firms. Only one metal price, the price of gold, was used because (a) the mining industry is known to respond to changes in commodity prices (when prices are low, mining projects are put on hold and operating

[10] Zero for all years before the legislation was introduced; the year minus the date of the legislation for all subsequent years.

mines are temporarily shut down), (b) gold is the metal choice for most producing and non-producing mining firms (Russell, 2003), and (c) multivariate analysis of the price of copper, silver, zinc, and lead revealed that the prices of these metals are significantly correlated. Because the industry needs to raise significant amounts of capital to finance exploration and to develop new mine sites, the Bank of Canada annual average rate [11] was included in the model as a measure of the availability of capital.

The regression analysis was repeated using the contagion model and the set of mining specific, independent variables and then repeated again using the density dependence model and the same set of mining specific, independent variables (Equations 3c and 1b). See Table 1.2 for these regression results. With the mining specific variables in the contagion model, twenty-five % of the variability in firm numbers was explained, but the negative feedback term, N (t-1), no longer explained a statistically significant portion of that variability, and the sign for the intercept coefficient was negative instead of positive. The price of gold and the introduction of the CEPA legislation were significant. The relationship between firm numbers and gold was positive, indicating that firm numbers rise and fall with the price of gold. For the legislation, the zero condition was positive, that is, firm numbers respond to the presence or absence of the legislation. Adding the quadratic for gold and the time trend for the environmental legislation did not improve the model. The tax change variables and the bank rate variable, with and without the time trend, were not significant.

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[11] The bank rate is the rate of interest that the Bank of Canada charges to commercial banks. Changes to this rate will affect other interest rates, including mortgage rates and prime rates charged by commercial banks (Galbreath & Galvin, 2004).

With the mining specific variables present in the density dependence model, 27 % of the variability in firm numbers was explained, and both the N(t-1) term and the $N(t-1)^2$ term were statistically significant. The price of gold and the introduction of the CEPA legislation were significant, and the relationship between firm numbers and gold was positive. For the legislation, the zero condition was positive. Adding the quadratic for gold and the time trend for the environmental legislation did not improve the model. The tax change variables and the bank rate, with and without the time trend, were not significant. The addition of the industry specific variables significantly improved the explanatory power of the model; that is, 27% of the variability in firm numbers was explained as opposed to only 4% of the variability for the model without the variables.

Geroski and Mazzucato's (2001) choice of dependent variable was predicated on the assumption that their observations of N(t) were not equilibrium values. Given the steep rise and fall in firm numbers that characterized their data set, this would appear to be a reasonable assumption. With the slow growth in mining firm numbers over much of the present data set, assuming non-equilibrium conditions may not be necessary. Substituting N(t) for $\Delta N(t)$ in both the contagion and the density dependence models of Geroski/Mazzucato (Equations 1c and 3d) produced a definitive result. Namely, under the equilibrium condition, the density dependence model was consistent with the data. That is, the signs for the coefficients met the requirements of the Geroski/Mazzucato density dependence model; both the N (t-1) and the square of the N(t-1) terms were significant; the *F* statistic confirmed the existence of a regression relation; and 97% of the variability in the number of firms was accounted for by the model.

A plot of the residuals versus the predicted values for this model revealed increasing variability in the distribution of the error terms. The Box-Cox procedure identified the square root of the dependent variable N(t) as the most appropriate transformation for stabilizing the error variance. (A similar transformation on the independent variables did not appear to be necessary.) Regressing the square root of N(t) on both the density and the contagion variables (Equations 1d, 3e) confirmed that the density dependence model was appropriate for the transformed data. The addition of the mining specific variables (Equation 1e), three of which were significant, did not appreciably improve the model (an adjusted *R Square* value of 0.979 without the variables, 0.986 with them).

In summary, the results reported in Table 1.1 indicate some support for both the density dependence and the contagion explanatory models. The addition of mining specific variables and the change in the choice of the dependent variable from the first difference in the number of firms, or net entry, to the square root of actual number of firms (Table 1.2), produced results that are more consistent with mining firm data.

Discussion

Three hypotheses were suggested by the Geroksi/Mazzucato models. Of the three, only Hypothesis 1, was supported; that is, there is a relationship between population size and density. As noted earlier, density was not the dynamic Geroksi and Mazzucato (2001) found to be consistent with their data. These researchers concluded that the rise and fall in the number of U.S. domestic car producers appeared to be the result of "... bandwagon responses to 'surprise' population movements" (2001,1019), a conclusion they were somewhat uncomfortable with, for it seemed unreasonable to them that large numbers of rational agents would choose to enter a market capable of supporting fewer than 20 firms in the long run. The distribution of mining firms, as illustrated earlier, follows a different trajectory from that of U.S. domestic car producers. That is, the number of mining firms increased steadily until the 1980s before beginning to decline, a pattern more consistent with rational behaviour.[12] That the contagion model was not found to be consistent with mining firm data is reasonable given a different industry and a different pattern of entry and exit. In addition, contagion is rarely found to be evolutionary dynamic.[13]

The finding that the negative feedback model was not consistent with the data, thus failing to support Hypothesis 2, was reasonable given the technological underpinnings of both the evolutionary and the technological change explanations represented by the model. The technological advances that allowed the mining industry to enter the modern age, that is, dynamite, electricity, and haulage trucks, were not unique to the industry; they existed before the start of the data series. Even the most noteworthy process innovation, differential sulphide flotation (McKnight, 2001), was available in 1920. The concept of a dominant design also does not apply to industries such as mining (Utterback, 1994). The model used to test Hypothesis 2 was initially conceptualized on expectations concerning profitability. Had profitability been the dynamic, there might still have been little support for the hypothesis because the real

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[12] Not that all mining firm entries and exits can be considered rational for Canada's mining history is replete with examples of entry and exit decisions predicated on unfounded optimism, the gold rushes of the 19th century being the most noteworthy examples (MacDonald, 2002).
[13] Chen (2002) and Messallam (1998) found a surprise event precipitated a major change in the number of firms.

returns for mining had been roughly 5% per year for much of the last quarter of the 20th century (McClements & Cranswick, 2001).

The finding that density is the dynamic is reasonable given (a) the strength of the model in accounting for firm numbers until the time of the shakeout, which in this study covers much of the data set, and (b) the lack of historical evidence to support the view that the carrying capacity for mining had been reached prior to the 1980s (Jeffery, 1981). The density dependence theory argues that it is the process of legitimating the organizational form that drives firm numbers prior to the shake-out, but the organizational forms for mining had been in place for some time. Open pit mining was legitimated before the start of the 20th century; underground mining, in the early part of the 20th century. And the non-producing organizational form was legitimated by the middle of the 20th century. As noted earlier, one of the difficulties with the density dependence model is that there are no direct measures of legitimacy or competition. With no confirming historical evidence of legitimacy, as defined by Hannan and Carroll (1992), the model may well be measuring other legitimating forces. Baum and Powell (1995) have suggested that other forces, including those of a socio-political nature, ought to be considered. In their view, "...the development of population-wide norms and practices and support from key institutional actors is, in part, the product of competitive struggles, and thus is vulnerable to resource constraints" (Baum & Powell, 1995,536). In the context of Canada's mining industry, several such institutionalizing actors could have been a factor. The Geological Survey of Canada, the Canadian Government, and the Ontario Department of Mines are three examples. A conclusion based on competition driving firm numbers after the shake-out is consistent with what is known about the mining industry. The tax reforms of 1972 and 1974, along with the introduction of environmental legislation, changed the cost structure for the mining industry at a time when commodity prices, in real terms, had begun their decline. The significance of the 1972 tax change, the price of gold, and the introduction of the CEPA legislation in the augmented model provide empirical support for this conclusion.

In summary, the findings provide clear evidence of a relationship between population size and density in Canada's mining industry and are in keeping with the findings of other researchers working with populations of long-lived firms. What is less clear is the nature of the legitimating force that shaped the trajectory of mining firm participation until the time of the shake-out.

Conclusion

The main argument of the essay is that population size in Canada's mining industry is related to one of density, market feedback, or non-rational market behaviour. The underlying dynamic was determined to be density, a result that supports previous research regarding the relationship between density and population size. The research also provides evidence of another evolutionary pattern, that is, a negatively skewed population distribution. The persistent entry that produced this negatively skewed distribution can be explained on the basis of a favourable regulatory regime for mining, relatively low technological barriers to entry, and the geographic dispersion of firms.

As noted earlier, testing the density dependence model on industries that have evolved well beyond their peak density has been challenged by Baum and Powell (1995).

In the present essay, the mining industry has not yet reached the low density conditions of late stage evolution that were a concern for Baum and Powell (Baum & Powell, 1995). In the absence of clear measures for legitimacy and competition, the actual dynamics driving firm numbers can only be assumed, particularly as there is no historical evidence to support an assumption of legitimacy of the organizational form. Applying the density dependence model to other socio-political forces besides legitimacy of the organizational form is clearly important. The findings noted in this essay that certain socio-political factors (i.e., changes in the tax regime and the introduction of substantive environmental legislation) can affect firm numbers suggest legitimacy could take other forms. The fact that mining firms were moderately taxed until 1972 and were also not required to internalize the environmental costs of production until after 1988 suggests legitimacy for mining might be related to social approval.

This research has empirically established (given conditions of equilibrium and non-equilibrium observations) that for mining, population growth rates vary with population density. However, the industry is entering its mature phase, a phase not readily explained by the density dependence theory (Baum & Powell, 1995). As noted earlier, the low density structure of the industry's early phase will be different from the low density structure of the industry's mature phase, a conclusion supported by the historical record. At the start of the 20th century, mining firms internalized most of the mineral processing activities; that is, mining firms were engaged in all aspects of the mine life cycle, from exploration through to reclamation. However, by the end of the 20th century, few mining firms were engaged in all aspects of the mine life cycle, a change that began about the time of the shakeout. As well, in the mid-1980s, many of the large mining firms downsized, releasing experienced geologists who created the non-producing exploration firm (MacDonald, 2002). And while entry and exit numbers are important sources of information on structural change, they do not provide insight into the selection process, which is being reflected in the population dynamics, nor do they unequivocally identify the underlying dynamic. These are issues, which still need to be examined.

Regression Equations

(a) Density

1. $\Delta N(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \varepsilon(t)$

1a. $\Delta N(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \rho_3 N(t-1)^3 + \varepsilon(t)$

1b. $\Delta N(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \rho_3$ (1972 Tax Change) + ρ_4 (1974 Tax Change) + ρ_5 (CEPA 1988) + ρ_6 (Au) + ρ_7 (Bank Rate) + $\varepsilon(t)$

1c. $N(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \varepsilon(t)$

1d. $\sqrt{N}(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2$

1e. $\sqrt{N}(t) = \rho_0 + \rho_1 N(t-1) + \rho_2 N(t-1)^2 + \rho_3$ (1972 Tax Change) + ρ_4 (1974 Tax Change) + ρ_5 (CEPA 1988) + ρ_6 (Au) + ρ_7 (Bank Rate) + $\varepsilon(t)$

(b) Negative Feedback

2. $\Delta N(t) = \alpha_0 + \alpha_1 N(t-1) + \varepsilon(t)$

2a. $\Delta N(t) = \alpha_0 + \alpha_1 N(t-1) + \alpha_2 t + \alpha_3 t^2 + \varepsilon(t)$

(c) Contagion

3. $\Delta N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \varepsilon(t)$

3a. $\Delta N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \psi_3 t + \varepsilon(t)$

3b. $\Delta N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 N(t-2) + \varepsilon(t)$

3c. $\Delta N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \psi_3$ (1972 Tax Change) + ψ_4 (1974 Tax Change) + ψ_5 (CEPA 1988) + ψ_6 (Au) + ψ_7 (Bank Rate) + $\varepsilon(t)$

3d. $N(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \varepsilon(t)$

3e. $\sqrt{N}(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \varepsilon(t)$

3f. $\sqrt{N}(t) = \psi_0 + \psi_1 N(t-1) + \psi_2 \Delta N(t-1) + \psi_3$ (1972 Tax Change) $+ \psi_4$ (1974 Tax Change) $+ \psi_5$ (CEPA 1988) $+ \psi_6$ (Au) $+ \psi_7$ (Bank Rate) $+ \varepsilon(t)$

Tables

Table 1.1 Regression Results for the Geroski/Mazzucato Models

Term	Density Dependence (Equation 1)	Negative Feedback (Equation 2)	Contagion (Equation 3)
Intercept	-21.974 (34.784)	34.671 (23.155)	43.86+ (22.67)
N (t-1)	0.141+ (0.076)	-0.016 (0.021)	-0.069* (0.027)
Δ N (t-1)			0.546** (0.19)
N $(t-1)^2$	-0.000064* (0.00003)		
Adjusted R^2	0.044	-0.005	0.092
F-value	2.6136+	0.6151	4.4667*

The entries in the table are unstandardized regression coefficients (β) with standard errors in round brackets ( ). *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$. The dependent variable was ΔN(t), as specified by Geroski and Mazzucato (2001).

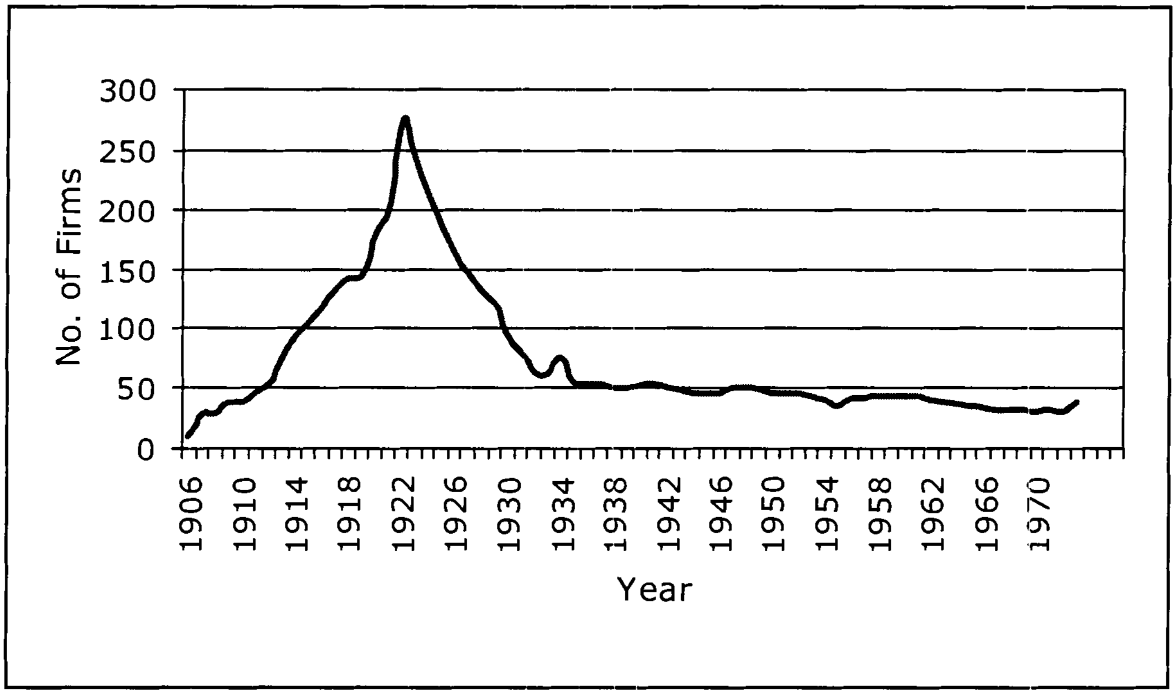
Table 1.2 Regression Results for the Augmented Models

Term	Contagion Model DV = Δ N(t) (Equation 3c)	Contagion Model DV = √N(t) (Equation 3f)	Density Dependence Model DV = Δ N(t) (Equation 1b)	Density Dependence Model DV = √N(t) (Equation 1e)
Intercept	-116.695+ (66.543)	12.472*** (1.548)	-249.147** (80.72)	5.377*** (1.015)
N (t-1)	-0.025 (0.052)	0.015*** (0.001)	0.245* (0.112)	0.030*** (0.001)
Δ N (t-1)	0.345+ (0.196)	0.0016 (0.004)		
$N(t-1)^2$			-0.00008* (0.00004)	-0.000005*** (4.525e-7)
1972 Tax Change [0]	6.593 (43.439)	-1.301 (1.011)	52.93 (45.60)	1.112+ (0.573)
1974 Tax Change [0]	27.847 (50.274)	0.569 (1.169)	20.99 (49.31)	0.664 (0.620)
CEPA 1988 [0]	105.832** (35.226)	1.810* (0.819)	111.11** (33.99)	1.249** (0.428)
Gold Price	0.714** (0.227)	0.005 (0.005)	0.748** (0.224)	0.007* (0.003)
Bank of Canada Rate	-9.088 (7.368)	0.037 (0.171)	-8.137 (7.279)	0.107 (0.091)
Adjusted R^2	0.252	0.950	0.274	0.986
F-value	3.749**	155.296***	4.0688**	564.824***

The entries in the table are unstandardized regression coefficients (β) with standard errors in parentheses.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

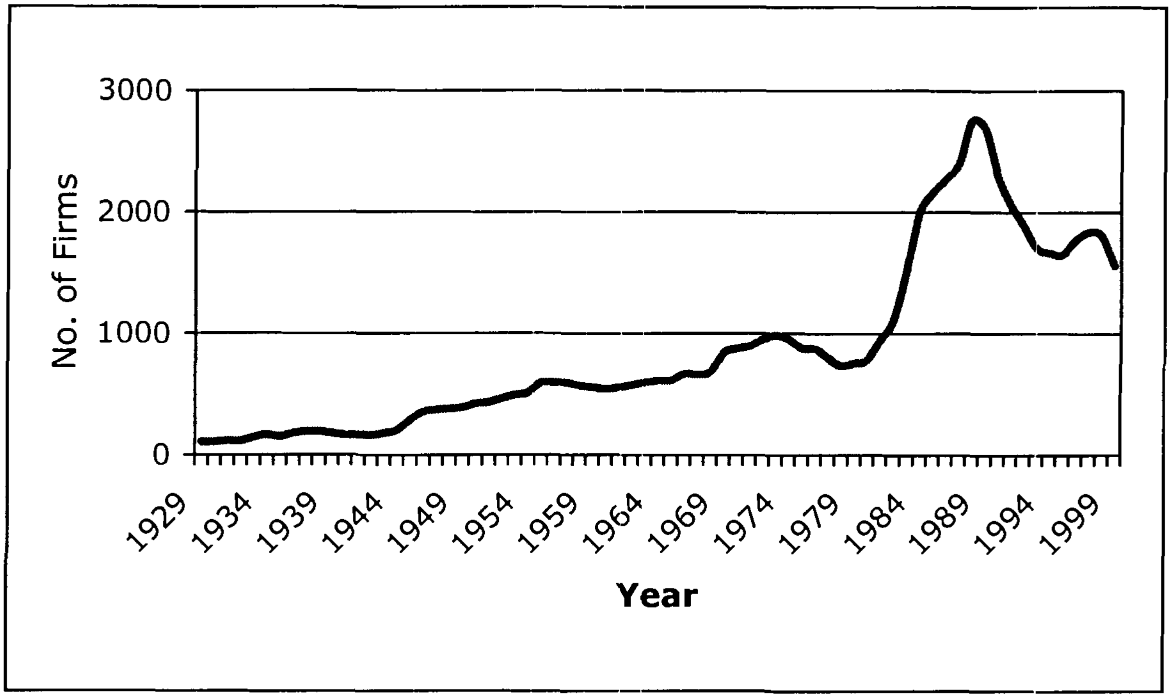
Figures

Figure 1.1 Number of U.S. Tire Producers



Source for the data: Jovanovic and MacDonald (1994)

Figure 1.2 Number of Canadian Mining Firms



Source for the data: Canadian Mines Handbook 1934-1999

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2:
CANADA'S MINING INDUSTRY – THE SURVIVAL PERSPECTIVE

Abstract

This essay explored the relationship between survival and the physical assets of a cohort of 741 Canadian mining firms for the years 1969 to 1999. Six factors were considered: the number of mines, the number of deposits, the ratio of deposits to prospects, the ratio of mines to deposits, size, and age. Based on a Cox regression analysis and the Kaplan-Meier procedure, five of the six factors were found to be contributing to firm survival, the exception being the ratio of deposits to prospects. The results suggest that physical assets should be included in the list of factors contributing to the survival of the firm and that the intangible assets of the firm are not the only source of competitive advantage when the measure of success is survival.

Introduction

This essay is about survival, or why it is that some firms manage to survive for very long periods of time when the average corporate life expectancy among firms in the northern hemisphere is less than 20 years (de Geus, 1997a), but more specifically, this essay is about how Canadian mining firms can survive on the basis of their resource-based assets.

Longevity or long-term survival of the firm is not an area of research that has attracted a great deal of interest among researchers, perhaps because few firms survive much beyond 20 years. Few of the studies that have considered longevity have controlled for industry effects, even though survival is known to be linked to both industry and firm effects (Audretsch & Mahmood, 1995). Among the single industry studies of longevity, there have been no studies of the mining industry.

The mining industry was chosen for this essay for three reasons. First, it is an industry that has what appears to be a significant number of long-lived firms. For instance, in 1999 there were over eighty Canadian mining firms that were fifty years of age or older and seven that were close to 100 years old (Southam Mining Group, 1999). Second, the technology of the industry is fairly standardized, and there is little or no product differentiation. The technologies of ore preparation are those of crushing, grinding, sizing, and sorting, technologies that have not changed in over 50 years (Ripley, Redmann, & Crowder, 1996). And the processing of the concentrated ore uses one or more metallurgical techniques, many of which have been in use for decades. The processes associated with aluminum production, for example, have been in use for over 120 years (Sirois & MacDonald, 1984). And third, certain of the assets created during the phases of mining (see Table 2.1 for the mining value chain) are tangible assets that could be considered resource-based assets for the purpose of generating a sustainable competitive advantage. Tangible assets have only recently been considered as candidates for resource-based assets; most researchers appear to have assumed that it is only the intangible assets of the firm that can provide a sustainable competitive advantage (Galbreath & Galvin, 2004). If the resource-based view of the firm holds for intangible assets that meet the required criteria of valuable, rare, inimitable, and non-substitutable, then the theory should also hold for any other asset class that meets these criteria. This study examines the relationship between tangible resource-based assets and survival, a relationship that has not been specifically examined.

The next section of the essay reviews the existing literature on firm survival and the resource-based view of the firm. The following sections, respectively, develop the hypotheses; describe the data, the variables, and the analytical procedures; present the findings; discuss the results, and the finally offer conclusions.

The Literature

Survival

It is generally held that most firms will fail (Schutjens, Starn, & Ververs, 2004), which is perhaps why failure or organizational mortality has been the lens through which much of the literature on survival has been approached, for in the process of studying failure, conclusions with respect to survival have been advanced. Industry level studies of failure and/or survival have found that profitability, expected growth rate, scale economies, and the technological regime of the industry determine when firms are most likely to fail; the firm level studies have found that age, size, type of entrant, ownership structure, attributes of the owner/manager, and certain operational and financial characteristics determine which firms are most likely to fail (Kauffman & Wang, 2001), (Vartia, 2004), (Thornhill & Amit, 2003).

The firm level studies are of two types: one that includes only failed firms in the analysis and one that includes both failed and survived firms in the analysis. Thornhill and Amit's (2003) study is an example of the first type of research as these researchers drew their sample from a population of bankrupt enterprises. Audretsch and Mahmood's (1995) study is an example of the second type of research, for they tracked all new establishments for ten years. See Table 2.2 for a list of firm-level studies in this second category.

The survival studies or studies that include both failed and survived firms are also of two types: those that track a cohort of firms for a relatively short period of time, that is, less than 20 years[14] and those that track a cohort of firms for a relatively long period of time, that is, 20 years or more.[15] This literature will be reviewed in the next two sections.

[14] Survival researchers are often forced to pick time periods that are relatively short to ensure that the basic technology does not change (Frech III, 2002).
[15] Twenty years was used to categorize the survival studies in the literature based on de Geus's (1997a) observation the average corporate life expectancy among firms in the Northern Hemisphere is less than 20 years.

Survival Studies of Less than 20 Years

Gimeno, Folta, Cooper, and Woo (1997) considered the question of why some firms survive while other firms with similar economic performance do not and found that survival is not strictly a function of economic performance. Firms have different thresholds of performance, and survival is based on whether performance falls above or below that threshold (Gimeno et al., 1997). Thornhill and Amit (1998) sought to distinguish high-growth new entrants from low-growth new entrants in a sample of firms that had survived ten years and found that innovation and a sensitivity to the environment influenced growth rates.

A number of researchers have empirically evaluated the contribution of a variety of variables to survival among firms selected from a number of different industries. Human capital was a factor in the survival of the firms in the studies conducted by Lerner and Khavul (2004), Cooper, Gimeno-Gascon, and Woo (1994)) and Bruderl, Preisendorfer, and Zeigler (1992). Bonn (2000) found that size, corporate direction, research and development, and ownership were significantly related to company survival; Chen (2002), that plant size, age, regulatory subsidies, technology use, and multi-plant coordination were contributory factors. Elston (2003) found that among German firms, those with banking interests had higher survival rates than those without such interests. Jain and Kini (2004) determined that the survival of initial public offering (IPO) firms was linked to investments in product line expansions and research and development. Kauermann, Tutz, and Bruderl (2005) in their research were able to confirm that the impact of certain risk factors such as planning, age of the found, and debt declines over time.

Using samples drawn from manufacturing enterprises, researchers have found that survival is linked to (a) the structure of ownership and start-up size (Audretsch & Mahmood, 1995); (b) age, size, and industry environment (Audretsch, Houweling, & Thurik, 2000), (Segarra & Callejon, 2000); (c) research and development activity (Kearns & Ruance, 1998)); (d) the financial health of the firm (Vartia, 2004); and (e) organizational heritage (Dahl & Reichstein, 2005). Hall (1994), who drew his sample of firms from the construction industry in the United Kingdom, found that it was the quality of the human capital, both internal and external, available to the firms that distinguished the survivor firms from those that failed. Carter, Williams, and Reynolds (1997) found among retail firms that those owned by women were less likely to survive. Start-up size, low branch density, and low industry concentration were found by Santarelli (2000) to be conducive to new-firm survival among Italian financial intermediaries. And finally, two, recent studies on software providers and Internet firms have added additional factors to the picture of firm survival. Cottrell and Nault (2004) found that older firms, firms with products in fewer application categories, and firms that offered integrated products, were more likely to survive; Banerjee, Kauffman, and Wang (2005), found that for Internet firms, or firms that generate 90% of their revenues through the digital channel, survival is increasingly contingent on financial capital and size.

Survival Studies of 20 Years or More

Few of the studies on firm survival have tracked a cohort of firms for periods longer than 20 years. The earliest critical analysis of longevity was Frasure's 1952 study (Carroll & Hannan, 2000) of a sample of U.S. manufacturing plants. Carroll and Hannan (2000) identified this study as the first comprehensive empirical evaluation of the factors contributing to longevity. The managerial capabilities of specific individuals and the reputation of the firms and their products were found to contribute to longevity (Carroll & Hannan, 2000). Mitchell's (1994) study of 327 firms operating in the medical sector product markets between 1952 and 1990 found that surviving businesses are increasingly more likely to be sold as they age and their sales increase. DeGeus (1997a) and Collins and Porras (cited by, de Geus, 1997b) added to the literature with their studies of companies that had been in existence for extended periods of time. They found that survivor firms have certain personality characteristics in common. For the thirty companies in DeGeus' (1997a) study, the characteristics were those of conservatism in financing, responsiveness to changes in the external environment, a sense of belonging inside the firm, and a tolerance for experimentation. For the firms in the Collins and Porras' (cited by, de Geus, 1997b) study, surviving firms were found to have a strong sense of identity, a sensitivity to the environment, and a lower priority on maximizing shareholder wealth. Hannah's (1998) observations of the world's largest industrial corporations in 1912 and again in 1995 indicated that the 1912 firms which were still among the world's largest corporations in 1995 were those which had been internationally focused in 1912. Gorg and Strobl (2000) considered the relationship between the presence of multinational companies among indigenous Irish high-tech firms and found that the presence of the multinationals had a positive impact on the survival of the indigenous firms. Staber's (2001) examination of firms in a declining industrial district showed that the size of the firm, the distance from export markets, and proximity to firms in the same or complementary industries influence survival. Early entry and prior experience were found to be factors in the survival of German automobile firms

(2004). Thompson (2005) also found that prior experience was a factor in the survival of U.S. shipbuilding firms. And finally, Mulotte and Dussauge (2005) in their study of firms in the global aircraft industry found that the use of pre-entry alliances had a positive impact on long term post entry success measured as survival in the line of business.

The Resource-Based View of the Firm

The resource-based view of the firm has engendered a significant body of research since Birger Wernerfelt first coined the term in 1984 (Fahy & Smithee, 1999). It is considered a theory of competitive advantage whereby firms in possession of certain resources can achieve a sustainable competitive advantage by effectively deploying these key resources in their product markets (Fahy & Smithee, 1999). Much of the research has focused on the effect of resources which fit the definition of a resource-based asset on firm performance, the assumption being that sustained competitive advantage can be inferred from sustained superior performance (Reed & DeFillippi, 1990).

Wernerfelt (1984) argued that certain assets of the firm, specifically those tangible and intangible assets that are semi-permanently tied to the firm, can lead to higher returns over time. Barney (1991) expanded on this work by introducing the resource-based model of sustained competitive advantage, a model that assumes (a) resource endowments are heterogeneously distributed among firms and (b) these differences in resource endowments are relatively stable over time. Resources are taken to include tangible and intangible assets of the firm, capabilities, and competencies (Amit & Schoemaker, 1993), (Reed & DeFillippi, 1990). Of these resources, those with the potential for generating a sustained competitive advantage have four characteristics:

They are valuable, rare among the firm's competitors, imperfectly imitable, and have few strategically equivalent substitutes (Barney, 1991).

Researchers have been able to establish a link between performance (typically measured in financial terms) and such advantageous assets as research competency (Henderson & Cockburn, 1994); portfolio interrelationships (Robins & Wiersema, 1995); long-term contracts (Miller & Shamsie, 1996); the auditing skill base of registered auditors (Maijoor & van Witteloostuijn, 1996); management quality, technological expertise, resource management, and innovation (Mehra, 1996); partner choice in interfirm collaborations (Mowery, Oxley, & Silverman, 1998); the development of resource positions (Pettus, 2001); and internal and external learning (Schroeder, Bates, & Junttila, 2002).

Most researchers have taken the view that tangible assets fail the tests for inimitability and non-substitutability (Fahy & Smithee, 1999) and have focused their inquiries instead on the role of intangible assets (Galbreath & Galvin, 2004). There are two studies now that have considered the possibility that tangible assets might qualify as resource-based assets and thereby provide a sustainable competitive advantage. Galbreath and Galvin (2004) analyzed the effects of both tangible and intangible assets on firm performance by surveying 291 manufacturing and service firms with respect to the contribution of these resources to the performance of the firm. They found that when the effects of tangible assets are considered, additional and significant explanatory effects on performance were found for certain intangible assets (organizational and reputational assets) but not for others (intellectual property assets and capabilities). Galbreath and Galvin (2004) interpreted these results as evidence that certain resources are dependent on other resources and that no single resource, tangible (they looked at financial resources and physical assets) or intangible, is the primary determinant of performance (Galbreath & Galvin, 2004). The second study, which examined customer satisfaction among North American insurance companies, demonstrated that firms may possess competitive advantages at the level of business processes which are not reflected in a firm's overall performance (Ray, Barney, & Muhanna, 2004). This study, like the Galbreath and Galvin study (2004), also considered both tangible and intangible assets. In this case, the tangible assets were technology resources and investments in the customer service process (Ray et al., 2004). The Ray et al. (2004) study is also noteworthy because it is one of the few resource based studies that did not use a financial measure of performance as the dependent variable; instead, the researchers used customer service.

In summary, what is known about survival has been gleaned primarily from studies which have tracked survival among firms which have been in existence for less than 20 years. The few studies that have systematically evaluated the characteristics of firms that survive for longer periods suggest that managerial capabilities, personality traits, technology spillovers, internationalism, size, early entry, and pre-entry experience contribute to longevity. Few of these studies have controlled for industry effects, and the single industry studies that have, have not considered the mining industry.

The resource based view of the firm, the dominant explanation for intra-industry performance differences (Hoopes, Madsen, & Walker, 2003), posits that firms in possession of resources which are valuable, rare, difficult to imitate, and for which there are few substitutes can generate a sustainable competitive advantage. Based on the empirical evidence to-date, intangible assets and recently certain tangible assets (physical assets and financial assets) have been linked to sustainable competitive advantage. With rare exception, sustainable competitive advantage has been defined in terms of the financial performance of the firm, a measure several researchers have found wanting (Hannan & Freeman, 1977), (Coff, 1999), (Sirgy, 2002). Hannah and Freeman (1977) have argued that survival, like a financial measurement, is a useful indicator of performance because it is easily measured and demonstrates an organization's success in both attracting resources and in adapting to its environment. Sirgy (2002) and Coff (1999) have gone even further and suggested that long-term survival is a better measure of performance than the more traditional returns to the shareholder, their position being that returns to the shareholder capture only that portion of the rents which accrue to the investing community. And recently, Thornhill and Amit (2003) have suggested that survival is an appropriate performance measure in applications of the resource based view of the firm.

What is missing in the literature is a study that explores the relationship between survival and the resource based assets of the firm, both tangible and intangible. The current research attempts to (a) add to the literature on longevity by examining the Canadian mining industry, an industry which has not previously been considered, and (b) fill the gap in the resource-based view of the firm literature by evaluating the role of tangible assets that meet the criteria for resource-based assets on survival.

The Hypothesized Relationships

The central proposition of the resource-based view of the firm is that resources that meet the criteria of valuable, rare, inimitable, and non-substitutable are capable of generating sustained competitive advantage. The phases of mining produce a limited set of physical assets, namely, prospects, deposits, projects, mines, and refineries/smelters (see Table 2.1), some of which qualify as resource-based assets. Prospects are properties with actual or probable mineral/metal deposits; deposits are properties with known concentrations of minerals or metals; projects are deposits that are in the process of being converted to a mine; mines are excavations in the earth from which minerals/metals are extracted; and refineries/smelters are industrial plants.

Not all of the assets associated with the phases of mining meet the criteria for resource-based assets. Prospects are not particularly valuable or rare, and they are substitutable. Deposits and mines are more valuable because significant amounts of time and money are expended in the process of creating them (Cottrell, Cameron, & Webster, 1999), and they are also rare. It has been estimated that for every 1,000 prospects with suspected mineralization, 100 may warrant further investigation, 10 may justify a drilling program, and one may eventually become a mine (MacDonald, 2002). Deposits with significant mineralization are not only valuable and rare, they are also not easily imitated, for no two deposits are exactly alike in terms of grade, shape, and location. Mines are not only valuable, rare, and inimitable, they are also not easily substituted. An operating mine cannot be easily replicated; that is, a competitor would need to find and prove an equivalent deposit, raise the capital, obtain the necessary operating permits, build the infrastructure, and then open the mine, a process that can take 10 years or more. The Teck Cominco/Sumitomo's Pogo Mine, for example, which is due to open in early 2006, was discovered in 1994. Projects are deposits that are in the process of being transformed into a mine, and although the project is valuable, it is (a) the deposit which contains the mineral/metal of interest and (b) the mining operation which will produce the saleable product that are considered the rare, valuable, inimitable, and non-substitutable assets. Refineries and smelters, while valuable, make use of standard technologies that have been in existence for a long period of time and are, therefore, not rare and are capable of being imitated or substituted. In fact, it is not unusual for mining firms to contract out their refining and/or smelting operations.

Given that of the five physical assets associated with mining, only deposits and mines meet the criteria for resource-based assets, it was posited that:

Hypothesis 1: The chance of failure will decrease for firms with a deposit.

Hypothesis 2: The chance of failure will decrease for firms with a mine.

Sustained competitive advantage has been found to be related to asset mass efficiencies; that is, adding to existing asset stocks is facilitated by possessing high levels of that stock (Dierickx & Cool, 1989). In other words, the more assets a firm controls, the easier it is to add additional assets as the marginal cost of adding to the firm's capital stock is lower (Knott, Bryce, & Posen, 2003). In mining, there are other reasons for firms to add to their existing asset stocks. The high levels of discovery risk, as noted above, and the long lead times before production begins (typically 8 to 10 years) make it important for firms to hold a number of mining assets, preferably at different stages of development. Based on these considerations regarding efficiency and risk reduction, the following hypotheses were developed:

Hypothesis 3: The chance of failure will decrease for firms as the number of deposits increases.

Hypothesis 4: The chance of failure will decrease for firms as the number of mines increases.

One of the challenges for mining firms is in finding a deposit that can be converted into an operating mine. As noted earlier, few of the many prospects evaluated by a firm will produce deposits of sufficient interest to warrant further consideration, and for those deposits which do appear promising, few will ever become mines. The ability of the firm to convert its prospects into deposits and its deposits into mines reflects on the capabilities of the firm and suggested two more hypotheses.

Hypothesis 5: The chance of failure will decrease for firms as the ratio of deposits to prospects approaches 1.[16]

Hypothesis 6: The chance of failure will decrease for firms as the ratio of mines to deposits approaches 1.

Size is a variable that is frequently included in survival studies. This prior research has demonstrated the probability that a firm will fail decreases with increasing firm size (Daily, 1995), (Moulton & Thomas, 1993), (Hall, 1992), (Bonn, 2000), (Chen, 2002), (Mitchell, 1994), (Audretsch & Mahmood, 1995), (Audretsch et al., 2000), (Santarelli, 2000), (Segarra & Callejon, 2000), (Banerjee et al., 2005)). A variety of

[16] A conversion ratio of 1 would mean that every prospect became a deposit and every deposit a mine.

measures have been used to indicate firm size: (a) number of employees (Segarra & Callejon, 2000), (Gorg & Strobl, 2000), (Santarelli, 2000), (Kearns & Ruance, 1998), (Audretsch & Mahmood, 1995), (Audretsch et al., 2000), (Vartia, 2004), (Kauermann et al., 2005), (Bruderl et al., 1992), (Ranger-Moore, 1997), (Banerjee et al., 2005) ; (b) invested capital (Kauermann et al., 2005), (Bruderl et al., 1992) ; (c) sales or revenue (Elston, 2003), (Mitchell, 1994), (Bonn, 2000), (Mulotte & Dussauge, 2005); (d) refining capacity (Chen, 2002); (e) IPO offer size (Jain & Kini, 2004); (f) log of assets (Daily, 1995), (Moulton & Thomas, 1993), (Thornhill & Amit, 2003); (g) market capitalization (Hannah, 1998); and (h) number of vessels launched (Thompson, 2005).

Age is another variable that is frequently included in survival studies. Age is useful as it can serve as a proxy for an omitted variable such as the knowledge or the capabilities accumulated by the firm over time that cannot be otherwise measured (Thompson, 2005). Age can also capture what Chen (2002) has described as "...the efficiency differences arising from different experiences, managerial abilities, production technologies, and firm organizations" (Chen, 2002 , 518). Researchers who have included this variable in their models have established that the probability a firm will fail decreases with the age of the firm (Daily, 1995), (Hall, 1994), (Chen, 2002), (Mitchell, 1994), (Audretsch et al., 2000), (Segarra & Callejon, 2000), (Cottrell & Nault, 2004). The findings of these researchers suggested the final two hypotheses:

Hypothesis 7: The chance of failure will decrease as the size of the firm increases.

Hypothesis 8: The chance of failure will decrease as the age of the firm increases.

The Data and the Methodology

Data Set

The principal source of information on Canadian mining firm assets is the Canadian Mines Handbook (Handbook), which has been continuously published since 1934. Each edition provides a profile of Canada's active mining companies, profiles that provide information on authorized capital, the major shareholders, and company interests, where available. Company interest information is descriptive, detailing (a) the type of interests (property, prospect, project, mine, option, or share interest); (b) the location of the interest, the percent owned, and the mineral/metal; (c) drilling results; (d) production, grade, and reserve estimates; and (d) financing arrangements. A limited amount of financial data is also provided, along with the five-year trading range for publicly traded companies. The cohort of firms chosen for this study encompassed the mining firms listed in the Trading Range Section of the Handbook for 1969-70 for which a high and low share price was provided. The high and low share price was taken as an indication that the firm was active in 1969-70. There were 741 firms in the cohort.[17]

Dependent Variable

The dependent variable was time to a terminal event, which was calculated based on a time variable and a status variable. The time variable was the number of years to a particular status. The start date was 1969 and the end date was 1999. The status variable

[17] Mining companies can stop trading for extended periods of time. A review of the Trading Range Section of the Handbook for 1999-2000 identified some 195 firms which were inactive in 1969-70. These firms were not included in the cohort as they were not active at the start of the study period.

was one of survived, acquired or merged, or failed. For example, for a firm that failed in 1972, the number of years to the event was 3, and the status at the time of the event was 0 (failed); for a firm that merged in 1972, the number of years to the event was still 3, and the status at the time of the event was 1 (acquired or merged). For a firm that was still in existence in 1999, the number of years to the event was 30, and the status at the time of the event was 2 (survived).

A survived firm was a firm that was continuously listed in the Trading Range of the Handbook between 1969-70 and 1999-2000; a failed firm was one that stopped trading during that period. Identifying a firm as acquired or merged was not as straightforward as identifying a survived or failed firm. For instance, does a firm cease to exist if it is acquired? When two firms merge, are they merging because they are failing, succeeding, or some combination of failing and succeeding? As it is fairly common for mining firms to be acquired or merged because of the long-lived nature of their assets, for the purposes of this analysis, the value of the firm's assets, assumed to be reflected in the share price at the time the firm stopped trading, was used to distinguish between an acquired/merged firm and a failed firm. Anecdotal information suggested this was a valid assumption. For example, Lornex had a high share price of $36.00 per share when it stopped trading, but the mine continued to operate for several years after it was acquired, suggesting the firm was not a failed firm. If the share price suggested the firm had assets of value when it ceased trading (last high share price equal to or greater than $1.00), the firm was assumed to have been acquired or merged. If the share price suggested otherwise (a last high share price of less than $1.00), the firm was assumed to have failed. The choice of a last share price equal to or greater than $1.00 was based on the observation that the share price of firms that were known to have failed tended to drop below a $1.00[18] and then continue to decline to a final share price of $0.05 or less, while the share price for those that were known to have been acquired or merged retained its value. For firms that had been dropped from the list, prior Handbooks were consulted to obtain the year in which the firm failed or merged and the last high share price.

Independent Variables

The independent variables, which were based on the assets of the firms in 1969/70, were the following: (a) the number of deposits with measured reserves, (b) the number of operating mines owned, in whole or in part, by the mining company of interest, (c) the ratio of deposits to prospects, (d) the ratio of mines to deposits, (e) the log of current assets, and (f) age. The number of deposits (*Deposits*) and the number of mines (*Mines*) were a count of the deposits and mines listed in the 1969/70 Handbook for the mining firm of interest. Entries for a deposit were typically recorded as follows: 'tin, molybdenum, tungsten, copper, zinc prospect[19], 118 claims, approx. 37 miles S of Fredericton, Charlotte Co., NB. Extensive surface & underground diamond drilling indicate potential 4,581,800 tons average 0.56% tin, 2.47% zinc, 0.24% lead, and 0.24% copper plus cadmium and silver values in 2 zones'. And those for a mine typically took the following form: 'Gold producer, Giant Mine'. As deposits and mines are physical

[18] As the choice of a last high share price of $1.00 was somewhat arbitrary, the analysis was replicated using a last high share price of $2.00. The change in classification affected 16 of the 141 acquired or merged firms in the sample and did not change the results.

[19] The terms prospect and deposit are often used interchangeably in the industry. In this example, a deposit has been labeled a prospect by the reporting company. Because a drilling program has been undertaken, the prospect is considered a deposit for the purposes of the analysis.

assets, they are considered here to be tangible assets, even though they might have characteristics which could qualify them as intangible assets .[20]

The ratio of the number of deposits to the number of prospects (*RatioDP*) and the ratio of the number of mines to the number of deposits (*RatioMD*) were included to measure productivity or the ability of the firm to convert its prospects into deposits and its deposits into mines. These ratios were calculated from the count of deposits and mines used for the variables *Deposits* and *Mines*. As these ratios measure capabilities, they are considered here to be intangible assets. The remaining data element needed in the calculations was the number of prospects (*Prospects*), and it was a count of the prospects listed in the Handbook for the mining firm of interest. Prospects were typically recorded as follows: 'Base metal prospect, 15 claims, Uchi Lake area, Red Lake mining district, NW Ont. Work planned 1969'.

The log of current assets (*LogCA*) was used as a measure of size and was calculated from the current asset number reported in the 1969/70 Handbook. Other researchers have used the log of total assets as a measure of size, but as only current asset information was available, the log of current assets was used as a proxy for size.[21]

Age (*AgeMean*) was calculated as the age of the firm in 1969, based on its incorporation date minus the mean age of the cohort of firms. This method of calculating age was used to define the baseline for age as mean age.

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[20] Mining assets are difficult to classify as tangible or intangible as they have characteristics of each. Mining assets are durable, they do not deteriorate, and they can be bought and sold -- all characteristics of tangible assets. Mining assets are also difficult to find, require considerable skill to bring into production, and are not easily substituted -- all characteristics of intangible assets.

[21] Most of the firms in the study reported current assets as only the producing firms had any other assets to report. The other measures of size noted in the literature such as number of employees and revenue were not available.

Methods for Empirical Analysis

The Cox proportional hazards regression technique, a technique that models the time to a specified event based upon the values of a set of covariates, is the most widely used method of survival analysis (Fox, 2002) and has been used by the following survival researchers: (Dahl & Reichstein, 2005), (Vartia, 2004), (Jain & Kini, 2004), (Elston, 2003), (Gorg & Strobl, 2000), (Segarra & Callejon, 2000), (Santarelli, 2000), (Kearns & Ruance, 1998), (Audretsch & Mahmood, 1995), and (Thompson, 2005). The model specifies the hazard function as follows:

$$h\ (t) = h_o\ (t)\ \exp^{(\beta)}$$

where h(t) is the rate at which firms exit at time t, given that they have survived in t-1; h_o is the baseline hazard function when all of the covariates are set to zero; and β is a vector of unknown parameters (Gorg & Strobl, 2000). A hazard ratio of 1 indicates that the corresponding covariate has no effect on the baseline hazard; a coefficient of less than 1, that an increase in the value of the covariate lowers the exit hazard; a coefficient greater than 1, that an increase in the value of the covariate raises the exit hazard (Thompson, 2005).

The specific models used in the analysis are listed in Table 2.3. Three models were evaluated under two censoring conditions. The first model contained the tangible resource-based variables *deposits, mines,* plus the variables for size *(LogCA)* and age *(AgeMean)*; the second, the ratio of deposits to prospects (*RatioDP)* and the variables *LogCA* and *AgeMean*; the third, the ratio of mines to deposits (*RatioMD*) and the variables *LogCA* and *AgeMean*. Each of the models was evaluated under two censoring conditions. The first (Condition 1) was that failure had occurred; 564 firms met this criterion. The second (Condition 2) was that both failure and merger had occurred; 705 firms met these criteria.

In addition to the Cox regression technique, the Kaplan-Meier procedure was used to estimate the survival functions. This technique has been used by other survival researchers such as (Gorg & Strobl, 2000), (Chen, 2002; Cantner et al., 2004). The Kaplan-Meier estimator is defined as follows:

$$\hat{S}(t) = \prod ((n_i - d_i) / n_i)$$

where n_i is the number of firms that are still at risk at t_i, and d_i is the number of firms that actually failed at time t_i (Kauffman & Wang, 2001). The Kaplan-Meier estimator is used to (a) compare the differences among groups and (b) to compare the results with those obtained using the Cox regression technique. To use the Kaplan-Meier procedure, the variables had to first be categorized. Deposits were categorized as 0 deposits, or 1 or more deposits; mines as 0 mines, 1 to 10 mines, or more than 10 mines; current assets as $0 to $99,000, $100,000 to $999,999, or greater than $1,000,000; and age as less than 10 years of age, 11 to 25 years, or greater than 25 years.

Results

Table 2.4 characterizes the cohort of firms on the basis of their 1969 assets. The profile that emerges is one where the majority of firms have no deposits or mines, have less than $100,000 in current assets, and are less than 10 years of age. For the firms that failed, 77.6% had no deposits; 86.4% had no mines; 90.5% had less than $100,000 in current assets; and 81.1% were less than 10 years of age. For the firms that were acquired or merged, 18.6% had no deposits, 10.9% had no mines, 6.2% had less than $100,000 in current assets, and 15.1% were less than 10 years of age. For the firms that survived, 3.8% had no deposits, 2.6% had no mines, 3.3% had less than $100,000 in current assets, and 3.9% were less than 10 years of age. The Pearson Chi-Square values were all significant.

Descriptive statistics for each of the explanatory variables included in the study are presented in Table 2.5. The mean number of deposits held by the cohort was less than one; the mean number of mines was also less than one; the log mean of current assets was 12.1; and the mean age was 16.4 years. Failing firms were characteristically young firms with few or no deposits or mines and limited assets. The strongest relationships were between (a) the number of mines and the ratio of mines to deposits (r = .944), (b) the number of deposits and the ratio of deposits to prospects (r = 869), (c) the log of current assets and the ratio of mines to deposits (r = .505), and (d) the number of mines and the log of current assets (r = .432). The relationships between the ratio variables and mines and deposits are understandable as the individual variables of *mines* and *deposits* are components of the ratios. The relationship between the log of current assets and the ratio of mines to deposits reflects the fact that firms with mines generally have higher current assets because of outstanding accounts receivables and inventories of finished product. The fourth relationship between the number of mines and the log of current assets is similarly explained.

Table 2.6 presents the results of the Cox regression analyses. For Model 1, the model with the tangible resource-based variables *Deposits* and *Mines*, the variable *deposits* was not statistically significant for either the failed event or the failed/merged event, given the other variables in the model, although the sign of the coefficient was negative, in keeping with hypothesis 1; that is, the chance of failure will decrease for firms with a deposit. On the basis of these results, Hypothesis 1 was not supported. However, a further test of the hypothesis using the Kaplan Meier technique was supportive. The Kaplan-Meier procedure indicated that the survival distributions for *deposits* are different for both the failed and the failed merged event. Figure 2.1 displays the survival functions for *deposits* for the failed condition; Figure 2.5, for the failed/merged condition. Firms with deposits did better than those with no deposits under both conditions. The log rank test statistic comparing the equality of the survival distributions was significant ($p = 0.0069$ for the failed condition, $p = 0.0034$, for the failed/merged condition). A comparison of the survival distributions for the failed condition (Figure 2.1) with that of the failed/merged condition (Figure 2.5) reveals the two distributions are similar. The hazard function (the risk of failure at time t conditional on survival to that time) for *deposits* indicated that the chance of failure for firms with five deposits was 60% of the hazard for firms with no deposits for the failed condition (55% for the failed/merged condition), all other variables held constant. These results support hypothesis 3 that the chance of failure will decrease as the number of deposits held by the firm increases.

The variable *mines* was significant ($p = 0.000$) for both the failed and the failed/merged event, and the sign of the coefficient was negative. This result supports hypothesis 2 that the chance of failure will decrease for firms with a mine. This result was also supported by the Kaplan Meier procedure. Figure 2.2 displays the survival functions for *mines* for the failed condition; Figure 2.6, for the failed/merged condition. These figures show that firms with mines did better than those with no mines, and firms with more than 10 mines did not fail. The log rank test statistic comparing the equality of the survival distributions was significant ($p = 0.000$) for both the failed and the failed/merged condition. A comparison of the survival distributions for the failed condition (Figure 2.2) with that of the failed/merged condition (Figure 2.6) reveals the two distributions are noticeably different for two of the three groups, that is, the group of firms with 0 mines and 1 to 10 mines. The hazard function for *mines* indicated that the chance of failure for firms with one mine was 53% times the hazard for firms with no mines under the failed condition (79% for the failed/merged condition), all other variables held constant. With five mines, the chance of failure was 4% of that for firms with no mines under the failed condition (30% for the failed/merged condition), again with all other variables held constant. These results support hypothesis 4 that the chance of failure will decrease as the number of mines increases.

The difference in the hazard rate for the variable *mines* between the failed and the failed/merged condition (53% versus 79% for firms with one mine; 4% versus 31% for firms with five mines) is probably related to the fact that the profile of the merged firms more closely resembles that of survived firms than that of the failed firms. For example, 13% of the total number of failed firms had mines as compared to 56% of the total number of acquired or merged firms (see Table 2.4). A comparison of the survival distributions (see Figures 2.2 and 2.6) seems to corroborate this finding. When acquired/merged firms are categorized as failed firms, the survival distributions for the two groups (those with 0 mines as compared to those with 1 to 10 mines) are more similar than when the acquired/merged firms are categorized as survived firms.

The variable *LogCA* was significant for both the failed and the failed/merged condition (p = 0.000 and 0.086, respectively), and the sign of the coefficient under both conditions was negative, in keeping with hypothesis 7 that the chance of failure will decrease as the size of the firm increases. The Kaplan Meier procedure also provided support for this hypothesis (see Figures 2.3 and 2.7). Figure 2.3 displays the survival functions for *current assets* for the failed condition; Figure 2.7, for the failed/merged condition. These figures show that firms with higher levels of current assets did better than those with lower levels. The log rank test statistic comparing the equality of the survival distributions was significant (p = 0.0000) for both the failed and the failed/merged condition. The survival distributions for the failed condition (Figure 2.3) as compared with that of the failed/merged condition (Figure 2.7) are noticeably different for two of the groups, namely, the group of firms with less than $100,000 in current assets and the group of firms with between $100,000 and $999,000 in current assets. When acquired/merged firms are categorized as failed firms, the survival distributions for the two groups are more similar than when the acquired/merged firms are categorized as survived firms. This too is in keeping with the data, for 94% of the total number of failed firms for which there were data had current assets of less than $1,000,000 as compared to 31% of the total number of acquired or merged firms for which there were data (see Table 2.4).

The variable *AgeMean* was significant for the failed/merged condition (p = 0.012) but not for the failed condition (p = .106). The sign of the coefficient was negative under both conditions. On the basis of these results, hypothesis 8 was partially supported. A further test of this hypothesis using the Kaplan Meier technique provided support for the hypothesis under both conditions. The Kaplan-Meier procedure showed the survival distributions for *age* to be different for both the failed and the failed merged event. Figure 2.4 displays the survival functions for *age* for the failed condition; Figure 2.8, for the failed/merged condition. Older firms did better than younger firms under both conditions. The log rank test statistic comparing the equality of the survival distributions was significant for both conditions (p = 0.000 for the failed condition, p = 0.007 for the failed/merged condition). A comparison of the survival distributions for the failed condition (Figure 2.4) with that of the failed/merged condition (Figure 2.8) reveals the two distributions are similar.

These results support the view that tangible mining assets in the form of deposits and mines contribute to the survival of mining firms. The importance of age and size to the survival of the firm demonstrated by other researchers finds further support here as well.

For Model 2, the first of the two models with an intangible resource-based variable, *RatioDP* was not significant for either the failed or the failed/merged condition, given the other variables in the model. This result does not support hypothesis 5 that the chance of failure will decrease for firms as the ratio of deposits to prospects approaches 1. The variable *LogCA* was significant for both the failed and the failed/merged condition (p = 0.000). The variable *AgeMean* was also significant for the both the failed (p = .014) and the failed/merged condition (p = 0.003). The relationship between survival and all three variables was negative; that is, the chance of failure (or failure/merger) decreased with this set of covariates, including the *RatioDP*.

For Model 3, the second of the two models with an intangible resource-based variable, *RatioMD* was significant for both the failed and the failed/merged condition (p = .008 and p = .022, respectively), a result that supports the sixth hypothesis that the chance of failure will decrease as the ratio of mines to deposits approaches 1. The variable *LogCA* was also significant for both the failed and the failed/merged condition (p = 0.000 and p = .051, respectively). The variable *AgeMean* was significant for the failed condition (p = .019) but not the failed/merged condition (p = 0.425). The relationship between survival and the covariates *LogCA,* and RatioMD was negative; the relationship between survival and *AgeMean* was positive.

Discussion

The first objective of this essay was to provide a specific test of the relationship between firm survival and the resource-based assets of the firm (i.e., rare, valuable, inimitable, and non-substitutable). The results provide support for hypotheses 1 and 2 that the chance of failure will decrease for firms with a deposit or a mine. This is the first research to link long term survival to physical assets that meet the criteria for resource-based assets. However, because the data only partially support hypothesis 1, suggests that only those deposits that become mines are valuable.

The relationship between survival and the firm's stock of physical assets (hypotheses 3 and 4) could be interpreted as support for the importance of asset mass efficiencies. It could also be interpreted as evidence of a risk reduction strategy. Each stage of the mine life cycle carries new risks. At the exploration stage, there is a very high risk of failure; at the deposit appraisal stage, there is high risk of failure; and at the project stage, there is a moderate to low risk of failure (MacDonald, 2002). As few deposits ever become mines and mines are depleting assets that must be replaced, the finding that firms with more of these assets are less likely to fail is reasonable.

The data used to calculate the ratios in Models 3 and 4 were self-reported data, so it is possible that the mixed results, with respect to hypothesis 5 and 6, reflect the data captured were incomplete. Prospect information, used in the *Ratio DP,* appeared to be the data element most likely to be under reported. Handbook entries such as 'copper prospects' or 'copper-nickel prospect, 52 claims' or 'holds several developed and partially developed properties and other groups of claims' were common, and in the absence of further details were counted as one prospect each. Additional prospect information would not have improved the ratio as the mean number of deposits per firm was less than 1. This ratio was intended to capture the firm's ability to convert its prospects into mines based on the assumption that the chances of failure would decline for firms as their conversion ratio improved. An alternative interpretation could be that the chance of failure might also decrease for firms as the ratio of deposits to prospects approached 0, based on the fact that a firm needs to consider many prospects before finding a mineable deposit, and the more prospects evaluated increases the likelihood of finding a deposit, thus lowering the chance of failure. The mean for the ratio of deposits to mines was 0.01 or 100 prospects to 1 deposit, a result more consistent with the alternative interpretation.

With respect to the second ratio (*RatioMD*), not all deposits are reported, and the mines that are reported may not have come from those deposits.[22] Nonetheless, the finding that the ratio of mines to deposits was significant further supports the importance of the ownership of mines to survival, although the ratio probably reflects the composition of the firm's reported portfolio of assets.

Because age is often used as a proxy for a variable that cannot be otherwise measured, the interpretation of the relationship between age and survival is not always straightforward. The finding that the chance of failure increases rather than decreases with age for the failed condition (Model 3) could be interpreted as evidence of structural inertia or failure to adapt to changing environmental conditions, which some researchers have suggested makes older firms more likely to fail (Barron, West, & Hannan, 1994), (Ranger-Moore, 1997). It could also be evidence that the underlying assets are depleting, and the firm's failure to convert more deposits into mines or to acquire more mines directly is increasing their chances of failure.

The data showed another interesting trend. The survival plots for deposits, mines, current assets, and age were all observed to diverge beyond year five (1974). This divergence coincides with changes that were taking place in the external environment, changes that increased competition and precipitated exits from the industry. The tax reforms of 1972 and 1974, along with the introduction of environmental legislation, changed the cost structure for the industry at a time when commodity prices, in real terms, had begun their decline. DeYoung (1977) examined the effect of the tax law changes, which basically removed and/or reduced many of the tax concessions of the pre-

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22 The Handbook is an important resource for investors so firms tend to report only those assets of interest to investors.

1972 era, and found that both exploration expenditures and investment in the Canadian mining industry declined in the post change years. The introduction of new federal and provincial legislation related to environmental issues was yet another factor that changed the competitive environment for mining in the last quarter of the 20th century (Jeffery, 1981). It would seem that in an industry that was becoming more competitive, those firms having valuable resources (deposits and/or mines), additional financial resources (over $100,000 in current assets), and more experience (over 10 years of age) were more likely to survive.

It is worth noting that only two of the thirty-six survivor firms did not own any prospects, deposits or mines in 1969. One had sold its properties and was seeking financing in 1969; the other was a holding company with shares in several other mining firms. Fifteen of the thirty-six survivor firms held prospects and/or deposits instead of mines in 1969, and over the thirty year period, the number of such assets per firm increased from an average of 2.6 prospects and/or deposits per firm to 3.7.[23] That these firms were able to raise sufficient capital to continue to finance their operations and to add to their portfolio of assets over thirty years suggests their exploration expertise (an intangible asset not measured here), in addition to the value of their physical assets, was contributing to their survival.[24]

A second objective of the current research was to broaden the literature on longevity by tracking a cohort of 741 mining firms over a 30 year period. What has been learned about survival, based on the experience of these firms, is that it is not just the

[23] Because the firms were known by name, the Handbooks for 1979-80, 1989/90, and 1999/2000 were consulted for an update on the resources of the firms.
[24] Ashton Mining Co. of Canada, founded in 1987, is a current example of a firm with exploration results sufficiently attractive to investors to sustain the company for almost 18 years.

older firms or the firms with more financial assets that are less likely to fail. Physical assets also appear to reduce the chance of failure, and as noted above, only two of the survivor firms did not own any physical assets. Seven of the survivor firms had current assets of less than $100,000; that is, they were small firms that managed to survive. Five of these firms were exploration firms, and as noted earlier, firms with exploration results of interest to investors can survive for long periods of time. For the remaining two firms with current assets of less than $100,000, both had temporarily suspended their mining operations so had limited current assets to report for 1969. Seven of the survivor firms had been operating for less than 10 years in 1969; they were young firms that managed to survive. All of these firms held prospects, deposits and/or mines. That young firms and firms with few financial assets in 1969 were able to survive for another 30 years suggests that size and age are not the only determinants of survival. The ability to develop a portfolio of deposits and mines also appears to be a factor.

Conclusion

This research confirmed the findings of other researchers that age and size matter when it comes to the survival of mining firms. The results also revealed that owning a number of valuable assets, in the form of deposits and mines, reduces the chances of failure. Of the 741 firms in the original cohort of firms, only 36 of these firms survived the 30 years period of the study. One would have expected the larger firms with more financial assets to survive. That almost half of the firms that survived had few financial assets in 1969 and a good number of them were recent entrants in 1969, suggests that size and age are not the only determinants of survival in mining.

This research has also empirically demonstrated that physical assets which meet the criteria for resource-based assets can contribute to the survival of the firm. As mining assets can be classed as tangible or intangible assets, it could be argued that possession of a tangible mining asset is not sufficient to reduce the chances of failure without the accompanying intangible asset of the skills and capabilities to bring the asset into production, an interpretation which supports the conclusion reached by Galbreath and Galvin (2004) that certain resources may be dependent on others for the success of the firm.

The choice of the success measure is an important consideration. Ray, Barney, and Muhanna (2004) were not able to link tangible assets in the form of investments in information technology to the success of insurance companies when success was measured as customer service performance. When the measure of success is survival, as it is in the current study, it is possible to link tangible assets to the long term success of the firm.

Galbreath and Galvin (2004), like Ray, Barney, and Muhanna (2004) were not able to link physical assets (land, buildings and other structures) to the performance of the firm. It remains to be determined if the relationship between physical mining assets and the financial performance of the firm, a more usual test of the resource-based view, holds as well. And finally, this research has identified a group of survivor firms that merit further attention, if only because there are so few firms that survive any length of time.

This research has two implications for the survival literature that guided the study. First, how failure is defined can influence the empirical results. When acquired or merged firms are classified as failed, the differences between the failed and the survived groups are not as noticeable and could lead to conclusions that might not hold when acquired or merged firms are excluded from the failed group. And second, the effects of changes in the external environment, thought here to be competitive changes, have to be considered, for the chance of failure may well vary over the study period.

Tables

Table 2.1 Mining Value Chain

Input	Activity	Output	Mining Asset
Property with suspected mineralization	**Exploration** (search for commercially exploitable resources)	Mineral/Metal Estimate	Prospect
Mineral/Metal Estimate	**Evaluation** (determine technical feasibility and commercial viability)	Feasibility Study	Deposit or a Reserve
Feasibility Study	**Development** (establish access to the resource and prepare for production)	Exposed Ore Body	Project
Exposed Ore Body	**Production** (extraction of saleable product and treatment of by-products)	Tonnage at Average Grade Or Saleable Product	Mine
Tonnage at Average Grade	**Beneficiating** (process ores or other raw materials)	Saleable Product	Smelter or refinery
Saleable Product	**Marketing** (sale of the product)	Revenue and Profit	
Revenue and Profit	**Divestiture or Closure** (Sale of asset or closure and remediation)	Change in economic parameters or depletion of the resource	

Information Sources: MBendi Information Services (Pty) Ltd. 2005, Cottrell, Cameron, et al. 1999, and the personal knowledge of the author

Table 2.2 Survival Studies

Author(s)	Population	Research Findings
Frasure (1952) cited by (Carroll & Hannan, 2000)	Pittsburg manufacturing organizations, 1873-1947	Longevity was found to be associated with the managerial capabilities of specific individuals and the reputation of the firm and its products.
Bruderl, Preisendorfer, and Ziegler (1992)	1,849 German new business foundings that took place in 1985/86	Founders interviewed in 1990. Founders' education and experience contributed to the survival of the business.
Cooper, Gimeno-Gascon, and Woo (1994)	1,053 new ventures	Determined that measures of general human capital influenced both survival and growth.
Hall (1994)	Twenty-eight small construction firms that had ceased trading in the previous five years matched to a sample of thirty firms that had survived.	Survival linked to the human capital embodied in the workforce.
Mitchell (1994)	327 medical sector companies that entered and exited the market between 1952 and 1990	Found that the effects of business sales and age on dissolutions and divestitures differ systematically by type of entry and type of exit in product markets.
Audretsch and Mahmood (1995)	12,251 new manufacturing establishments that started in 1976	Over the ten year period of analysis, determined that the structure of ownership and start-up size can substantially shape the likelihood of survival.
Carter, Williams, and Reynolds (1997)	203 U.S. retail firms between 1 and 6 years old at the time of the survey	Found a higher rate of discontinuance among firms owned by women.
Collins and Porras (cited by, de Geus, 1997b)	Eighteen firms that had been in existence sixty years or more.	Surviving firms found to have a strong sense of identity, sensitivity to the environment, and a lower priority on maximizing shareholder wealth.

Author(s)	Population	Research Findings
de Geus (1997b)	Thirty companies that were in business in the latter part of the 19th century and still had strong corporate identities in the early 1980s.	Corporate longevity correlated with four personality traits: (a) conservatism in financing, (b) sensitivity to the world around them, (c) an awareness of their identity, and (d) a tolerance for new ideas.
Gimeno, Folta, Cooper, and Woo (1997)	1,547 U.S. entrepreneurs of new businesses in existence in 1983 and still in existence in 1987	Firms with low performance thresholds may choose to continue despite comparatively low performance.
Hannah (1998)	The top 100 global industrial firms in 1995 as compared to 1912.	Found (a) that the United States was the preferred headquarters country for better than 40% of the firms in the top 100 in both 1912 and 1995 and (b) that the chances of survival in 1995 of the top 100 firms in 1912 ranged from 19% in the United States to 47% in the United Kingdom.
Kearns and Ruane (1998)	2,114 Irish manufacturing plants over the period 1986 to 1996	Concluded that research and development activity was an important factor in plant survival.
Thornhill and Amit (1998)	2,962 companies that started operation between 1983 and 1986 and were still in operation in 1993.	A positive relationship was found to exist between innovation and growth, as well as between environmental benevolence and growth.
Audretsch, Houweling, and Thurik (2000)	2,017 Dutch manufacturing firms tracked for 10 years	Concluded that the likelihood of firm survival is shaped by characteristics specific to the firm (age and size) as well as the industry environment.
Bonn (2000)	Thirty large Australian survivor firms that were in business in 1982 and still in business in 1993.	Found that size, corporate direction, research and development, and ownership were significantly related to the company survival, when survival was defined as (a) ranking in the top 100 companies and (b) operating under the same name and basic organizational structure for the years 1982 and 1993.
Gorg and Strobl (2000)	17, 789 manufacturing firms between 1973 and 1996	Found that the presence of multinationals increased the chance of survival among indigenous firms in high-tech industries.
Santarelli (2000)	182 new Italian financial intermediary firms between 1989/90 and 1994/95	Start-up size along with certain industry specific characteristics was found to be conducive to new firm survival.

Author(s)	Population	Research Findings
Segarra and Callejon (2000)	156,884 Spanish manufacturing firms between 1994 and 1998	Survival consistent with the findings of other researchers with respect to age, size, and type of industry.
Staber (2001)	1,213 knitwear enterprises in Baden-Wurttemberg and active for a least 1 year between 1960 and 1998	Larger firms and firms with more distance export markets were more likely to survive. Location in clusters of firms in the same industry increased failure rates; location in diversified clusters of firms in complementary industries, decreased failure rates.
Chen (2002)	U.S. petroleum refining plants between 1981 and 1986	Plant size, age, regulatory subsidies, technology use, and multi-plant coordination found to be key determinants of refinery life duration after deregulation.
Elston (2003)	719 German firms between 1970 and 1986	Bank influenced firms had higher survival rates than independent firms.
Cantner, Drebler, and Kruger (2004)	351 German automobile manufacturers in existence during the period 1886 to 1939	Determined that early entry and prior experience are associated with lower risk of exit.
Cottrell and Nault (2004)	U.S. firms supplying software products that were listed in the Software Catalog: Microcomputers between 1981 and 1986	Found that older firms, firms with products in fewer application categories, and firms that offered integrated products were more likely to survive.
Jain and Kini (2004)	3,837 IPO issuing firms that went public between 1980 and 1997	Demonstrated the impact of strategic investment decisions of issuing firms on post-IPO operating performance and survival.
Lerner and Khavul (2004)	170 firms that founded by new immigrants to Israel that received loans in 1995	Found that five years after receiving the loans, manufacturing firms, firms founded by women, firms with limited human capital were more likely to fail.
Vartia (2004)	121,124 observations of entry, exit, and survival of Finnish manufacturing plants between 1989 and 2000	Found that the financial characteristics of the firms owning the entering and exiting plants are important determinants of plan survival.
Banerjee, Kauffman, and Wang (2005)	115 publicly traded Internet firms between 1996 and 2003	Concluded that as firms grow, their survival is increasingly contingent on their financial capital and size.

Author(s)	**Population**	**Research Findings**
Dahl and Reichstein (2005)	4,456 observations of start-ups among all new Danish manufacturing entrants between 1984 and 1996	Organizational heritage was found to be important for the survival of new organizations.
Kauermann, Tutz, and Bruderl (2005)	1,123 firms founded in 1985/86	Over the five year period of analysis, determined that the effect of certain risk factors such as planning, age of the founder, and debt decreases with time.
Mulotte and Dussauge (2005)	84 aircraft firms from the Western World between 1944 and 2000	Determined that the entry choices at the time of entry, which are affected by pre-entry resources, are critical to post-entry success and survival.
Thompson (2005)	90 year plant level panel data set on the U.S. iron and steel shipbuilding industry between 1825 and 1914	Found that relevant pre-entry experience has large effects on survival.

Table 2.3 Cox Regression Models

Model Number	Model
1	$h(t) = h_o(t) \exp(\beta 1 \text{ Deposits}, \beta 2 \text{ Mines}, \beta 3 \text{ LogCA}, \beta 4 \text{ AgeMean})$
2	$h(t) = h_o(t) \exp(\beta 1 \text{ LogCA}, \beta 2 \text{ AgeMean}, \beta 3 \text{ RatioDP})$
3	$h(t) = h_o(t) \exp(\beta 1 \text{ LogCA}, \beta 2 \text{ AgeMean}, \beta 3 \text{ RatioMD})$

Table 2.4 Characteristics of the Cohort

Variable	Categories	% Fail (N[1])	% Merge (N)	% Survive (N)	P Value[2]
Deposits	0 deposits	77.6% (475)	18.6% (114)	3.8% (23)	
	1 to 10 deposits	69.0% (87)	21.4% (27)	9.5% (12)	0.013
Mines	0 mines	86.4% (491)	10.9% (62)	2.6% (15)	
	1 to 10 mines	42.0% (71)	46.7% (79)	11.2% (19)	
	> 10 mines	0% (0)	0% (0)	100% (2)	0.000
Current Assets	$0 to $99,999	90.5% (382)	6.2% (26)	3.3% (14)	
	$100,000 to $999,999	73.3% (44)	23.3% (14)	3.3% (2)	
	> $1,000,000	21.1% (28)	67.7% (90)	11.3% (15)	0.000
Age	< 10 years	81.1% (210)	15.1% (39)	3.9% (10)	
	11 to 25 years	72.3% (136)	23.4% (44)	4.3% (8)	
	> 25 years	59.2% (84)	28.9% (41)	12.0% (17)	0.000
	Total Number of Firms	564	141	36	

[1] N = Number [2] Pearson Chi-Square

Table 2.5 Means, Standard Deviations, and Pearson Correlations

Variable	N	Range	Mean	Standard Deviation	1	2	3	4	5	6
1. Deposits	738	0-5	0.22	0.55	--					
2. Mines	739	0-20	0.39	1.24	.145**	--				
3. Log Current Assets	613	0-18	12.1	2.4	.116**	.432**	--			
4. Age	589	<1 - 68	16.4 Years	13.8 Years	.097*	.230**	.314**	--		
5. Ratio of Deposits to Prospects	570	0-5	.01	.35	.869**	.021	.067	.103*	--	
6. Ratio of Mines to Deposits	125	0-20	.52	2.02	.007	.944**	.505**	.194*	-.024	--

** Correlation is significant at the 0.05 level of significance (two tailed test)*
*** Correlation is significant at the 0.01 level of significance (two tailed test)*

Table 2.6 Cox Regression Analyses

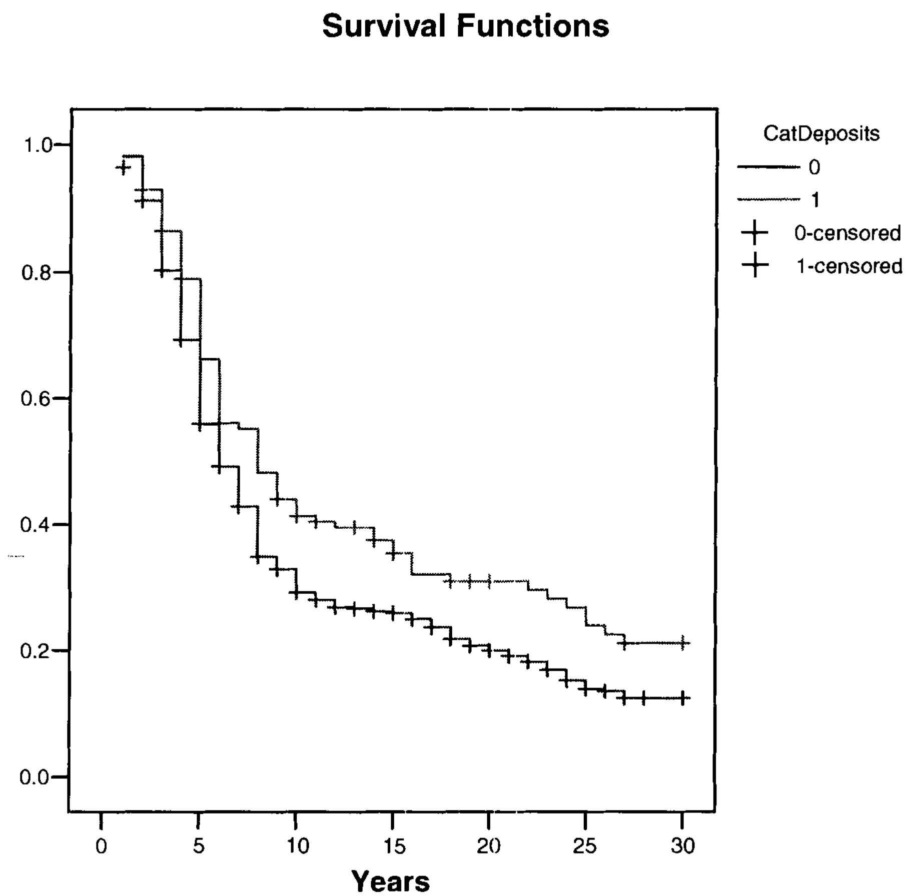
Variable	Model 1 (Fail)	Model 1 (Fail/Merge)	Model 2 (Fail)	Model 2 (Fail/Merge)	Model 3 (Fail)	Model 3 (Fail/Merge)
Deposits	-.101 (.094) [.904]	-.120 (.080) [.887]				
Mines	-.635*** (.128) [.530]	-.231*** (.063) [.794]				
LogCA	-.161*** (.026) [.852]	-0.041+ (.024) [.960]	-.180*** (.026) [.835]	-.094*** (.025) [.910]	-.293*** (.079) [.746]	-.133+ (.068) [.876]
AgeMean	-.007 (.004) [.993]	-.009* (.003) [.991]	-.011* (.005) [.989]	-.012** (.004) [.988]	.024* (.010) [1.025]	.008 (.010) [1.008]
RatioDP			-.040 (.155) [.961]	-.059 (.145) [.943]		
RatioMD					-1.420** (.532) [.242]	-.499* (.217) [.607]

The entries in the table are the regression coefficients (β) with standard errors in round brackets ( ). The corresponding hazard ratios (Expβ) are in square [ ] brackets.

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$

Figures

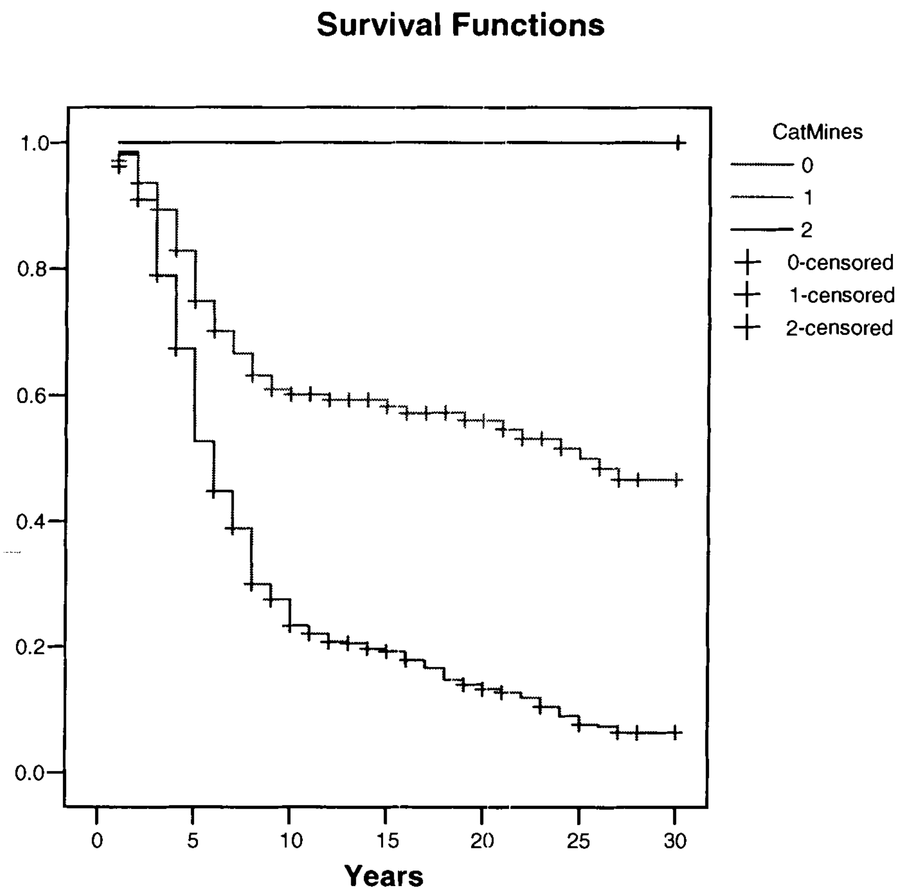
Figure 2.1 Survival Functions for Deposits (Failed Event)



Category 0 = 0
Category 1 = 1 or more Deposits

Log Rank Test Statistic Significance 0.0069

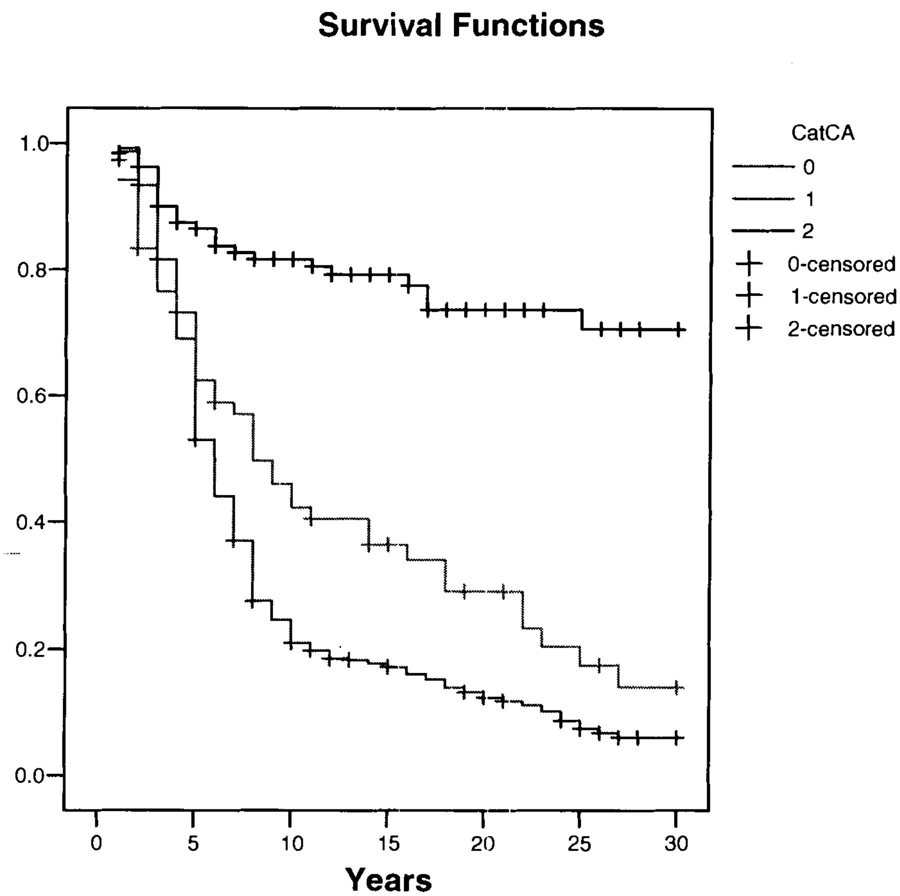
Figure 2.2 Survival Functions for Mines (Failed Event)



Category 0: 0 mines
Category 1: 1 to 10mines
Category 2: > 10 mines

Log Rank Test Statistic Significance 0.000

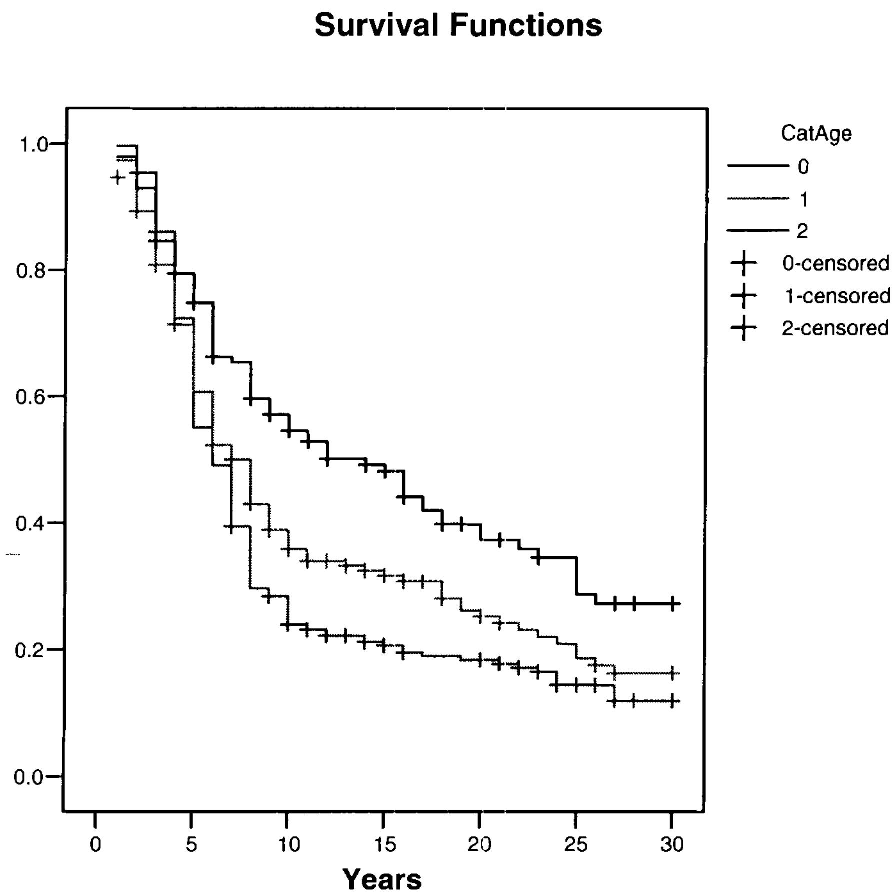
Figure 2.3 Survival Functions for Current Assets (Failed Event)



Category 0 = $0 - $99,999
Category 1 = $10,000 - $999,999
Category 2 = > $1,000,000

Log Rank Test Statistic Significance 0.000

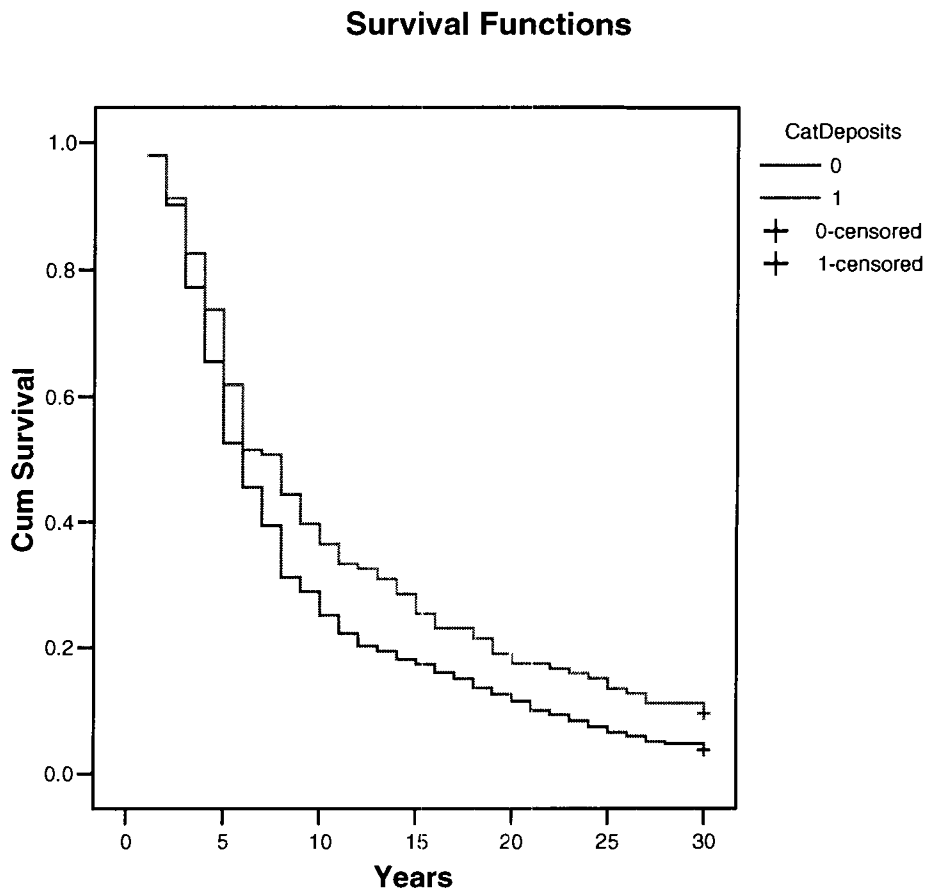
Figure 2.4 Survival Functions for Age (Failed Event)



Category 0 = < 10 years
Category 1 = 11 – 25 years
Category 2 = > 25 years

Log Rank Test Statistic Significance 0.000

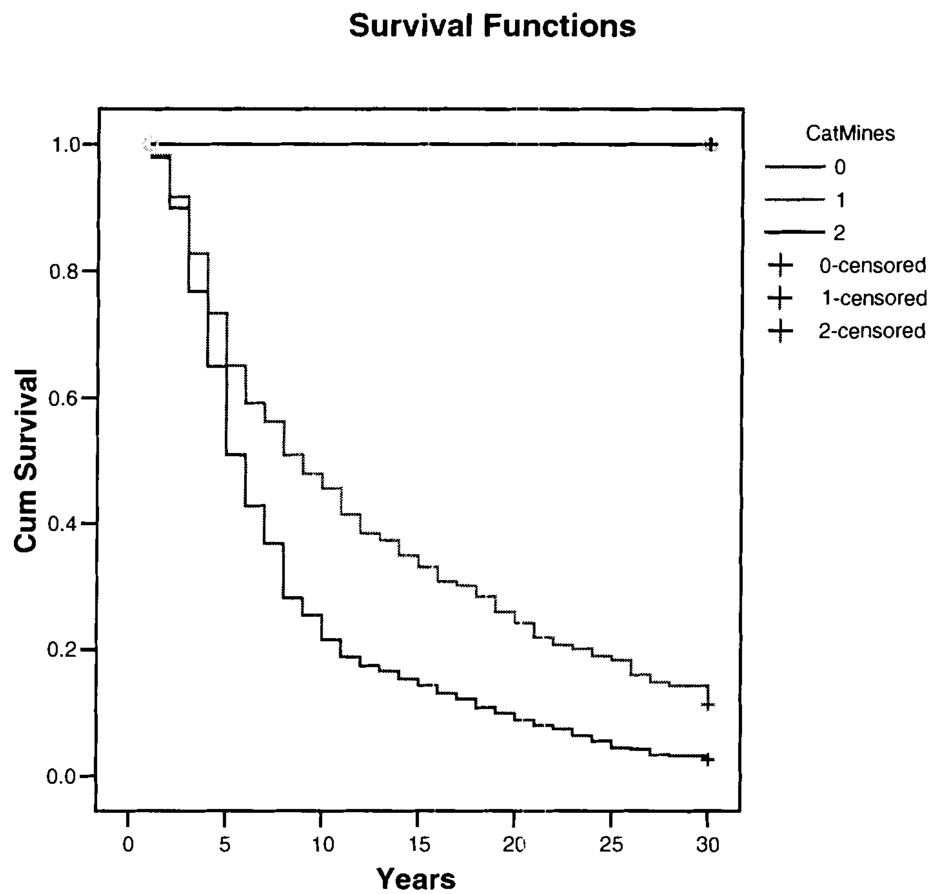
Figure 2.5 Survival Functions for Deposits (Failed/Merged Event)



Category 0 = 0
Category 1 = 1 or more Deposits

Log Rank Test Statistic Significance 0.0034

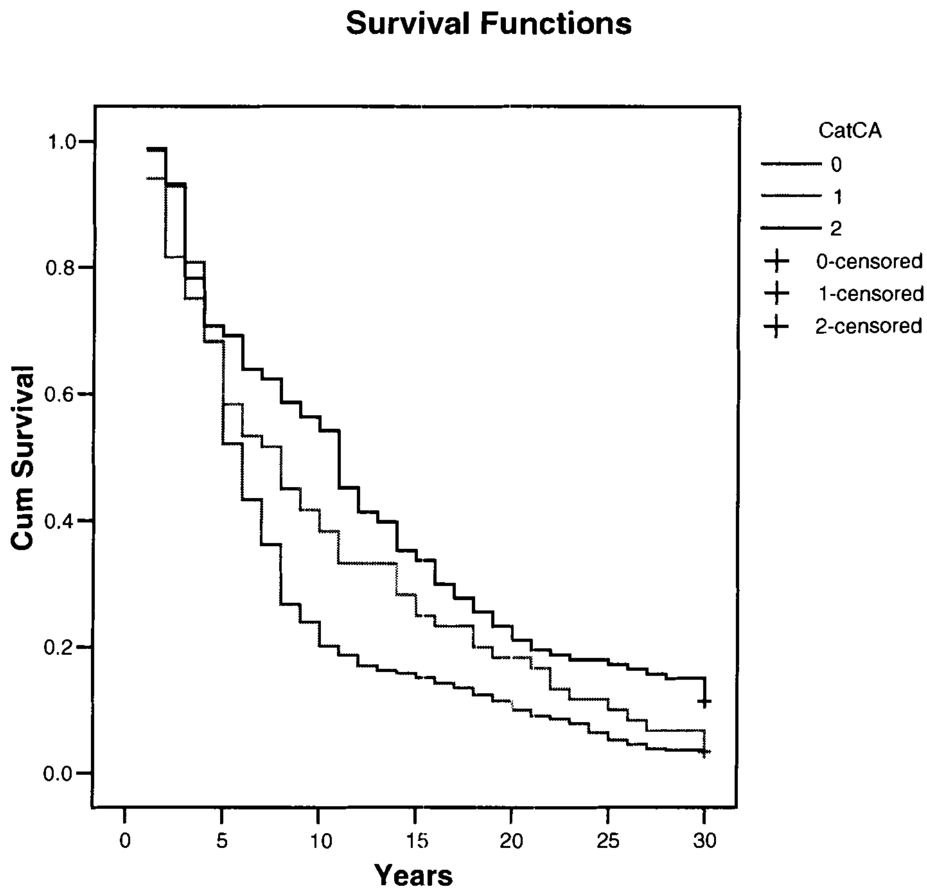
Figure 2.6 Survival Functions for Mines (Failed/Merged Event)



Category 0: 0 mines
Category 1: 1 to 10mines
Category 2: > 10 mines

Log Rank Test Statistic Significance 0.000

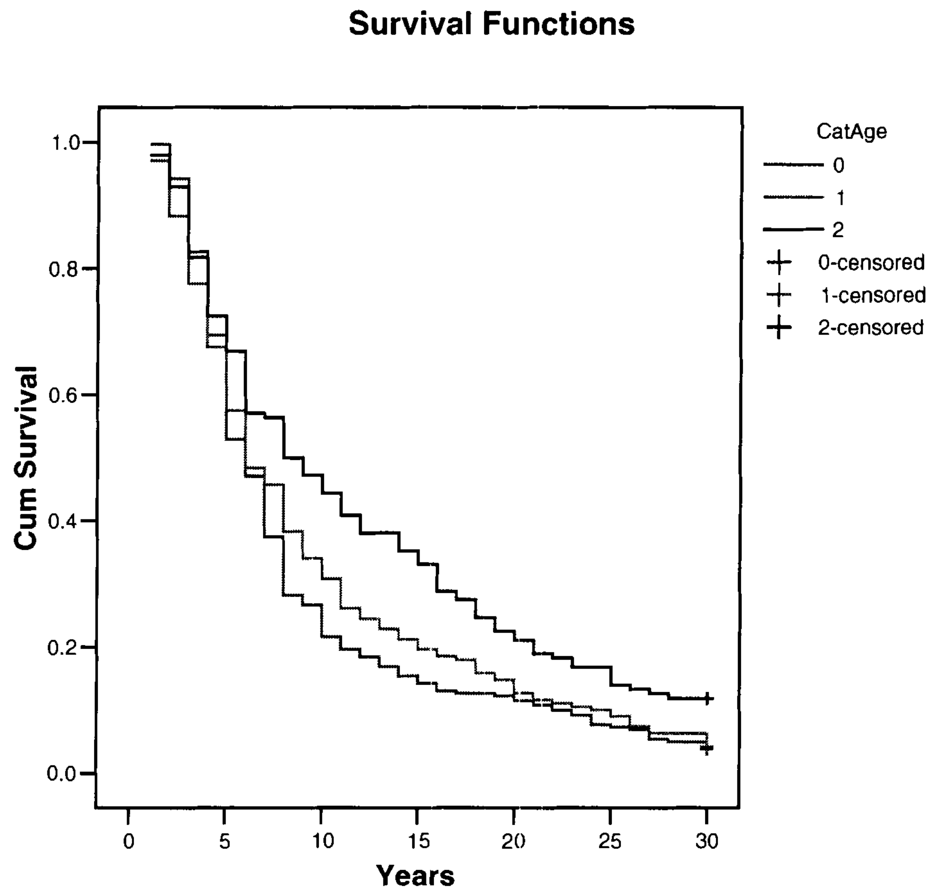
Figure 2.7 Survival Functions for Current Assets (Failed/Merged Event)



Category 0 = $0 - $99,999
Category 1 = $10,000 - $999,999
Category 2 = > $1,000,000

Log Rank Test Statistic Significance 0.000

Figure 2.8 Survival Functions for Age (Failed/Merged Event)



Category 0 = < 10 years
Category 1 = 11 – 25 years
Category 2 = > 25 years

Log Rank Test Statistic Significance 0.007

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3:
CANADA'S MINING INDUSTRY – THE STRATEGIC PERSPECTIVE

Abstract

This essay offers insights into the corporate strategic behaviour of the world's top ranking mining firms. The findings reported here demonstrate that within an industry expected to be homogeneous, a certain degree of heterogeneity can be discerned, and this heterogeneity appears to be associated with differences in firm performance, measured as the ratio of operating profit to total assets. Three strategic clusters were identified: one dominant cluster containing the majority of mining firms under consideration, and two non-dominant clusters, one of which held the majority of the firms with an above average operating profitability over the period 2002-2004. The essay provides a more detailed understanding of intra-industry heterogeneity and confirms the importance of using firm level data in strategic research.

Introduction

This essay had two objectives. The first was to examine the degree of corporate strategic heterogeneity in the mining industry, an industry where little strategic variety would be expected. The second was to examine the degree to which performance is related to the strategic position of the firm.

There are two schools of thought on how much strategic heterogeneity to expect among firms within the same industry: one school holds that strategy is generic and largely determined by the environment; the other, that strategy is unique and emanates from the skills or activities in which the firm excels (Aharoni, 1993). Proponents of the first school, which draws its insights from neoclassical economics, industrial organizational economics, institutional theory, and efficiency theory, argue that there is very little difference in the strategies of firms within the same industry because competition eliminates differences among competitors (Rumelt, Schendel, & Teece, 1994), and over time "... firms conform to many common influences and are interpenetrated by relationships that diffuse common knowledge and understandings" (Oliver, 1997, 706). Further, there are only a few basic patterns that businesses can select to achieve their strategic goals (Hambrick, 2000). Proponents of the second school, which draws its insights from organizational ecology, evolutionary ecology, and the resource-based view of the firm, argue that differences among competitors can be deliberate or random and can arise because of differing conceptual views, organizational processes, or levels of organizational learning (Rumelt et al., 1994).

With respect to the mining industry, proponents of the first school posit that the industry should demonstrate little strategic heterogeneity for a number of reasons. First, mining is a mature industry, and variety has been found to decline as an industry matures (Miles, Snow, & Sharfman, 1993). Second, the top ranking mining firms sell similar products in many of the same markets as their competitors, suggesting there ought not to be significant differences in the strategies and behaviours of similar firms in different countries (Lindell & Karagozoglu, 1997). Third, while mining assets can be depleted, the core activities of mining (drilling, blasting, mucking, hauling, crushing, milling, and refining) are stable. This stability puts mining on what McGahan (2004) has called the *creative change trajectory* where change occurs when core assets are under threat, but core activities, including relationships with customers and suppliers, are generally stable. And fourth, Seth and Thomas (1994) have argued that industries with relatively simple group structures and high concentration are characterized by relatively homogenous firms. While the organizational form of mining companies can be fairly complex because of the many jurisdictions in which they operate, mining companies at the level of the business unit are relatively straightforward. For example, Alcoa Inc., the largest mining company in the world, has five major business segments: engineered products, flat rolled products, primary metals, consumer packaging, and alumina/chemicals). And the mining industry is becoming increasingly more concentrated (PriceWaterhouseCoopers, 2005), the second criterion of Seth and Thomas (1994) for an industry with little heterogeneity.

Proponents of the alternative view suggest that the mining industry should demonstrate some degree of heterogeneity because the resource characteristics of each of the firms is different. One potential source of strategic heterogeneity is home country, for country effects have been found useful in explaining variability in firm behaviour and performance displayed by multi-national firms (Makino, Isobe, & Chan, 2004). The possibility that country effects could result in some degree of strategic heterogeneity arises from the fact that eleven countries are represented among the top ranking mining firms in the world, yet one country, Canada, has more top ranking mining firms than any other country and has almost double the number of firms of its two closest rivals, the United States and Australia. Canada's mining firms are also recognized internationally for their expertise in financing, engineering, geology, mine management, and operations (MacDonald, 2002).

Intra-industry firm heterogeneity studies have not attracted the interest of many researchers. One possible explanation for this may lie in Capasso, Dagnino, and Lanza's (2005) observation that the concept of strategic heterogeneity is frequently overlooked or assumed to be a given in strategic research. Some researchers have considered intra-industry heterogeneity from the perspective of firms in a single industry but only in the context of one country. For example, Hatten and Schendel (Hatten & Schendel, 1977) have studied market conduct as a source of intra-industry heterogeneity among firms in the American brewing industry; Insead and Collins (2001), the evolution of intra-industry firm heterogeneity in the American telephone industry; Ferrier and Lee (2002), the degree to which a firm's sequence of competitive actions influenced stock market returns among a sample of U.S. market leading firms; and D'Este (2005), the extent to which a firm's knowledge base affected intra-industry heterogeneity among Spanish pharmaceutical firms. The present research adds to this body of literature as it examines strategic heterogeneity among the major firms in a single industry from a multi-country perspective.

The next section of the essay reviews the literature on strategic variety. The essay is then organized into five sections: (a) the development of the research questions, (b) a description of the data and methodology; (c) a report of the results, (d) a discussion of the results, and (e) conclusions.

Review of the Literature

The basic theoretical underpinnings of the two dominant positions on strategic variety and prior studies that have considered the relationship between strategic variability and performance are examined first. The section concludes with a review of the arguments that have been advanced for the differential effects of country on performance.

Strategic Homogeneity

Four theoretical explanations suggesting why the strategic behaviours of firms should be the same have been advanced. The first is drawn from neoclassical economics where homogeneity among firms in all aspects of production, except for scale, is assumed (Seth & Thomas, 1994). Neoclassical economists perceive of a world where (a) there is perfect information, (b) there are large numbers of buyers and sellers, (c) goods bought and sold in a given market are identical in all aspects including quality, (d) there are no barriers to entry or exit, (e) there are no economies of scale, and (f) economic agents are motivated by profit maximization (Institute of Development Studies, 2000)). Given this set of assumptions about the environment in which the firm operates, the only choice left to the firm is to set an appropriate output quantity based on market price (Dobbin & Baum, 2005).

Industrial organization theory provides a second explanation. The basic tenet of this theory is that the structure of an industry dictates the conduct of the industry's buyers and sellers, which in turn determines the economic performance of the industry. Known as the S-C-P paradigm, the theory proposes that firms operating within the same market structure and facing the same basic conditions of supply and demand should realize the same economic results. Under these conditions, each firm when faced with the same set of circumstances makes an independent decision that is similar to that of other firms (Seth & Thomas, 1994).

Institutional theory suggests a third explanation. DiMaggio and Powell (1983) have argued that the interconnectedness of organizations facing similar environmental conditions results in the organizations becoming more similar over time in terms of their organizational structures, practices, and strategic behaviours, a phenomenon known as organizational isomorphism. Most industries are characterized by ambiguity and uncertainty, two states which lead to hesitancy regarding the appropriate strategic response. As a consequence, organizations create norms of strategic behaviours, which tend to diffuse across an industry as (a) the strategies of successful firms are imitated by less successful firms, and (b) organizations learn about the norms through industry associations and their network of relationships (Deephouse, 1996). Firms that choose to adopt strategies which are radically different from those of their competitors are subject to legitimacy challenges which restrict their ability to acquire resources (Deephouse, 1999), a circumstance that reinforces the need to conform.

And finally, strategic conformity can be explained using efficiency theory; that is, efficient strategies tend to diffuse across organizations (Dobbin & Baum, 2005). For the past two decades, according to Porter (1996), firms have been continuously benchmarking their activities against the activities of their competitors and adopting the technologies and management techniques of their rivals to improve operational effectiveness. The more firms benchmark each other, the more alike they become, the result being strategic convergence.

The assumptions of strategic homogeneity theories have long been challenged by the presence of strategic heterogeneity among firms within the same industry (Houthoofd & Heene, 2002). To accommodate this challenge, the concept of strategic groups emerged (Parnall, 2002).[25] Strategic groups are viewed as groups of firms within an industry pursuing similar strategies and having similar resources (Hatten & Hatten, 1987). While individual firms may differ in their strategies, such differences are not significant enough to prevent sorting the firms into homogenous groups (Thomas & Venkatraman, 1988). In addition, the strategies themselves are fairly generic.

Strategic Heterogeneity

Three theoretical explanations, drawn from the fields of organizational ecology, evolutionary economics, and the resource-based view of the firm, have been suggested for why the strategic behaviours of firms might be different (Durand, 2001).

[25] The term was introduced by Michael Hunt in the 1970s and subsequently popularized by Michael Porter in the 1980s (Hatten & Hatten, 1987).

Organizational ecology theory, the first of these explanations, is built on two concepts: a population and a niche. A population is a collection of organizations with a common form; a niche is a collection of resources that can sustain a population (Geroski, 2001). Based on the characteristics they hold in common, organizations that share a common form share a similar set of survival risks and a similar set of strategic patterns (Freeman, 1995). Further, an organization exists in a resource space, or niche, where securing the resources needed to survive is a fundamental strategic issue. Firms that choose to be different by pursuing a niche strategy different from that of their competitors will face less competition for resources (Deephouse, 1999). The organizational heterogeneity that emerges reflects the fact that the environment favours some strategies and some resource allocations over others (Cockburn, Henderson, & Stern, 2000).

In evolutionary economics theory, strategic variability among firms is to be expected. Organizational routines[26], especially those associated with the ability to generate and gain from innovation, differentiate one firm from another (Nelson, 1994). These differences in routines are a result of the diverse decision-making strategies employed by the firm over time and are a source of durable, inimitable, differences among firms (Nelson, 1991). When a new technology or innovation emerges, individual firms develop different strategies with respect to the technology, and some of these strategies will prove to be more acceptable to the marketplace than others (Nelson, 1991). The organizational heterogeneity that emerges reflects the fact that the marketplace selects certain strategies, companies, and new technologies over others (Nelson, 1994).

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[26] Organizational routines are the processes used by firms as part of their normal business activities (Nelson, 1991).

The basic premise of the resource-based view of the firm is that the assets of the firm which are valuable, rare, inimitable, and non-substitutable (Barney, 1991) and for which the firm is organized to exploit (Hitt, Ireland, Hoskisson, & Sheppard, 2002) create a uniqueness that allows the firm to appropriate rents inaccessible to their competitors (Mahoney & Pandian, 1992). This view of the firm rests on two assumptions: one, firms within an industry may possess strategically different skills and capabilities, and two, these differences can persist (Rumelt et al., 1994). Firms with strategically different skills and capabilities can be expected to exploit these advantages by implementing firm specific strategies that differ from those of their rivals.

Strategic heterogeneity theorists also make use of the concept of strategic groups, but unlike the industrial organization theorists who group firms that resemble each other on the basis of structures, practices, and behaviours, strategic heterogeneity theorists group firms with similar resources and competencies (Houthoofd & Heene, 2002). However, not all theorists are convinced that strategic groups actually exist (Houthoofd & Heene, 2002). Resource-based theorists, for example, consider each firm's control over resources and strategy development to be unique and, therefore, argue that strategic groups cannot exist (Parnall, 2002).

In summary, each of the three perspectives on strategic heterogeneity focuses on uniqueness among firms. For organizational ecologists, uniqueness arises from a niche strategy that protects a firm against selection; for evolutionary economists, innovation is the means by which firms create uniqueness; and for the resource-based view of the firm theorists, the idiosyncratic capabilities and competencies of the firm create uniqueness.

Strategic Variety and Performance

The precise relationship among strategic differentiation, competition, and resulting performance has not been conclusively demonstrated (Deephouse, 1999). Miles, Snow, and Sharfman (Miles et al., 1993) found in their analysis of 12 industries that those industries with the greatest strategic variability were the most profitable. Cool and Dierickx (Cool & Dierickx, 1993) found that over time as the strategies pursued by firms within the same industry became more diverse, the average profitability of the entire industry fell. Gimeno and Woo (Gimeno & Woo, 1996) in their study of the airline industry found that rivalry increased and financial performance (measured as revenue per passenger mile) decreased when firms pursued similar strategies. Miller and Chen (1995) and Chen and Hambrick (1995) noted that non-conformity was associated with declines in performance. Dooley, Fowler, Miller (1996) found in their study of 61 manufacturing industries that very high levels of either heterogeneity or homogeneity are more likely to be associated with industry profitability. However, Deephouse (1999) in his study of commercial banks showed that moderately differentiated firms perform better than either highly conforming or highly differentiated firms. Gonzalez-Fidalgo and Ventura-Victoria (Gonzalez-Fidalgo & Venutra-Victoria, 2005) surveyed a sample of Spanish manufacturing industries and found, like Dooley, Fowler et al. (1996), that industries benefited from either high strategic homogeneity or high strategic heterogeneity.

When the analysis of performance differences moves from the level of the industry to that of the strategic group, strategic heterogeneity among the member firms gives rise to performance differences, even though by definition all of the firms are pursuing similar strategies (McNamara, Deephouse, & Luce, 2002). McNamara, Deephouse, and Luce (2002) in their study of strategic groups within the commercial banking industry found that within a group, the secondary firms (firms that are loosely aligned with one another) outperform both the primary firms (firms that are tightly aligned with one another), as well as the solitary firms (firms that are pursuing unique strategies). This recent work is in keeping with the findings of earlier researchers (Lawless, Bergh, & Wilsted, 1989) (Cool & Schendel, 1988) who also noted within group performance differences. Lawless, Bergh, and Wilsted (1989) found that the relationship between strategic group membership and performance among manufacturing firms was moderated by the characteristics of the individual firms; Cool and Schendel (1988) showed that in the U.S. pharmaceutical industry, historical differences among groups members may result in performance differences.

This review suggests that at the level of the industry, high or low levels of strategic heterogeneity may give rise to higher levels of performance; whereas, at the level of the firm, strategic heterogeneity among firms gives rise to performance differences.

Country Effects

Makino, Isobe, and Chan (2004) have identified two theoretical explanations for how differences in country attributes could influence the performance of an industry. The first explanation is drawn from trade theory, which assumes that the factors of production and the associated prices vary from country to country, as does the intensity with which these factors are used (Makino et al., 2004). According to the theory, a country with an abundance of one or more of the factors of production and an ability to use a factor or factors intensively can produce goods at a lower cost of production relative to other less well endowed countries. In the same vein, it has been suggested that the munificence of home country environments differs to such an extent that firms from different countries face dissimilar opportunities and constraints (Wan, 2005). Firms from countries which have abundant resources and well established institutions have an advantage over competitors in countries with fewer resources and less well established institutions, and these advantages can be leveraged in international markets (Wan, 2005).

The second explanation is based on Porter's (1990) theory on the competitive advantage of nations. Porter (1990) argues that countries differ not only in their inherited factors of production but also in their productivity because countries have differing capabilities with respect to technology and innovation. Firms based in countries with a greater capacity for supporting technological development and innovation at the firm level have an advantage over their foreign rivals in both domestic and foreign markets (Makino et al., 2004).

Explanations offered by other researchers include (a) home country bias in demand and sources of capital (Hawawini, Subramanian, & Verdin, 2004); and (b) differences in national value systems (Hofstede, 1985), (Porter, 1990), in corporate governance systems (Leighton & Garven, 1996), and in business cycles (Lessard, 1976), (Roll, 1992).

The empirical support for country effects has been mixed as two recent studies demonstrate: Brouthers's (1998) study of 167 American, European, and Japanese firms; and Hawawini, Subramanian, and Verdin's (2004) study of over 1,300 firms in four countries. Brouther (1998) found that country-specific variables were significantly related to cross-national differences in the profitability of multi-national corporations;

whereas, Hawawini et al. (2004) found the importance of country effects, including the comparative advantage effect, to be low. Hawawini et al (2004) also found that global industry effects were becoming increasingly more important than country effects, suggesting that a firm's national origin as a source of competitive advantage will have less and less relevance. Makino, Isobe, and Chan's (2004) study of performance variability among 5,183 foreign affiliates of over 600 Japanese multinational corporations, representing 159 industries and 79 host countries, showed that country effects were as strong as industry effects. These researchers take the view that national contextual factors influence firm behaviour and economic performance (Makino et al., 2004).

Research Questions

The mining industry presents an interesting opportunity to examine strategic heterogeneity, that is, the degree to which a firm's strategy matches or deviates from the strategies of its competitors. It is an industry where little heterogeneity would be expected given the characteristics of the industry: standardized technology, slow growth, little or no product differentiation, and international exchange-based pricing for many of its products. Dye's (2002) contention that firms within an industry are not usually homogenous and that patterns of heterogeneity reflecting persistently different strategies can be observed in most industries suggested the first two research questions.

1. *Can patterns of strategic heterogeneity be observed among the world's top ranking mining firms?*

2. *Are differences in strategic choice reflected in differential performance?*

The presence of seven mining firms from Canada among the world's top ranking mining firms suggested the third question.

3. *Are differences in home country reflected in differential performance?*

The Data and the Methodology

Data Sources

Company websites, annual reports, press releases, and U.S. Security and Exchange Commission (SEC) filings were used to obtain data on the mining companies examined in this study. Other researchers have used company annual reports as a data source, recognizing that company annual reports and SEC filings, in spite of their known limitations, are often the only consistent source of comparable data (Bansal, 2005), (Ferrier, 2001), (Olusoga, Mokwa, & Noble, 1995). All of the firms included in the study had published annual reports, and over half had SEC filings. The Hoovers website (www.hoovers.com) had comparable financial information for all of the firms.

Selection of Mining Firms

A preliminary list of large mining firms was compiled from a report produced by PriceWaterhouseCoopers on the largest mining companies in the world (2005) and from a list of attendees at BMO Nesbitt Burns' 2005 Global Resources Conference, attendees representing the world's leading mining companies (BMO Nesbitt Burns, 2005). In order to be included in the study, the firm had to have over US$1 billion in revenues in 2003 (as reported on the Hoovers' website), have what is known as 'hard rock' mining[27] operations, and have mineral/metal interests. Twenty-six firms met these criteria (see Table 3.1). Fourteen of the firms were from the Americas (7 were Canadian), 4 from Europe and Africa, and 8 from Asia and the Pacific. Eleven of the firms were predominantly base metal producers, 6 were predominantly precious metal producers, 2 were base metal and precious metal producers, 6 were base metal producers with aluminum interests, and one was a diamond producer.[28] Two of the firms were state owned. These 26 firms represented over 80% of the market capitalization for mining in 2003.

Methodology

Characterizing the Strategies

The most common measures of corporate strategy are market diversification, product diversification, firm size, research and development intensity, and capital intensity (Lee & Habte-Gioris, 2004). Four of these measures were selected for this study. The first two, geographic scope and product scope, were derived from measures used by other researchers, for example, (Denis, Denis, & Yost, 2002), (Stabell & Fjeldstad, 1998), (Hitt, Hoskisson, & Kim.H., 1997), (Dooley et al., 1996), (Olusoga et al., 1995), (Miles et al., 1993), (Capon, Farley, & Hoenig, 1990). Geographic scope is

[27] Hard rock mining refers to the extraction of minerals or metals from the earth by means of open pits or underground rooms or stopes (Answers.Com, 2005).

[28] Because metallic elements are often found together in nature, for example, silver and lead are often found together as are copper and gold, this characteristic complicates classifying firms as either a base metal or a precious metal producer based on the composition of their ore deposits. If the firm described itself or was known as a base metal producer (Teck Cominco Ltd. for example), it was classified as such even if it also produced precious metals. Similarly, if a firm described itself or was known as a precious metal producer (Barrick Gold Corporation, for example), it was classified as such even if it also had some base metal production. Freeport McMoran Copper & Gold Inc., a firm which produced both a base metal and a precious metal, was classified as a base metal producer as the bulk of its revenue came from copper.

usually defined as the percentage of sales per region. An alternative measure of geographic scope, the number of countries in which the firms had business interests per region (i.e., where the firm had its producing assets as well as its exploration assets), was included along with the more traditional measure, because geographic sales data only capture the destination of the product not the full geographic scope of a mining firm's activities.[29] Product scope was defined as the percentage of sales per line of business.[30] These three measures were based on 2003 firm data and were calculated as Herfindahl Indices[31]. The calculations were as follows:

(a) Geographic scope

Measure 1:

Σ (number of countries in region 1 / total country interests)^2 + (number of countries in region 2 / total country interests)^2 ....

Alternative Measure 2:

Σ (sales in region 1 / total sales)^2 + (sales in region 2 / total sales)^2 ....

(b) Product scope

Σ (sales in line of business 1 / total sales)^2 + (sales in line of business 2 / total sales)^2 ....

In addition to the measures of corporate strategy (i.e., geographic and product scope), two ratios similar to those used by other researchers as measures of strategic

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[29] The use of a counting methodology, used here in the count of countries, is well established in the literature (Capon et al., 1990). The classification by region was based on a classification used by Rugman and Verbeke in their work on the regional and global strategies of multinational enterprises (2004).

[30] Line of business information has been used by other researchers (Acar & Bhatnagar, 2003) as a measure of the diversity of the firm.

[31] The Herfindahl index, a measure of industry concentration calculated as the sum of the squares of the market shares of each individual firm, has been used by other researchers as a weighted measure of diversification (Wan & Hoskisson, 2003).

variety (Dooley et al., 1996) were used: (a) exploration plus research and development expense to sales, and (b) the dollar value of plant, property, and equipment to employee. The first ratio (Exploration/R&D Intensity) was suggested by the work of Porter (1979), who argued that expenditures on research and development as a percentage of sales were a competitive decision variable, reflecting differences in the competitive strategies of firms. This ratio combined exploration expenditures (mining assets are depleting assets that must be replaced, and the level of exploration expenditures is a way of measuring the firm's investment in this activity) with research and development expenditures because some of the firms reported these two expenditures as one, and the two expenditures were highly correlated. Of the 26 firms, 6 did not report exploration or research and development expenditures as a separate line item in their financial statements; for those that did, 11 reported one of the elements, and 9 reported both. Capital intensity, the second ratio, is considered a key competitive factor and one that can be used to distinguish between strategic groups (Miles et al., 1993). The two ratios were based on 2003 data.

Measure of Performance

Accounting profitability, calculated as the ratio of operating income, or earnings before interest and taxes (EBIT), to total assets, was chosen as the measure of performance for several reasons: (a) it represents a return on invested capital, (b) it captures operating performance, revenue growth, and market share, and (c) it reflects current and historic management capabilities (McGahan, 1999). Operating profit (the earning measure used in calculating the accounting profitability) is also considered appropriate in cross-country studies because of the differing tax rules and capital structures of firms from different countries (Wan & Hoskisson, 2003). Data for the years 2002 through 2004 were used to calculate a three year average operating profit. The 2002 results reflected the position of the firms prior to the year in which the strategy observations were made; the 2004 results, the position of the firms one year after the observations were made. A three year average was used in recognition of the fact that the strategic decisions reflected in the performance of the firms in the current period were made in the past.

Data Analyses

Several methods were used to analyze the data. Descriptive statistics (minimum, maximum, mean, and standard deviation) and Pearson correlations were calculated for the strategic measures. Cluster analysis (using a within group clustering technique) was used to identify homogeneous subgroups, and scatter plots were produced to identify the outlier firms (defined here as plus or minus one standard deviation of the mean). Cluster analysis, in spite of its limitations,[32] is a technique that has been used by strategy researchers since the late 1970s for sorting observations into groups (Ketchen Jr. & Shook, 1996). To address certain of the limitations associated with the technique, the variables included in the analysis were established measures of strategy; they were standardized as part of the analysis, and none was highly correlated. An analysis of the outlier firms was included, for it has been argued by Aharoni (1993) that much can be learned from an examination of the particularly successful or unsuccessful organizations in a population of firms.

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[32] Cluster analysis does not have a test statistic that can be used to confirm between group differences.

Results

The first research question was, Can patterns of heterogeneity be observed among the world's top ranking mining firms? Table 3.2[33] characterizes the cohort of firms based on the measures of strategy identified above. For geographic scope, the mean on the country measure of geographic scope was 0.43 (standard deviation 0.23), with a range from 0.22 to 1.00. (A score of 0.22 represents high geographic diversification, whereas a score of 1.0 represents no diversification.) Seventeen (65%) of the firms had a Herfindahl index of between 0.22 and 0.39. In order to obtain a score in this range, the firm had to be active in three or more regions of the world. The five top ranking firms (with scores in the 0.22 to 0.27 range) had a presence in countries in all five regions. Three firms were active in just one country – two state owned firms, i.e., the Chilean firm, Codelco, and the Russian, Alrosa; and the South African firm, Implats. The mean on the sales measure of geographic scope was 0.46 (standard deviation 0.16), with a range from 0.28 to 0.85. Based on this measure, fewer firms (11 or 45%) had a Herfindahl index of between 0.22 and 0.39 (the dominant category on the country measure of geographic scope), suggesting sales scope was less diverse than country scope.

For product scope, the mean was 0.55 (standard deviation 0.33), with a range from 0.15 to 1.00. (A score of 0.15 represents high product diversification; a score of 1.0, no diversification.) Nine firms had scores in the range of 0.1 to 0.2, suggesting they were well diversified by line of business, and eight firms had scores in the range of 0.9 to 1.00, suggesting limited diversification. Based on line of business information and a four

[33] See Table 3.3 for a list of the data sources by company.

category diversification schema, that is, (a) dominant (70% or more of their revenues from mining, milling, and refining), (b) related diversification, (c) unrelated diversification, or (d) mixed diversification, fourteen of the firms were dominant firms, 7 were related diversified firms, and 5 were mixed diversified.[34] There were also three unique business lines: merchant banking (Newmont), construction materials and housing (Sumitomo), and engineering services (Mitsui).

For the combined exploration/research and development intensity measure, the mean was 0.019 (standard deviation .019), indicating the top ranking mining firms expended approximately 2% of their sales revenue on exploration/research and development activities in 2003. This result is below the mean of 3.3% for non-manufacturing firms (Ho & Ong, 2005). The range of expenditure was from < 1% to 8%. The two Canadian gold producers (Barrick and Placer) were notable exceptions; these firms spent between 7% and 8% of their revenues on exploration/research and development activities in 2003. Although it might be expected that a higher percentage of sales would involve activities that included exploration, this behaviour was not observed, possibly reflecting the fact that the major mining firms depend on the junior mining firms to do much of the industry's exploration work (MacDonald, 2002). Some firms also use their joint venture partners for exploration, with Lonmin being one example. And PriceWaterhouseCoopers (2005) has noted that the ratio of exploration to acquisition spend has been declining among the major mining companies because acquired reserves are more certain than those that have yet to be found.

For the capital intensity measure, the mean was 0.336 (standard deviation 0.242), indicating the top ranking mining firms invested approximately $336,000 US per

[34] Diversification strategy classification adapted from that of Hill and Ireland (1985).

employee in plant, property, and equipment in 2003. This result is comparable to that obtained by Dooley, Fowler, and Miller (1996) for manufacturing. The range of expenditure per employee ranged from a low of \$31,000 US for the South African platinum producer, Implats, to a high of \$975,000 US for the Australian base metal producer, WMC. WMC's investment in plant, property, and equipment per employee was more than double the amount of the other mining firms. More than half of WMC's workforce in 2003 was made up of contract employees (WMC Resources Ltd., 2003), and if these employees are included in the calculation, WMC's average capital investment per employee in plant property and equipment is more in keeping with that of other firms.

The strongest relationships were between (a) country geographic scope and product scope (r = 0.422) and (b) product scope and exploration/research and development expense (r = 0.484). The relationship between country geographic scope and product scope is understandable because the geology often dictates where mineral/metals are found. For example, commercially viable gold deposits have been found in a limited number of countries (South Africa, the United States, Australia, Brazil, Canada, China and Russia) (Mineral Information Institute, 2005). The relationship between product scope and exploration/research and development expense is also understandable as certain product lines (e.g., smelting and refining) are more amenable to the application of technology than others, and the reserves for certain commodities (e.g., platinum) are insufficient to meet future demand.

Figure 3.1 presents a hierarchical cluster analysis of the firms based on country geographic scope, product scope, exploration/research and development intensity, and capital intensity. Three clusters can be identified from the dendogram. The first cluster of 15 firms can be characterized as firms with moderate to high geographic and product scope, as well as average capital and exploration/research and development intensity. The second cluster of 5 firms can be characterized as firms with low product and/or low country geographic scope, average exploration/research and development intensity, and average to below average capital intensity. The third cluster of 2 firms can be characterized as firms with high country geographic scope, low product scope, average capital intensity, and high exploration/research and development intensity. Four firms were excluded from the cluster analysis because of missing data points. However, based on their geographic and product scope scores, they do fit within the three clusters: Dowa, Grupo, and Xstrata in cluster one; Norilsk in cluster two. The results of the cluster analysis provide evidence of strategic homogeneity as well as strategic heterogeneity: homogeneity, in that most of the firms appear to be pursuing a common strategy, and heterogeneity, in that there are some firms that are not. The cluster analysis using the alternative measure of geographic scope (i.e., the sales measure) produced similar results.

Figure 3.2 plots country geographic scope against product scope for each of the firms. All but one of the firms, the state owned Russian diamond producer, Alrosa, was within one standard deviation of the mean for both geographic scope and product scope. Two firms (Codelco and Implats) that were within one standard deviation of the mean for product scope were outside one standard deviation for geographic scope. Twelve firms that were within one standard deviation of the mean for geographic scope were outside one standard deviation for product scope. Within this group of twelve firms, five (Alcan, Alcoa, Anglo, BHP, and Rio) were highly diversified in that they had more than six lines of business; whereas, seven firms (Barrick, Freeport, Inco, Lonmin, Newmont, Norilsk, Placer) were not highly diversified in that they had no more than two lines of business, and one line represented more than 90% of their sales revenue.

With 25 of the 26 firms within one standard deviation of each of the means, there would appear to be a high degree of strategic conformity with respect to diversification. That some of the firms were able to position themselves differently on one of the dimensions supports the cluster analysis findings, that is, both homogeneity and heterogeneity were observed. The firms that chose to position themselves differently occupied an outlier position of (a) limited geographic diversification (Alrosa, Codelco, and Implats), (b) high product diversification (Alcoa, Alcan, Anglo, BHP, and Rio), or (c) low product diversification (Alrosa, Barrick, Freeport McMoran, Inco, Lonmin, Newmont, Norilsk, and Placer). The high product diversification firms were all base metal producers with other mineral/metal interests. The low product diversification firms were either precious metal producers or major nickel producers.

Figure 3.3 plots capital intensity against exploration/research and development intensity. All of the firms for which there were data were within one standard deviation of both means. Two firms, Barrick and Placer, were outside one standard deviation for exploration/research and development intensity; six firms were outside one standard deviation for capital intensity. With all of the firms within one standard deviation of both means, there would appear to be a high degree of conformity with respect to strategic investments. That some of the firms were able to position themselves differently on one of the dimensions supports the results of the cluster analysis where both homogeneity and heterogeneity were observed. The firms that chose to position themselves differently occupied an outlier position of (a) high investment in exploration and research and development activities (Barrick and Placer) (b) low investment in property, plant, and equipment per employee (Lonmin and Implats), or (c) high investment in property, plant, and equipment per employee (Inco, Sumitomo, Rio, and WMC).

Based on these observations, the answer to the first research question would appear to be *yes*. A high degree of commonality of strategic approach, coupled with distinctive patterns of heterogeneity, was observed. This observation supports the findings of other researchers that firms within an industry are not usually homogenous (Dye, 2002) and that firms tend to cluster in groups based on a common strategic approach (Han, 2005). Interestingly, the heterogeneous firms cluster at the extremes.

The second research question was, Are differences in strategic choice reflected in differential performance? Figure 3.4 plots the three year average operating profit against product scope for each of the firms.[35] The mean average operating profit for the period 2002-2004 was 10% (standard deviation 7%), with a range from 3% to 32%. All but one of the firms, the British platinum producer, Lonmin, were within one standard deviation of the mean for both average operating profit and product scope. Three firms (Codelco, Implats, and CVRD) that were within one standard deviation for product scope were outside one standard deviation for operating profit. The strategic position for Lonmin, Codelco, and Implats' was that of limited geographic and product diversification. CVRD's strategic position was that of moderate country geographic and product diversification, but it produces a commodity (iron ore) for which the Company has few competitors.

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[35] Product scope was chosen for this comparison because all but three of the firms, two of which are state owned, were within one standard deviation of the mean for geographic scope.

Eight firms in total were able to generate an operating profit of more than 10% (the mean for the group). Six of the firms occupied outlier strategic positions, that is, (a) low country geographic diversification (Implats), (b) low product diversification (Freeport, Lonmin, and Norilsk), or (c) low geographic and low product diversification (Alrosa and Codelco), and two did not (BHP and CVRD). The six outlier firms were all in the second strategic cluster, suggesting that the strategic heterogeneity afforded by an outlier position might be a factor in their above average performance. The two remaining firms were in the first strategic cluster with most of the other firms. That two firms out of fifteen in the same strategic position were able to achieve above average performance suggests some factor other than strategic position was contributing to their success. BHP, along with four other firms (Alcoa, Alcan, Anglo, and Rio), shared a high geographic and high product diversification strategic position. Three of these firms (Alcoa, Anglo, and Alcan) had diversified into non-mining lines of business such as packaging and engineered products, which could explain their below average performance. The remaining firm, Rio, had significantly fewer assets than BHP in 2003 ($41.4 billion US for BHP versus $24.7 billion US for Rio in 2003) (BHP Billiton, 2003), (Rio Tinto plc, 2003). CVRD's moderate geographic and product diversification position was one adopted by 10 other firms, but here again, the other competitors had significantly fewer assets (CVRD had $16.3 billion US in assets in 2003 compared to an average of US$6.4 billion for the other ten firms) (Companhia Vale do Rio Doce , 2003). It would thus appear that a focus on mining and size could be compensating for a common strategic position.

Four firms (Placer, Barrick, Newmont, and Inco) occupied the outlier position of low product diversification yet were not able to generate an above average operating profit. Placer, Barrick, and Newmont produce gold, a commodity that ranked 14th on the Porter based attractive commodity scale of Garren, Bird, and Sutton-Pratt's (2002)[36]. The remaining firm, the nickel producer, Inco, had significantly fewer assets in 2003 than Norilsk, the comparable outlier nickel producer (US$10.7 for Inco versus US$13.6 billion for Norilsk), and had diversified into nickel products (Inco Limited, 2003), (Mining and Metallurgical Company Norilsk Nickel, 2003). It would thus appear that occupying an outlier strategic position is not enough to ensure above average performance; limited diversification outside of mining, size, and commodity attractiveness also appear to be necessary factors.

Figure 3.5 plots the three year average operating profit against capital intensity.[37] All but two of the firms (Lonmin and Implats) were within one standard deviation of the mean for both operating income and capital intensity. Lonmin and Implats had the lowest investment in property, plant, and equipment per employee of all the firms and were above the mean for operating profit. The four firms with the highest investment in property, plant, and equipment per employee (Inco, Sumitomo, Rio, and WMC) were all below the mean for operating profit.

Based on these observations, the answer to the second research question would appear to be *yes*. The differences in strategic choice that were observed were matched with differences in performance. In the main, the firms that displayed a common strategy

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[36] Attractiveness was based on the producers perceived ability to exert power over suppliers and buyers, resist threats from new entrants and substitutes, and to drive demand (Garren et al., 2002).

[37] Capital intensity was chosen for this comparison because there were more outliers for capital intensity (6 firms) as well as a wider range of variability in investment.

did not perform as well as those that displayed an outlier strategy. Not all of the firms exhibiting an outlier strategy were among the above average performers, suggesting other factors such as commodity choice, focus, and size along with strategic position were associated with the differential performance.

The third research question was, Are differences in home country reflected in differential performance? Figure 3.6 plots the firms by average operating profit. Four countries were represented by a single firm, and three of the four firms (Codelco, CVRD, and Implats) were among those with an above average operating profit. For the countries represented by more than one firm, the firms from Russia (Alrosa and Norilsk) earned above average profits, and all of the firms from Canada and Japan earned below average profits. For the remaining three countries (the United Kingdom, the United States, and Australia), the results were mixed. At least one of the firms in the group earned an above average operating profit, with the remaining firms earning below average profits, results consistent with the findings of other researchers examining differential performance among members of a strategic group, which in this case is country (McNamara et al., 2002).

These findings suggest the answer to the third research question would appear to be mixed: *yes* for the firms from Russia, Japan, and Canada and *no* for the firms from the United Kingdom, the United States, and Australia. As the number of firms represented by each of the countries is small, the differential performance results observed here may not be related to country. It is also possible that Canada is over represented because the industry in Canada has only recently (i.e., with the last 20 years) entered its mature phase.

It is known that as an industrial population matures, the industry becomes more concentrated and tends to be represented by a few very large firms.

Discussion

The results suggest that even within an industry where little strategic variety would be expected, a certain degree of strategic heterogeneity can be observed. In terms of strategic positioning, the dominant strategy among mining firms seems to be moderate geographic and product diversification. The non-dominant strategies observed were (a) low geographic diversification, (b) high product diversification, or (c) low product diversification. Only one firm (Alrosa) could be classified as pursuing both a low geographic and a low product diversification strategy, a strategy that would not be unexpected for a state owned firm. State owned enterprises are typically focused on their domestic market, providing these markets with a narrow range of products (Mascarenhas, 1989). In terms of strategic investments, the dominant strategy noted was for average investments in plant, property, and equipment per employee and exploration/research and development. The non-dominant investment strategy was for (a) high investment in exploration and research and development activities and (b) either high or low investment in property, plant, and equipment per employee.

The results also suggest that differences in strategic choice are associated with differences in performance. The average performance of the firms in cluster 1, the dominant strategic cluster, was approximately 8%; for the firms in cluster 2, the first of the non-dominant clusters, approximately 20%; and for the firms in cluster 3, the second of the non-dominant clusters, 4%. The six firms in Cluster 2 were firms with a limited number of lines of business in a limited number of geographic locations. The presence of two state-owned firms among the six firms in this group was unexpected, for several researchers have empirically established that government owned firms are less profitable than privately owned firms (Deventer & Malatesta, 2001), (Boardman & Vining, 1989). Low production costs may be factor in the profitability of these two firms. And exceptions to the generalization that occupying a non-dominant strategic position is associated with above average performance suggest there are other factors besides strategic position associated with performance.

Prior research on the relationship between geographic scope and performance has provided empirical support for both a positive and a negative linear relationship. One body of research has demonstrated that increasing levels of geographic scope positively impact performance; and another body, that increasing levels of geographic scope negatively impact performance (Goerzen & Beamish, 2003), (Hill, Hitt, & Hoskisson, 1992). The findings reported here provide some support for a relationship between limited geographic scope and above average performance. The firms with above average operating profits that chose a low geographic diversification strategy had operations in a limited number of jurisdictions.

Prior research on the relationship between diversification strategy and performance has produced inconclusive results (Hill et al., 1992). Studies have shown, however, that diversified firms are valued at a discount relative to single-segment firms and that the degree of industrial diversification has been decreasing over time (Denis et al., 2002). One of the reasons suggested for this trend is a renewed focus on core lines of business, necessitated by increased global competition (Denis et al., 2002). Leaven's 2001 study of 1,914 firms representing 18 countries found that when a combined measure of diversification was used, both product and geographic diversification destroyed firm value at high levels of diversification (Leaven, 2001). The findings of the current study provide some support for a relationship between limited diversification and above average performance. The firms with above average operating profits that chose a low product diversification strategy and/or low geographic scope were producers of a limited range of commodities with interests in a limited number of countries.

Other studies have demonstrated that investments in research and development are positively related to firm performance (Capon et al., 1990). Few firms in this study reported expenditures in research and development, and among those that did, two firms (BHP and CVRD) had an above average operating profit over the period 2002-2004. The expenditures were relatively small as a percentage of sales (2%), and there were no data for the other firms with an above average operating profit, suggesting research and development is not a major activity among mining firms. Low capital investment has been identified by others as a strategy variable that increases firm and business performance (Capon et al., 1990), and the results reported here support that conclusion.

In addition to strategic position, the results suggest that commodity choice, size, and country are other factors associated with differential performance. Platinum, diamonds, and iron ore were the three top ranked commodities on Garren, Bird, and Sutton-Pratt's list of attractive commodities (2002), and the four firms that focused on the production of these commodities (Lonmin, Implats, Alrosa, and CVRD) were among the limited number of firms with an above average operating profit in 2003. Firm size is a recognized determinant of performance (Lee & Habte-Gioris, 2004). The size of the world's top ranked mining firms in 2003, measured in terms of total assets, ranged from a low of US$2.3 billion (Dowa Mining Co., 2003) to a high of US $52.2 billion (Anglo American plc, 2003). And the firm with the highest operating profit in 2003 had total assets of US$2.7 billion (Impala Platinum Holdings Inc., 2003). It is possible that beyond a certain level of assets, diseconomies of scale negatively impact performance.

The role of country effects remains uncertain with respect to the performance of mining firms. Makino, Isobe, and Chan (2004) found that country effects were as strong as industry effects, ranking behind affiliate and corporate effects. This finding that corporate effects take precedence over country effects could explain the below average performance of the firms from Japan and Canada that had adopted the dominant strategic position with respect to corporate, geographic, and product diversification. The below average operating profit of the Japanese mining firms is also consistent with the findings of Brouthers (1998) who concluded from his research on the profitability of successful European, American, and Japanese manufacturing firms over the period 1978 to 1992 that country effects were a factor in the below average profitability, defined as return on assets, of the Japanese firms.

Conclusion

There are two themes running through this essay: intra-industry variety and the relationship between strategic choice and performance. The results support the following conclusions. One, within an industry that appears to be homogeneous, a certain degree of heterogeneity can be discerned when the focus of inquiry is on the individual firms. And two, performance differences appear to be associated with differences in strategic choice. When the focus of inquiry is at the level of the firm, it is possible to consider the outlier firm. According to Aharoni (1993) researchers should look for the firm that is unique or different rather than search for central tendencies in a population of firms. Aharoni (1993) suggests, it is the outlier firm that may have the competitive advantage that leads to above average returns. Most of the outlier firms in this study were able to generate above average operating profits over the period 2002-2004. That not all outlier firms were able to do this confirms the findings of other researchers that the relationship between strategic position and firm performance is a complex one which cannot be explained by one or two factors. The fact that strategic difference was found to matter, even among a small group of firms in one industry, supports the position advocated by Deephouse (1999) that firms need to be as different as their industry will legitimately allow.

The findings reported here demonstrate the importance of considering questions of corporate strategy at the firm level and add to the limited body of research on intra-industry diversification. Aggregate data, even for small groups of firms, mask subtle differences in strategy that may result in differences in performance. As Acar and Bhatnagar (2003) have noted, the use of aggregate data in strategic research is a major source of inaccuracy. Further, multinational corporations typically have some resource advantage (Aharoni, 1993), which can be examined using firm level analysis.

This research has produced results which could provide an impetus for additional research. First, the performance time length examined in this study was three years. It would be interesting to explore how long the strategic benefits of an outlier position last. A longitudinal study of the outlier firms would provide insights into the sustainability of this position over time and the means by which it can be maintained. Second, the mixed results with respect to country suggest country effects bear further investigation. Researchers have demonstrated that business unit, corporate, and industry effects can account for as much as 50% of the variability in firm performance (Rumelt, 1991), (McGahan & Porter, 1997), which leaves a significant portion of the variability yet to be explained. The contribution of country effects to the unexplained variability needs to be studied.

Tables

Table 3.1 Major Global Mining Companies

Company	Sales 2003 US$ Millions	Net Income 2003 US$ Millions	Country	Historical Date	Metal/Mineral Interests
Alcoa Inc. (Alcoa)	21,504.0	938.0	United States	1894	bauxite, specialty chemicals, and coal
Anglo American plc (Anglo)	18,637.0	1,592.0	United Kingdom	1917	gold, platinum, copper, zinc, nickel, diamonds, aggregates, and coal
BHP Billiton (BHP)	15,608.0	1,900.0	Australia	1885	bauxite, base metals, petroleum, and coal
Alcan Inc.(Alcan)	13, 640.0	167.0	Canada	1902	bauxite and specialty chemicals
Rio Tinto Group (Rio)	9,228.0	1,508	Australia	1873	bauxite, copper, gold, iron ore, diamonds, industrial minerals, coal, and uranium
Companhia Vale do Rio Doce (CVRD)	5,350.0	1,548	Brazil	1942	bauxite, copper, nickel, iron ore, kaolin, and potash
Mining and Metallurgical Company Norilsk Nickel (Norilsk)	5,196.0	861.0	Russia	1935	gold, platinum, copper, nickel, palladium, and natural gas
Noranda Inc. (Noranda)	4,657.0	34.0	Canada	1922	bauxite, copper, zinc, and nickel
Phelps Dodge Corporation (Phelps Dodge)	4,142.7	94.8	United States	1834	copper and molybdenum
Codelco (Corporación Nacional del Cobre de Chile)	3,781.8	89.2	Chile	1976	copper and molybdenum
Xstrata plc (Xstrata)	3,481.6	277.0	Switzerland	2001	copper, zinc, and coal
Mitsui Mining & Smelting Co. (Mitsui)	3,159.1	25.7	Japan	1950	zinc and lead
Newmont Mining Corporation	3,157.8	475.5	United States	1921	gold, copper, and zinc
Sumitomo Metal Mining Co. (Sumitomo)	2,964.1	(9.8)	Japan	1590	gold, silver, platinum, copper, zinc, nickel, and lead
Inco Limited (Inco)	2,474.0	137.0	Canada	1915	gold, silver, copper, nickel, and cobalt
Grupo Mexico, S.A. de C.C. (Grupo Mexico)	2,456.3	(125.0)	Mexico		copper, zinc, silver, and gold
WMC Resources Ltd. (WMC)	2,258.2	184.8	Australia	1933	nickel, copper, molybdenum, gold, phosphate

Company	Sales 2003 US$ Millions	Net Income 2003 US$ Millions	Country	Historical Date	Metal/Mineral Interests
					fertilizers, and uranium
Freeport-McMoRan Copper & Gold Inc. (Freeport-McMoRan)	2,212,2	181.7	United States	1967	copper, gold, and silver
Falconbridge Limited (Falconbridge)	2,083.5	194.4	Canada	1928	copper, zinc, nickel, cobalt, and ferronickel
Barrick Gold Corporation (Barrick)	2,035.0	200.0	Canada	1983	gold, silver, and copper
AK "ALROSA" (Alrosa)	1,939.8	330.3	Russia	1992	diamonds
Teck Cominco Limited (Teck)	1,861.5	115.1	Canada	1906	gold, copper, zinc, lead, indium, and germanium
Dowa Mining Co. (Dowa)	1,844.4	(21.9)	Japan	1884	gold, silver, platinum, palladium, rhodium, and copper
Placer Dome Inc.(Placer)	1,763.0	229.0	Canada	1910	gold, silver, and copper
Impala Platinum Holdings Inc. (Implats)	1,581.0	457.3	South Africa	~ 1970s	platinum, nickel, copper, and cobalt
Lonmin plc (Lonmin)	1,298.0	123.3	United Kingdom	1909	platinum, palladium, and rhodium

Source: Annual Reports, SEC Filings, Company Websites, Firms ranked by sales

Table 3.2 Means, Standard Deviations, and Correlations

Variable	N	Range	Mean	Standard Deviation	1 (a)	1 (b)	2	3	4
1. Geographic Scope									
(a) Country	26	0.22 to 1	0.43	0.23	--				
(b) Sales	24	0.28 – 0.85	0.46	0.16		--			
2. Product Scope	26	0.16 to 1	0.55	0.33	0.422*	0.026	--		
3. Exploration / R&D Intensity	22	0.003 to 0.079	0.019	0.019	- 0.228	0.203	0.484*	--	
4. Capital Intensity	22	0.031 to 0.975 (US$ Millions)	0.336 (US$ Millions)	0.249	- 0.295	-0.273	-0.089	-0.192	--

** Correlation is significant at the 0.05 level of significance (two tailed test)*
Sources: Annual Reports, SEC Filings, Company Websites

Table 3.3 Sources for Company Information

Company	Annual Reports	U.S. SEC Filings	Website
Alcoa Inc.	2002-2003	Form 10-K	www.alcoa.com
Anglo American plc	2002-2003		www.angloamerican.co.uk
BHP Billiton	2002-2003	Form 20-F	www.bhpbilliton.com
Alcan Inc.	2002-2003	Form 10-K	www.alcan.com
Rio Tinto Group	2002-2003	Form 20-F	www.riotinto.com
Companhia Vale do Rio Doce (CVRD)	2002-2003	Form 20-F	www.crvd.com.br
Mining and Metallurgical Company Norilsk Nickel	2002-2003		www.norilsknickel.ru/en
Noranda Inc.	2002-2003	Form 40-F	www.noranda.com
Phelps Dodge Corporation	2002-2003	Form 10-K	www.phelpsdodge.com
Codelco (Corporacion Nacional del Cobre de Chile)	2002-2003		www.codelco.com/english
Xstrata plc	2002-2003		www.xstrata.com
Mitsui Mining & Smelting Co.	2002-2003		www.mitsui-kinzoku.co.jp/en
Newmont Mining Corporation	2002-2003	Form 10-K	www.newmont.com
Sumitomo Metal Mining Co.	2002-2003		www.smm.co.jp
Inco Limited	2002-2003	Form 10-K	www.inco.com
Grupo Mexico, S.A. de C.C.	2003		www.gmexico.com
WMC Resources Ltd.	2002-2003	Form 20-F	www.wmc.com

Company	Annual Reports	U.S. SEC Filings	Website
Freeport-McMoran Copper & Gold Inc.	2002-2003	Form 10-K	www.fcx.com
Falconbridge Limited	2002-2003	Form 40-F	www.falconbridge.com
Barrick Gold Corporation	2002-2003	Form 40-F	www.barrick.com
AK “ALROSA”	2002-2003		www.rustocks.com
Teck Cominco Limited	2002-2003	Form 40-F	www.teckcominco.com
Dowa Mining Co.	2002-2003		www.dowa.co.jp
Placer Dome Inc.	2002-2003	Form 40-F	www.placerdome.com
Impala Platinum Holdings Inc.	2002-2003		www.implats.co.za
Lonmin plc	2002-2003		www.lonmin.com

Figures

Figure 3.1 Cluster Analyses Dendogram

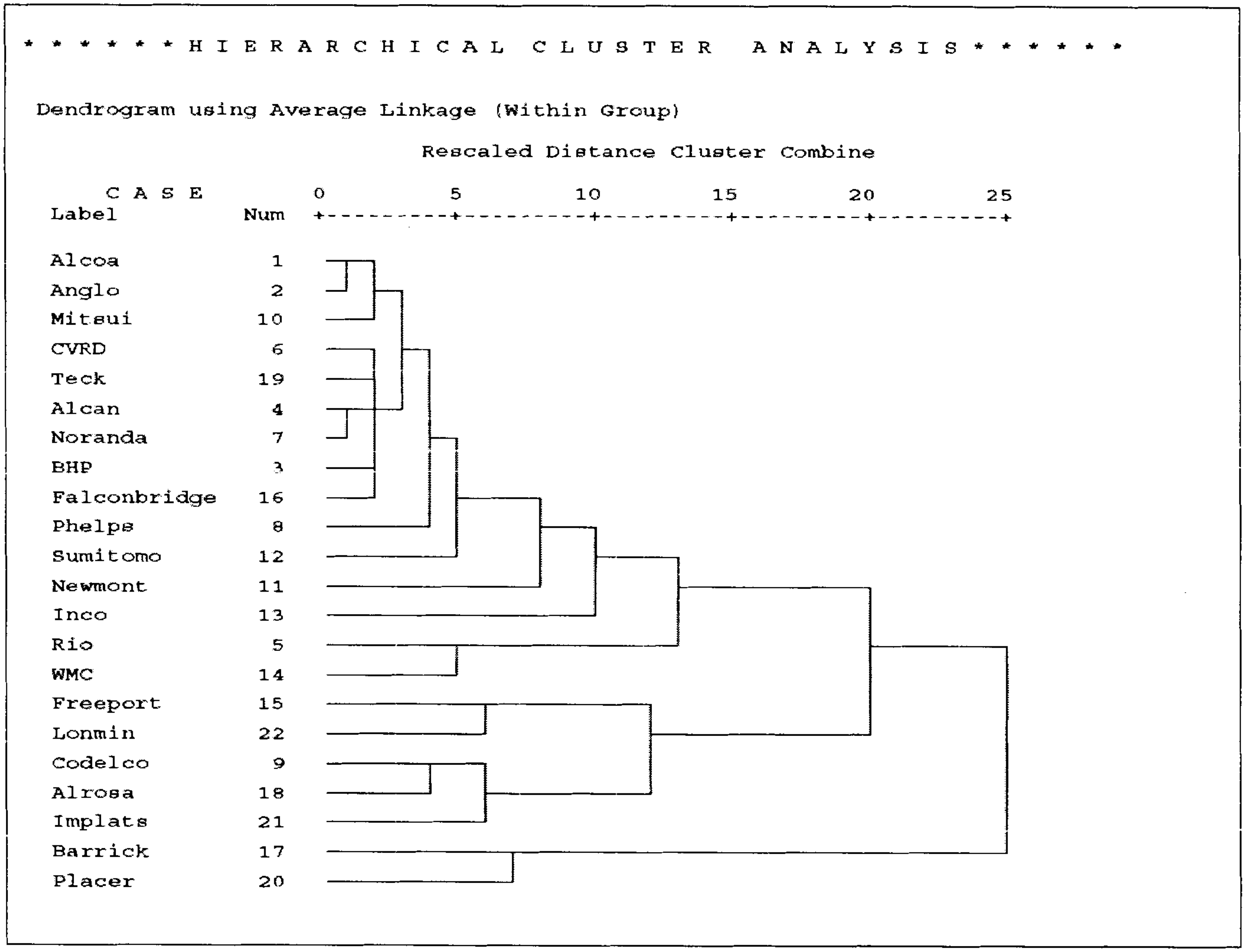
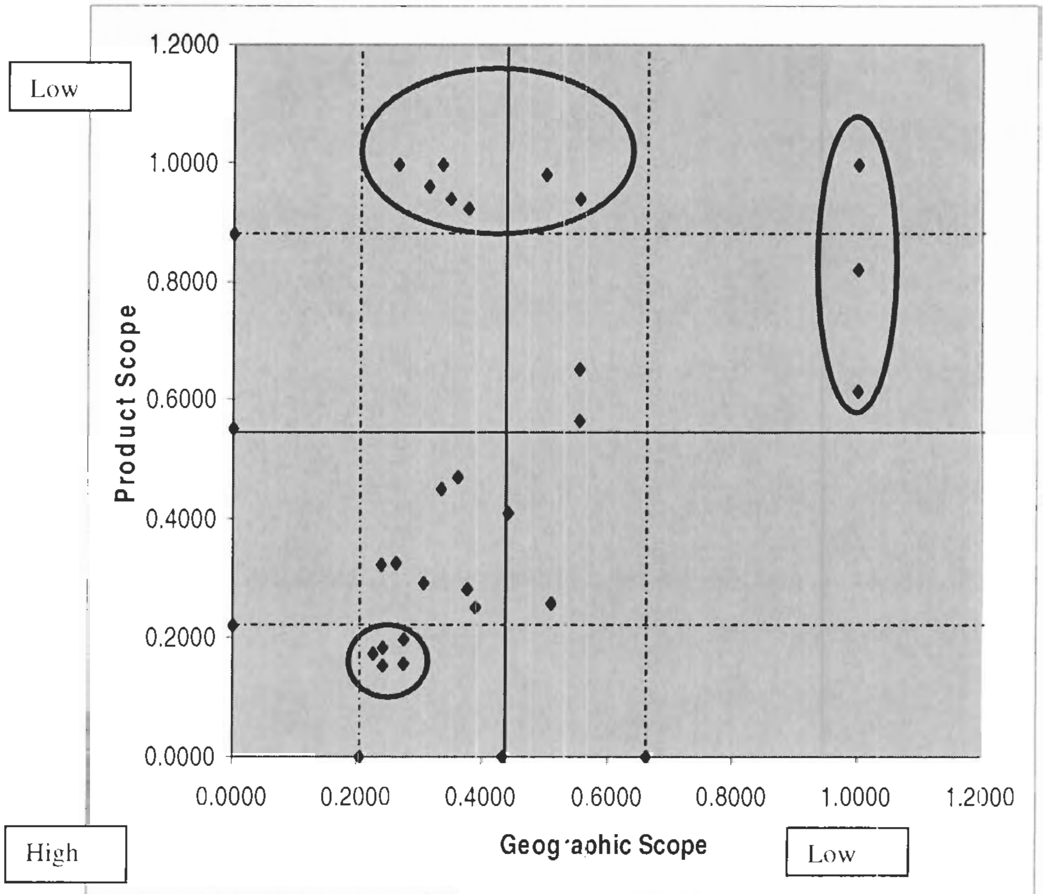
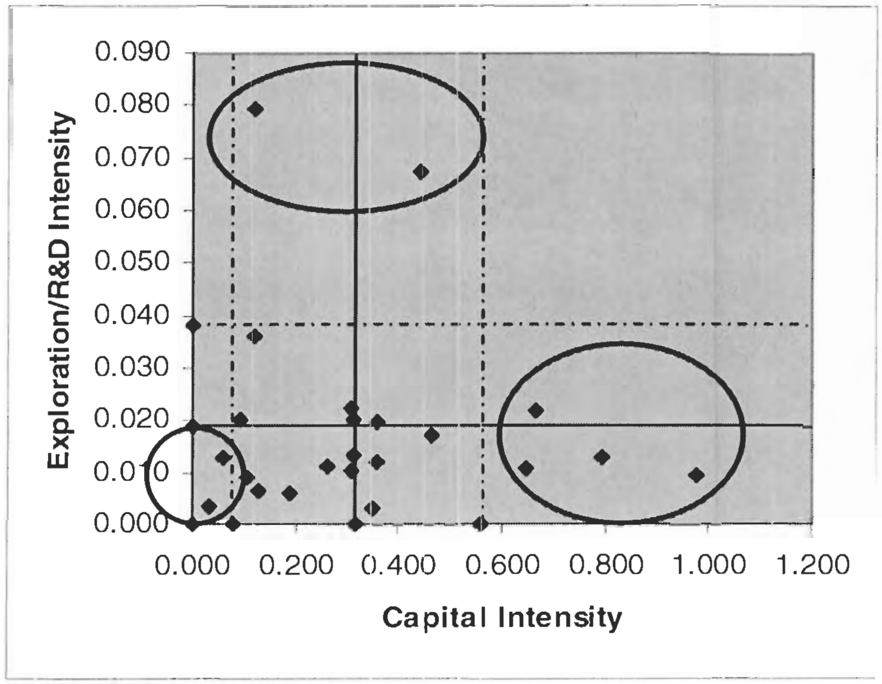


Figure 3.2 Product/Country Geographic Scope



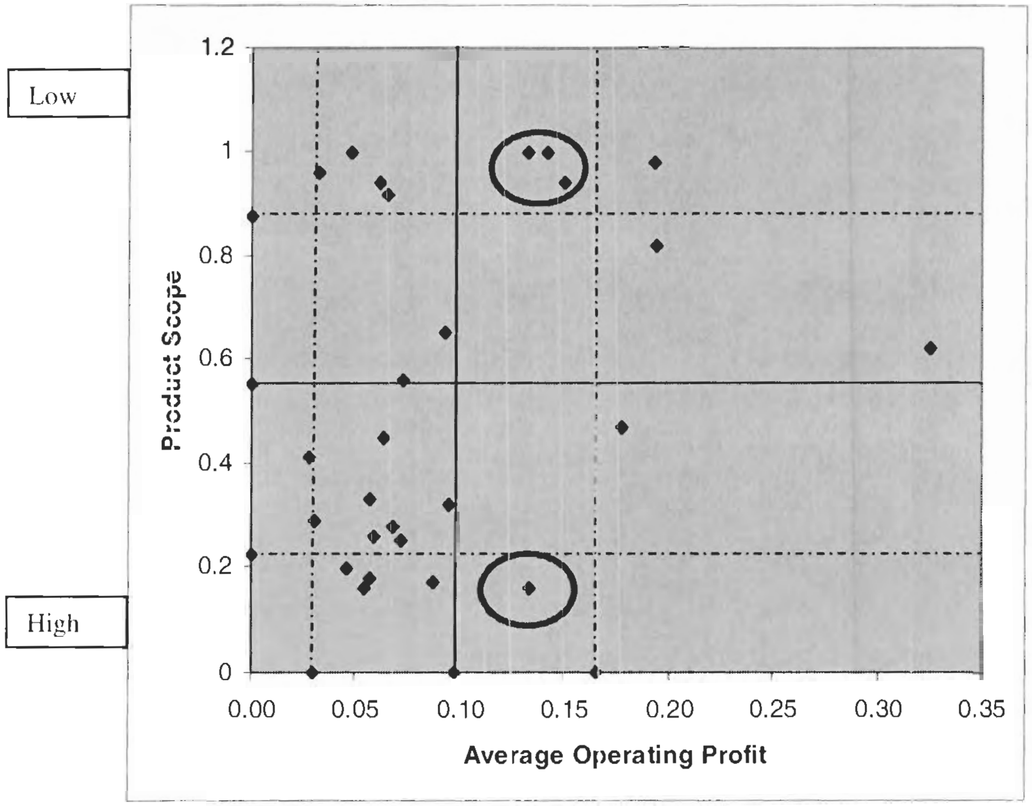
Dotted lines are ± 1 standard deviation from the mean

Figure 3.3 Exploration and R&D Intensity / Capital Intensity



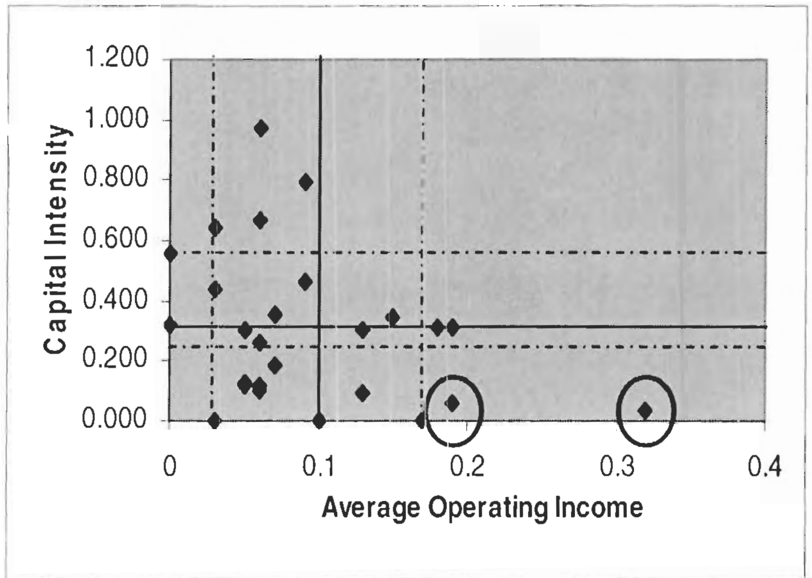
Dotted lines are ± 1 standard deviation from the mean

Figure 3.4 Product Scope / Average Operating Income



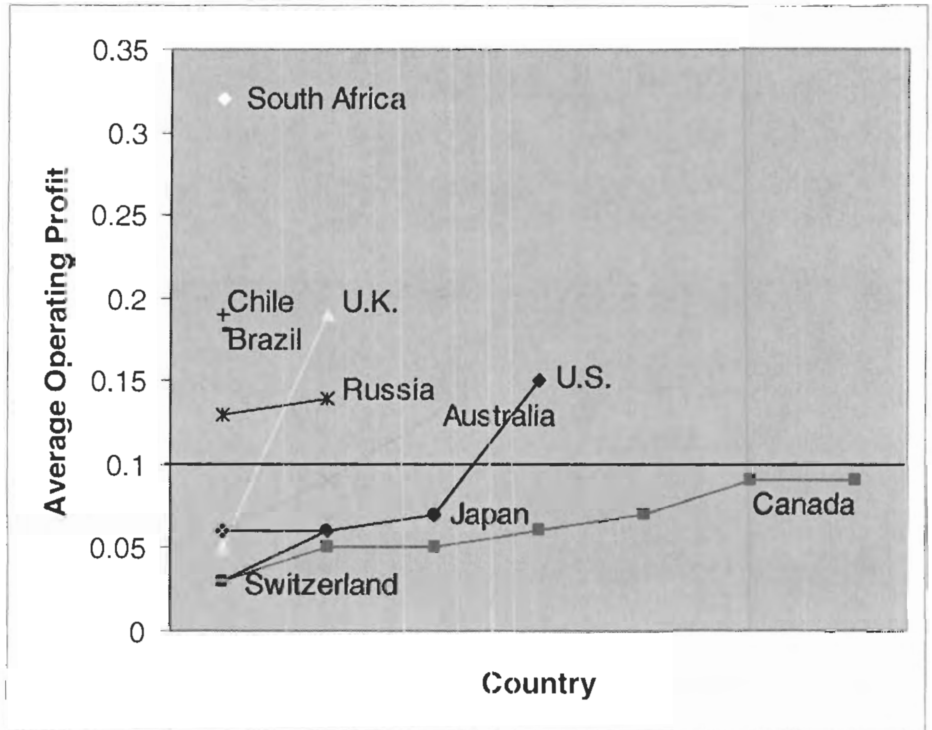
Dotted lines are ± 1 standard deviation from the mean

Figure 3.5 Capital Intensity / Average Operating Income



Dotted lines are ± 1 standard deviation from the mean (solid line)

Figure 3.6 Average Operating Profit by Firm by Home Country



Solid Line is the mean 3 year average operating profit

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