# SURVIVAL OF FIRMS AND PLANTS IN A SUPPLY-CONSTRAINED INDUSTRY

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**Abstract**

We analyze duration of firms in a supply-constrained industry — the Australian black-coal industry — using our thirty-two-year database. We test the hypothesis that the exhaustion of coal reserves of individual mines (their plants) will be reflected in the firm's duration, and find negative duration dependence with the age of the firm. In contrast to the results from studies of manufacturing industries, we find no relationship between firm size and survival. For individual mines (plants) we find no dependence with age but positive dependence with size — the larger the mine, the longer it survives. We find that the exit of firms is driven by the depletion of their reserves, and by the entry of new firms seeking the supply-constrained resource.

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## 1. Introduction

This paper contributes to the literature on the dynamic processes governing industry structure by comparing the duration of firms in a supply-constrained industry with the duration of their plants. This is an extension of others' research, mainly of manufacturing industries, to an industry in which a necessary input is depleted over time. We draw a parallel between the plants of manufacturing firms and the mines of extracting firms, and consider the relative hazards of mines and coal-mining firms, and the underlying processes affecting each.

In 1982 Jovanovich developed a model of manufacturing firm survival and growth. He argued that as the firm’s experience grew — as it aged — it would learn about its costs, as well as its product market, which would mean that it would be less likely to fail through low efficiency and consequent poor performance (the price-cost margin, simply put). Jovanovich argued that there must be a positive relationship between age and survival, and between size (as measured by the level of output produced per period) and survival. Beginning in the late 1980s, a series of researchers examined manufacturing firms in the U.S., Canada, and other countries (Fariñas and Moreno 2000) and found just such positive relationships reflected in the data: "One of the most striking stylized facts regarding the dynamics of industries that has emerged from empirical studies is that the survival rates of businesses are positively related both to establishment size and age" (Audretsch and Mahmood 1995, p.95). Research with a narrower focus, on new firms, using a database from the U.S. Small Business Administration, also found these positive relationships (Phillips and Kirchhoff 1989, Audretsch 1991). These papers, for the most part, used infrequent, aggregated time series of periods up to 15 years long, although Agarwal (1997) developed a database that was almost a century in length.

They were not only, or perhaps primarily, concerned with survival (as reflected in changing survival rates over time, or age), but with firm growth[1]. Caves (1998, p.1949) organized "the recent profusion of stylized facts" and his paper provides an excellent review of the literature surrounding the issues at that date.

The industry we analyze is supply-constrained in two ways: first, the primary input, coal, is exhaustible. Second, although owning a coal deposit is necessary for production, it is not sufficient: a further requirement is permission-to-mine, as embodied in a mining permit. In the state of New South Wales (NSW), Australia, the State Government has traditionally identified prospective coal-mining areas and will grant exploration and mining permits for these areas at periodic intervals by sealed bid auction. Rights to in-situ coal are transferable, as are permits to mine.

Because of the exhaustion of mine reserves and the restrictions on access to reserves, the duration dependence of firms in an extractive industry is likely to differ from the dependence in manufacturing. Analysis of duration should give insights into the economics of the industry, and perhaps reveal other differences. Since the coal industry is of significant economic importance to Australia, a better understanding of the factors that influence its structure and evolution is valuable[2]. Moreover, our findings may generalize to other extractive industries, such as natural gas and other minerals in other

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[1] "Survival of firms has . . . been studied as a side issue to growth of firms" (Agarwal 1997, p.571).

[2] Since 1985 Australia has been the world's largest exporter of coal and coal is Australia's largest export earner (McLennan 1999); the states of NSW and Queensland are the exporting regions and the major producing regions. While Queensland has now exceeded NSW in annual exports, NSW has a longer history of substantial coal mining and coal exports.

countries with well-established property rights, and to other supply-constrained industries.

In the coal-mining industry the firm's "plants" are its mines, necessary for producing its coal from the main resource of the firm, the in-situ coal reserves. Exhaustion of its coal equates to exhaustion, and death (exit), of the mine. But a coal-mining firm may comprise more than a single mine. The lives of coal-mining firms and their plants — the mines — are decoupled, through trade in mines and trade in firms. The lives of these firms are therefore distinct from the birth and death of their mines. Although the life of a working mine is necessarily finite, a firm could in principle survive indefinitely, by opening new mines, or buying operating mines from other firms, or acquiring firms with operating mines. This implies that firm hazard should be less than mine hazard, but we report counter results below.

Are there any non-extracting industries that are supply constrained? We argue that manufacturing industries are not in general supply-constrained, but that some service-sector industries might be. Any industry — such as free-to-air broadcasting, banking or insurance — in which a government permit is necessary for operation, could be supply-constrained.

As well as the large literature on manufacturing, there is a small literature on duration in the services sector. Audretsch et al. (2004) found that there is no relationship between survival and size in the Dutch hospitality industry, but this industry is characterized by a large number of small firms, and, as the authors pointed out, "industry dynamics in small-scale services might not simply mirror that in manufacturing". They concluded that this is due to the Dutch hospitality industry having minimal sunk costs, with low capital intensity and scale economies. Cameron and Hall (2003) investigated the hazard rate of Australian mutual fund closure, and the variation over time in the conditional probability of fund closure, given fund survival to date. They found a hump-shaped hazard function that is consistent with learning, and is typical of lognormal distributions.

Freeman et al. (1983) found that death rates of young labour unions, electronics manufacturing firms and newspaper publishers were much higher than those of older organisations. But rather than this "liability of newness", we find a senescence effect, as discussed below. Some studies examine the effect of the technological regime on survival (Audretsch 1991, for example) but in our industry firms share similar technology: coal-mining and coal-preparation methods and equipment are equally available to all firms.

We analyze the durations of NSW coal-mining firms and coalmines in operation from mid-1969 to mid-2001. We test the influence of size and age on duration. We also explore relationships between duration and control for foreign ownership and the competition from firms in Queensland (Australia's other major coal-producing region). Because coal firms and mines depend on exhaustible reserves, we expect their survival to be negatively related to age (cet. par.). We expect that survival will also be negatively related to size — large firms and mines may deplete their coal reserves faster than do small firms and mines.

We compare the behaviour of firms and plants in our supply-constrained industry with those in manufacturing industries, which in general are not constrained in one necessary input resource. We have developed a thirty-two-year database of the ownership and operations of coal-mining firms, and their mines (extending some firms back a further 10 years and some mines a further 20 years), and use these to examine whether, in this extractive industry, the clear relationships seen in manufacturing industries still hold: is coal-mining firm survival positively related to the age of the firm? Is coal-mining firm survival positively related to the size of the firm? What of mine survival? Because firms buy, sell, and develop mines, there is no reason to suppose that mine exhaustion is necessarily reflected in such firms, exhibiting a negative relationship between survival and firm age, is there?

We test three hypotheses:

**Hypothesis 1:** unlike manufacturing industries, the survival of firms and plants in the NSW coal industry is negatively related to their age;

**Hypothesis 2**: the hazard of plants is greater than the hazard of firms in our industry;

**Hypothesis 3**: unlike manufacturing industries, the survival of both firms and plants is negatively related to their size in our industry,

The structure of the paper is as follows: Section 2 discusses the ways in which firms can enter and exit the extractive industry, and ways in which firms' "plants" (i.e. individual mines) can begin, can cease operations, or can be bought and sold while continuing to operate. Section 3 discusses the construction of the database of Australian black-coal mines and firms. Section 4 reports the survival functions and hazards of firms and plants, and tests the relationship between size and duration. Section 5 discusses our findings, and compares and contrasts them with the duration of firms and their plants in other industries. Section 6 concludes. Appendix 2 contains a discussion on left censoring.

## 2. Plants and Firms

We distinguish between the "plant" (the "mine" for an extractive industry[3]), which is the producing and main employment centre, and the "firm", which is the corporate entity that owns the plant(s)[4]. Many studies of manufacturing industries, such as Dunne et al. (1989), analyze only the plant, while others, such as Evans (1987a) and Dunne et al. (1988), analyze only the firm. The plant's survival is neither necessary nor sufficient for the firm's survival: firms can survive the closure of some of their plants, and firms can fail while some of their plants remain profitable assets, to be sold off to new owners. Indeed, some previously unprofitable plants can be turned around by the new firm, to become profitable again, not least if their reduced purchase prices reflect write-downs on their old values, a loss borne by the owners of the exiting firm. In our study we expect the relationship between plant (mine) survival and firm survival to be weak, as a mine will only be closed when the resources are economically exhausted and not when an individual firm finds the mine unprofitable. The government may disallow the closure of a mine if it thinks extraction could be profitable for another firm.

We analyze separately the duration of mines and firms. We are concerned with an industry, unlike manufacturing, in which "plants" cannot survive indefinitely. In an

[3] For manufacturing, a plant is "defined as a unified complex of production faculties on a single site — a single factory, mill, refinery, works, shop, etc." (Bain 1966, p.26). Our "plant" includes the mine, coal handling and preparation facilities, indeed all the equipment to produce, condition and load the coal onto transport to leave the mine site. The firm will also have a head office, and possibly other mines.

[4] "A 'firm' is any independent ownership and/or control unit" (Bain 1966, p.73).

extractive industry, when the resource in the mine is exhausted, the mine closes. Despite this, firms in the extractive industry might, by buying existing "plants" (mines) or by developing new "plants", survive beyond the "plant" failures. The industry — the Australian black-coal industry — relies on an exhaustible resource (black coal) that is extracted from mines and sold, mainly into export markets. Its "plants" — the coalmines — will one day cease operations, either because they have been physically exhausted of all resources, or because, more likely, the rising cost of operation as the coal is mined has made them unprofitable, a case of Ricardian exhaustion[5].

Our data (see below) reveal that most new mines are developed by existing firms and that almost all new firms enter the industry by purchasing existing operating mines. This could be a result of the restriction on the release of new mining areas by the Government (the main reason for the supply constraint) and the reluctance of firms to wait for such releases in order to enter the industry. It could also be the of lack of experience or the risk aversion of new firms wishing to enter the industry and so being reluctant to commit to a new mine — the purchase of an existing mine brings with it the existing equipment, production configuration and experienced mining crews[6]. The world demand for energy increased from 1970 to 2001, and the demand for coal as an energy source in the Asia/Pacific region (the principal market for Australian coal) increased at an increasing rate — especially after the oil shocks of the 1970s and

[5] As the coal is extracted, the haulage distance to the processing plant and transport facilities increases — increased depth of mining increases safety considerations and other costs.

[6] In the Australian coal-mining industry there is little technology proprietary to mining firms. The equipment suppliers are the main vehicles of equipment technological development and, coupled with the strong controls by State Governments, the resulting mining methods were very similar.

1980s[7]. Coal has appeared attractive for investors, and firms have attempted to enter the industry to capitalise on this. But, as we show, the constraint on the availability of coal-mining tenements has been a barrier to entry.

One study has previously examined survival and hazard in an extractive industry. Merrell (2000) examined mine closure in the U.S. coal-mining industry, using a twenty-year government database of mines. That is, Merrell studied "plants," not firms. He found that favourable energy-market conditions and productivity differences tended to reduce the time to mine failure, while older mines tend to have shorter remaining life, ceteris paribus. This duration dependence of "plants" in an extractive industry is not, of course, surprising, since every unit mined will reduce future mine life, ceteris paribus. Merrell posited three forces that determine the date of mine closure (or exit): market demand, productivity, and resource exhaustion. He found that after some date in the life of the mine, exhaustion dominated the former two forces, as one would expect.

## 3. Data

At the beginning of our timeseries — 1 July 1969 — there were 26 firms working a total of 93 mines in the industry. At the end of the timeseries, 32 years, later there were 15 firms working a total of 55 mines. But only one firm and 15 working mines survived the whole 32 years, and in the meantime 40 other firms came and went and 40 other mines opened and closed. That is, the database contains 78 firms that either exited the industry during the 32-year period (63) or survived at the end (15), and 171 mines likewise (116 and 55).

[7] Over the period 1965 to 2001, world primary energy consumption rose by 237% while coal consumption in the Asia/Pacific region rose by 357% (BP 2003).

We tracked the initial 26 operating firms and 93 working mines back ten and twenty years before mid-1969, respectively: we were able to determine the ages and means of entry of 12 of the 26 firms, leaving 14 firms (18%) whose ages and means of entry we do not know (we refer to these as “left-censored” below), and likewise we determined the ages of 47 of the 93 mines, leaving 46 mines (27%) left-censored.

The final survivors — the 15 firms and 55 mines still working at 30 June 2001— we refer to as "right censored," since of course we have no data on their ages at eventual exit. Of the 14 firms that existed at 30 June 1960 and the 46 mines that existed at 30 June 1950, only one firm and four mines survived beyond 30 June 2001 and are referred to below as "double censored". We use financial years (1 July to 30 June), so the year 1960 refers to the twelve months ending 30 June 1960.

Our data are from the NSW black-coal industry, part of the Australian black-coal industry, ANZSIC code 1100. Queensland and NSW are the major black-coal-producing states in Australia. Our analysis is for mines and firms extant at mid-1969 or entering after that date and before mid-2001[8]. Firms are defined as those entities that control the marketing decisions of a single coalmine or a group of coalmines. In most cases, control results from greater than 50% ownership, but may result from being the largest shareholder (less than 50%, but with effective control) or by having a management agreement with other owners. The designated "firm" is the ultimate owner of the mining assets although in many cases it is not the immediate corporate entity publicly listed as the owner. Provided a firm maintains a controlling interest in at least

[8] Data of individual mines are from Joint Coal Board internal records, Joint Coal Board (various years) annual reports and from NSW Department of Mineral Resources (various years).

one coalmine, its status does not alter in our analysis if one or more of its mines closes or is disposed of. We delete the small number of firms (in electricity supply, steel manufacturing and cement manufacturing) that mine coal solely for their own consumption.

We record the age of mines from 1950 because that is the year in which the first "continuous mining" machinery was introduced (Eyre 1988)[9]. We record the age and means of entry of firms from 1960 because that was start of the major export market and so effectively started a new industry,[10] and we do not have earlier data. The inclusion of earlier data for mines and firms extant at mid-1969 reduces the number of left-censored entities (as explained above[11]). More details on the construction of the database are given in Appendix 1.

Figure 1 shows the general form of the duration data of firms, with the data for firms in Tables 1 and 2 and for mines in Tables 3 and 4.

Figure 1 here

[9] Before this mechanisation, annual production from most mines was very low, and many had very long durations.

[10] Prior to 1960 the dominant market was domestic, and the Joint Coal Board controlled prices. From 1960, export sales started to become the major revenue source for NSW producers, and for many firms it was the only revenue source.

[11] We distinguish between left censoring and left truncation. As Guo (1993, p.220) explains, "left truncation arises when sampling from an incomplete population. Left-truncation event-history data are incomplete because they do not include those subjects that have survived long enough to be observed". He refers to the "event" having occurred before the start of the study, this being an incident such as a heart attack. Our duration is the total age of the firm (in the industry) so the "event" is the exit of a firm, and we use Kiefer's (1988) interpretation of left censoring.

Tables 1, 2, 3 and 4 here

Our measure of firm (or mine) size is the ratio of average annual production over the life of the firm (or mine) to the average industry annual production for the same period, so "size" is the average share of industry production over the life of the firm (or mine). Given the improvements in coal-mining technology over the period, production capacities grew, and had we used absolute size, then a mine classified as "small" in a later period would be have been "large" in an earlier period. As the number of firms (and mines) does not change significantly each year, the firm's (and mine's) share of total production is an appropriate measure of size relative to other firms (and mines). Figure 2 shows the average firm and mine size each year over the period of the study, which is indicative of the general growth of firm and mine capacity over time. The growth of the largest mine size in any year reveals a similar trend. Production is the most appropriate unit of size — total asset value is not useful, as a number of firms use contractors for a large portion of their operations, which greatly reduces value of the assets owned. Employment is often used as a measure of size (Santarelli 1998) and (Merrell 2000) but, because of the difference in labour productivity between underground mines and surface mines, it is not appropriate in our study.

Figure 2 here

During the 1980s, many firms controlled mines across both NSW and Queensland. The different properties of coals in NSW and Queensland, which resulted in differentiated markets, as well as the different geological and regulatory conditions, are a justification for our assumption that NSW coal producers constitute a separate industry, and hence for our analysis of NSW firms only. But, with recent changes in customer requirements and the growth of very large firms owning mines in both states, the two markets may be converging. Further research on the duration of Queensland firms and on firms operating in both states will follow.

Earlier studies by others have suffered from: lack of longitudinal databases with clear identification of the actual start-up and closure dates of establishments (Audretsch and Mahmood, 1995); infrequent data (sometimes only every five years); aggregate data (such as four-digit SIC categories) rather than data on individual establishments (Audretsch, 1991); and the lack of data on mergers and acquisitions (Evans 1987b). Our data do not suffer from these shortcomings.

## 4. Duration Analysis

### 4.1 The hazard of firms

How does the hazard (and the duration) of firms change over the study period? For manufacturing firms it mostly falls (older firms survive longer in the industry). To answer this for our industry, we follow the analysis of Kiefer (1988) (and Diaz 1999, Requena-Silvente and Walker 2005 and others), to produce the Kaplan-Meier (1958) product-limit estimator of the survivor functions. We use an adjusted survivor function proposed by Turnbull (1974) to compensate for the left censoring (see Appendix 2), in order to estimate the hazard function (the ratio of the number of mines exiting to the number at risk, see Kiefer 1988), and to calculate the integrated hazard function. With a number of tied ages, the hazard function is very irregular and the integrated hazard is sometimes easier to interpret[12].

[12] The hazard may be viewed as the instantaneous probability of failure at a specific time, conditional on having reached that time (Lawless 1982). The integrated hazard (−ln[survivor function]) is not a probability.

We see from Figures 3 and 4 that the hazard of firms generally increases over time, in contrast to the results by others for manufacturing firms, confirming the behaviour of firms in Hypothesis 1. An integrated hazard convex to the origin means the hazard is increasing.

Insert Figures 3 and 4 here

## 4.2 The hazard of mines

As with the firm data, the mine data too are left censored. We use the suggestion by Iceland (1977) and Moffitt and Rendall (1995) of running the analysis twice: excluding the left-censored data, and including the left-censored data without adjustment (tacitly assuming that the left-censored mines started at 1960). Both methods produce increasing hazards and we average the results. (See the Appendix 2 for discussion of left censoring.) We find that the hazard trend for mines rises slightly, but the integrated hazard is approximately linear, which is consistent with a fairly constant hazard, contrary to our expectation of the behaviour of plants (Hypothesis 1).

Given the inevitable economic exhaustion of individual mines and the firms' freedom to buy, sell and (to a limited extent) open new mines, Hypothesis 2 states that mines will fail first, and that the hazard of mines will exceed that of firms. But, contrary to our expectations, we find that the hazard for firms is much greater than that of mines, except for very young mines which have a slightly higher hazard than firms of the same age (Figures 3 and 4). We use a log rank test of the integrated hazards of firms and mines (Diaz 1999, Bland and Altman 2004) and find that the difference between the two hazards is highly significant (a test statistic of 14 with one degree of freedom).

### 4.3 Factors affecting firm duration

What factors affect firm duration? We use a Cox (1972) proportional-hazards regression model with covariates firm size, foreign competition, and interstate (Queensland) competition to answer this.

In 1995 Audretsch & Mahmood were the first to estimate a Cox proportional-hazard duration model of firm and plant survival. Previously, database restrictions had precluded this. For the Cox proportional-hazard regression analysis of firms, we cannot use the Turnbull (1974) correction method for left-censored data because it creates non-integral numbers of firms. (This is not a problem with the Kaplan-Meier product limit estimator.) We have the choice of the treatment by Allison (1984, p.56), who advises that left censoring for time-to-event data should be handled by "treating the initial censored interval as if it began at the beginning of the observation period" if the hazard rate depends on age, or of ignoring the left-censored data (see Appendix 2). We choose to ignore the left-censored data because from 1960 the export market expanded rapidly, encouraging the growth of firms — so pre-1960 firms would have behaved differently from firms post-1960. We find, moreover, that the correction made in the Kaplan Meier survivor function by the Turnbull method is not very different from the survivor function when the left-censored data are ignored.

Without evidence of economies of scale, an activity will not exhibit size-dependence of duration. The coal industry is characterized by highly capital-intensive entry, but Lawrance (2002) has shown that there is no evidence of economies of scale for firms (as distinct from individual mines) in the NSW coal industry. Moreover, Lawrance and Marks (2006) find that the Gibrat proportional growth rule applies to firms in this industry, which is consistent with absence of economies of scale. A large firm may own mines smaller than the single mine of a small firm, and the multiple mines of a large firm may be widely separated geographically, which means that equipment cannot be shared. Moreover, the economies of scale in head-office administration of a large firm may be countered by the use of rapid communication in a small firm. Frequently a small firm will have better industrial relationships with its workforce and may obtain some preferential treatment from export customers who wish to maintain negotiating pressure on the larger suppliers[13].

We use a static duration model of survival for the Cox proportional-hazards model, in which there are different hazards for different covariates[14]. We assume that the variables have a multiplicative effect on the hazard function, which implies that these hazard functions are proportional to one another (Lawless, 1982)[15]. The reference hazard function is that produced by the null covariate vector and is the "baseline" or "observed" hazard (Leung et al. 2003). We test for a negative correlation between size of the firm and duration in the NSW coal industry from 1970 to 2001, controlling for competition from Queensland and for foreign ownership[16]. Contrary to our expectations (Hypothesis 3), we find no relationship between firm size and firm survival. As a control for changed economic conditions, we test for any change in hazard between the two periods 1970–1985 and 1985–2001, but find no significant

[13]See Fitzgerald (2002) for an example of this.

[14] Examination of the data shows that, while the trend of real prices is downward, the apparently random short-term fluctuations of prices do not permit a time-dependent analysis.

[15] See Lehrer (1988) and Leung et al. (2003) for applications of the proportional hazards model.

[16] In 1990 foreign firms controlled 48% of NSW export coal producers (excluding the captive mines of the major steel producer and the State Government), while in 2001 the proportion had risen to 83% (NSW Department of Mineral Resources, various years).

effect. Empirical results by others for manufacturing companies show a positive relationship between size and duration, but we find no relationship for our data (Table 5).

Table 5 here.

The entry of a new firm is usually only made possible by the exit of an existing firm (or by the sale of some of an existing firm's assets), and a firm wishing to enter the industry looks to purchase the asset(s) of an existing firm, that is, it has a call option on the asset of a willing seller: the investment will represent an irreversible expenditure and the decision to exercise the option can be delayed (Pindyck 1991). Since there are barriers to exit — a firm abandoning a mine may have substantial liabilities for mine rehabilitation and workers' entitlements, and, moreover, the government will not allow a mine to be abandoned (and the coal to be "sterilized"[17]), if it thinks extraction is still economically feasible — an exiting firm must find a willing buyer. Rather than a liability of newness, we expect a liability of obsolescence or of senescence for incumbent firms.

The Cox model assumes that the hazards are proportional and, to test the validity of this assumption, we superimpose the survivor function derived from the multiple covariates onto the observed survivor curve (that produced by no modifying variables), in Figure 5. The survivor curves are very similar, which validates the proportional hazards assumption (Kleinbaum 1996).

Fig. 5 here.

[17] Rendered impossible to extract in the future.

There is no direct duration dependence of NSW firms on other factors, such as the competition from Queensland firms, although this may be reflected in the price. With Kimura and Kiyota (2004) we find no evidence of "footloose" behaviour by foreign ownership — there is no relationship between the foreign or domestic ownership status of firms and their survival.

**4.4 Factors affecting mine duration**

What factors affect mine duration? Again we use a Cox proportional-hazards regression model. Because of the strong government control over the closure of mines, we do not think it useful to include variables other than size and type of mine (viz. surface or underground) in the Cox analysis. Unlike the result for firms, and contrary to Hypothesis 3, we find (Table 6) that there is a positive relationship between mine survival and mine size (the negative coefficient shows a decrease in hazard with age), which is consistent with Merrell's (2000) results. Our post-hoc conclusion is that the usual causal relationship is reversed, with mine size resulting from (potential) longevity rather than the other way around. A mine that has a large resource deposit will be equipped with the technology that produces high output, and this expensive equipment will only be installed if there is a long life over which to depreciate it. Coal-mining firms typically use a twenty-year discounted cash flow analysis for any major capital expenditure, and so a mine with a small resource deposit will not generally be equipped with expensive, high-output equipment.

Our test for type of mine — surface or underground — finds significance when the left-censored data are included, with a negative relationship between duration and hazard for underground mines. When, however, the left-censored data are deleted, there is no such significance. This results from 45 of the left-censored mines being underground, and all the left-censored mines having an average life (after 1 July 1950) of 37 years, while uncensored mines have an average life of 17 years. As 20 of these 37 years are from 1950 to 1970, we can deduce that, since 1970, there is no significant difference in the size/duration dependence between surface and underground mines.

Insert Table 6 here

## 5. Discussion

While we anticipated that firm hazard would increase with age (Hypothesis 1), we assumed that the coal-mining firm's ability to buy and sell existing mines, to develop new mines, and even to acquire existing coal-mining firms would offset the positive influence on hazard of resource depletion exhibited by individual mines (Merrell, 2000), which would lead to firms having a lower hazard than their mines. As we argue above, there is no reason for the inevitable exhaustion of its individual mines (or "plants") to necessitate the exit of the firm. Our results, however, show that, in general, the hazard of firms is positively related to age, over the past forty-odd years, in the NSW coal-mining industry, while the hazard for mines rises only slightly over time. That is, the duration dependence of the firm does not have the same duration dependence of the "plant," here the mine. The duration dependencies between firm and plant for manufacturing was found by Dunne et al. (1989) and Audretsch and Mahmood (1995) to be the same, although their results for firms was the reverse of ours: the older the manufacturing firm, the less likely is its imminent failure. But in our analysis, contrary to Hypothesis 2, the hazard of mines is significantly lower than that of firms (except for very young mines and firms, where the hazard of mines slightly exceeds that of firms), emphasizing the nature of the coal industry where the mine, not the firm, is the basis of the industry. Some firms sell their mines to other firms, which prolongs the life of the mines beyond that of the firm. The higher hazard of mines in the early years may result from a number of very small mines, with limited coal reserves, which have a short life. An established miner may open a short-term mine to exploit a small deposit.

Contrary to Hypothesis 3, we find no relationship between the size of coal-mining firms and their survival (in contrast to the results by others for manufacturing firms), but a positive relationship between size and survival for the plants (as also with manufacturing plants). To this extent, the coal-mining firm does behave differently from its “plant,” the mine, for which size is negatively related to hazard. Mines are expected to show economies of scale, and size/duration dependence can follow from this (as well as from the need for a large resource for a long life as discussed above), but, as mentioned above, the work of Lawrance (2002) and Lawrance and Marks (2006) indicates no economies of scale for coal-mining firms.

We conclude that the exit of firms from the extractive industry studied is strongly influenced by the depletion of reserves, and the associated higher costs and lower profitability. This is a senescence effect, or a liability of aging, which should also be evident in industries in which the core capital is depleted over time.

Others have suggested many reasons for the exit of firms: Audretsch and Mahmood (1994) referred to three strands of literature on firm exits, viz. firms operating at too small a scale; technological changes that increase costs and uncertainty; and ownership structure, where diversification can lead to exit. Jovanovic (1982) proposed that firms learn of their efficiency and those that are inefficient fail and exit. Love (1996) looked at the lack of managerial skills in the local area. Camerer and Lovello (1999) gave three possibilities for failure: first, "hit and run" enterprises; second, "expensive lottery tickets" in which both the risk of failure and the possible returns are high; and, third, over-confident entering firms. Others such as Mata and Portugal (2002, p.323) have found "survival to be determined by ownership advantages, size and growth strategies, the internal organization of firms, and by industry characteristics such as economies of scale, and industry entry and growth". While such aspects may be present in our industry, the data reveal that the reasons for exit are: resource exhaustion; financial difficulty (the financial difficulty may also arise from the depletion of reserves as discussed above); and takeover activity facilitated by the ready market for the assets to firms wishing to enter the industry (Tables 5 and 6).

Tables 5 and 6 here

If sunk costs are ignored, a firm could write-down the value of its mines to the market value and then invest in new technology, and thus survive. For a number of reasons, that we do not explore here, most firms in our industry act differently[18]. Where a firm is willing to tackle the existing cost and labour structure, and invest in new equipment, it may extend its duration significantly. Several firms in our industry appeared to do this and had a commitment to the industry, with resulting long durations.

The category of "incidental to other activity" in Table 5 refers to firms entering the industry by acquiring other firms for reasons other than their coal mine operations — such firms usually exit the industry within a short time. All major oil firms have exited the Australian (and international) coal industry, returning to their core business after finding little synergy between oil extraction and coal mining. Cibin and Grant (1996) examine the restructuring of the major oil firms. The exits of oil firms may be idiosyncratic.

In many previous studies, mergers are not recognized, which is an acknowledged disadvantage in their analysis (Evans 1987b). In our study, of 63 firm exits, only 12 were the result of mine exhaustion; the other 51 exits occurred by merger or by sale of all mines. Fifty-four percent of new entrants resulted from mergers with existing firms (resulting in the exit of the selling firm), and fourteen percent of new entrants resulted from buying part of an existing firm. As mergers and acquisitions are the predominant cause of exits here, we do not believe it is useful to examine models with different modes of entry and exit, as others have done.

Prices and price changes must influence duration, but there is no discernable pattern to coal prices over the period of the study. Coal prices fluctuate from year to year, and are dependent on world supply and demand, on the exchange rate, and on the price of substitutes such as oil and natural gas. From 1969 through 2001 the real price of coal fell by 24% — there were 20 years of price falls and 12 years of price rises. While falling prices will influence exits, they do not necessarily inhibit entries. Because firms cannot abandon their legal responsibilities of the mine site (such as rehabilitation) and because economic reserves may remain, almost always one firm's exit is accompanied by another firm's entry to the industry, or by an existing firm buying the firm or its mines as a going concern.

This paper is primarily empirical, but a natural extension would be to ask how our results might shed light on understanding the general phenomenon of the duration of firms and mines. This would entail a model. Such a model would not be simple: births and deaths are discontinuities, and it might be that techniques and insights from the

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[18] Selling an under-performing asset rather than trying to turn it around seems to find favour with

market-trading models of finance could be borrowed for such a model. As with stock traders, the purchaser will in general expect a higher return than does the seller, in this case perhaps because assets are traded at a discount. Since coal mining is relatively capital-intensive, discounted assets might be necessary (if not sufficient) for the firm's profitability: a new firm enters the industry with a favourable return on funds employed and then is subject to the further diminution of reserves and the consequential higher costs. The major influence on duration in this supply-constrained industry is the senescence effect of the depletion of the coal reserves, reflected in the increasing hazards over time for both firms and their mines.

Such a model should exhibit the hazards for firms and mines increasing with age, consistent with the depletion of the resource, and firm profitability falling over time (unless the firm acquires discounted mine assets). The model would include: an exogenously constrained supply of resources (limited in-situ reserves and scarce mining leases); the possibility of the firm's mines being opened, closed, or bought and sold as going concerns; and the possibility of the firms themselves entering, failing, and being bought and sold. As extraction costs rise with depletion, mines would become less profitable, based on their initial capital cost, cet. par. Firms should seek to maximise their profits, given their resources (including their in-situ coal resources, their managerial expertise, and perhaps their contracts) and given their expectations of future costs and revenues. The challenge for the model would be to endogenise the firm's decisions to enter, exit, buy and sell. It is possible that an agent-based model would be able to derive sufficient conditions to generate our observed duration results, at least (Tesfatsion and Judd, 2006).

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directors and financial analysts who may have lost confidence in the ability of the managers.

## 6. Conclusion

We have analyzed the durations of firms and their plants — the mines — in an extractive industry that is supply-constrained. Our analysis shows that the survival of coal firms and plants in the NSW export coal industry is inversely dependent on age, as proposed in Hypothesis 1. This result is consistent with the increasing cost of extraction as reserves are depleted. Contrary to Hypothesis 2, the hazard of firms is greater than the hazard of plants (mines). We can conclude that coal-mining firms exhibit different age dependence in duration than do their plants, the mines: the older the firm, the more likely to exit soon, despite the possibility of the firm surviving any single mine's exhaustion. This is in contrast to manufacturing firms and their plants.

Hypothesis 3 proposes a negative relationship between size and survival. We find no relationship between coal-mining firm size and hazard, while both coalmines and manufacturing plants exhibit a negative relationship between size and hazard. We propose a reverse causal relationship — their owners only allow mines that can survive for a long time to become large.

We find that the coal-mining firm and its plants are distinct and have different survival characteristics. While there is evidence that the depletion of reserves controlled by the firm influences its duration, the complete exhaustion of a mine is linked to exit of the firm in only 19% of our cases. Individual mines are frequently owned by a succession of firms, which is consistent with the observed lower hazard for mines than for firms. While firms may cease operations and leave the industry, the coalmine itself may remain open and so remain in the industry.

Our study is conducted on firms that are supply-constrained and are price takers — they are at the extreme of a continuum of these two conditions. Future research could usefully explore any trade-off between the degree of supply-constraint and the degree of market power on survival dependence. We expect that further research will reveal that other extractive mineral industries, and other industries in which "capital" of some sort is exhausted over time will exhibit similar characteristics, since there is no reason to believe that our extractive industry is unique.

## **Appendix** 1. **Data base**

Our data are from the NSW black-coal industry, part of the Australian black-coal industry, ANZSIC[19] code 1100. While other states produce a small amount of coal from a small number of coalmines, the coal is not exported, and is generally sub-bituminous.[20] We define firms as those entities that control the marketing decisions of a single coalmine or a group of coalmines. In most cases, control results from greater than 50% ownership, but may result from being the largest shareholder (less than 50%, but with effective control) or by having a management agreement with other owners. The designated "firm" is the ultimate owner of the mining assets, although in many cases it is not the immediate corporate entity publicly listed as the owner. Provided a firm maintains a controlling interest in at least one coalmine, it survives: its status does not alter in our analysis if one or more of its mines closes or is disposed of. We delete the small number of firms (in electricity supply, steel manufacturing and cement manufacturing) that mine coal solely for their own consumption[21].

[19] Australian and New Zealand Standard Industrial Classification
[20] In 1995-96 South Australia and Western Australia produced 2,499,000 tonnes and 5,897,000 tonnes respectively of sub-bituminous coal, and Tasmania produced 390,000 tonnes of bituminous coal McLennan, W. (1998) Australian mining industry 1995-96*,* Australian Bureau of Statistics, Canberra..
[21] These are deleted because they do not participate in the open market and so are not directly influenced by competition and prices.

The measure of the size of the operator is the annual quantity of coal produced by the mines controlled by the operator. This is the most appropriate unit of size—assets value is not useful, as a number of coalmine owners now use contractors for a large portion of the operations and this greatly reduces the assets involved (it is not possible to capitalise the value of the contracts, as such information is not generally available). Moreover, it is possible that many coalmines are over-capitalised. Asset value can be misleading in relation to effective size.

Production is a reasonable measure of "size", and measure of market share, as coal is bulky and expensive to store, and frequently is liable to spontaneous combustion in storage. In general, all coal produced is sold without any appreciable time lag. Also, the high cost of production and the low profit margin frequently force stock sales to provide cash flow.

The data for firms with descriptive statistics are shown in tables 1 and 2 and for mines in tables 3 and 4.

For firms the analysis period is from 1 July 1969 to 30 June 2001, and for mines it is from 1 July 1949 to 30 June 2001. The year ending 30 June 1960 is used for firms as that was approximately the start of the major export market for Australian coal (which effectively started a new industry) and we have earlier data on only a few firms. We record the age of mines from the year ending 30 June1950 because that is the year in which the first "continuous mining" machinery was introduced (Eyre 1988)[22].

[22] Before this mechanisation, annual production from most mines was very low, and many had very long durations.

**Sources**

The first references used are the Joint Coal Board *Annual Reports* (Joint Coal Board, various-a), *Black Coal in Australia* (Joint Coal Board, various-b)and the *NSW Coal Industrial Profile* (NSW Department of Mineral Resources, various-b) which record coal mine ownership. The Joint Coal Board *Annual Reports* give a list of all operating mines and their owners, only from 1975-76 , and even then no indication is given of the ultimate owners. From the 1984 edition of *Black Coal in Australia*, details of ownership structure are recorded and this continues in the *NSW Coal Yearbook* (Joint Coal Board, 1989-b) until the *NSW Coal Industry Profile* takes over. Prior to 1975-76, the Joint Coal Board only comments on "major owner groups" and does not record any operator's production below 500,000 tons per annum, although some changes in ownership are recorded. *MINFO Mining and Exploration Quarterly* (NSW Department of Mineral Resources, various-b) is an excellent reference on opening and closing of mines, although its first edition is only in October 1983.

The Joint Coal Board workers' compensation records (available only from the Joint Coal Board) are a major reference; they record owners and mines and dates of opening and closing of mines. The "opening" date is not always accurate for the start of a mine, but gives a date at which the mine is certainly in operation, so it is known that the start date was that date or some date before it.

The annual reports of those companies that were listed on the stock exchange (some have since been de-listed) are checked and, in certain cases, the records of the NSW Corporate Affairs Commission. Such records frequently give the date of acquisition or disposal of mines. *Jobson's Mining Year Book* (Dun and Bradstreet, 1996), the *Coal*

*Manual* (Tex Report, various), the *International Coal Report* (McCloskey, various) were searched, together with company and coal histories: *The Coal Masters* (Jay, 1994), *Wallsend and Pelton Collieries* (Tonks, 1990), *Coalfields and Collieries of Australia* (Power, 1912), *Miners in the 1970s* (Thomas, 1983), and *A History of the Miners' Federation of Australia* (Ross, 1970). Newspaper records, particularly the *Australian Financial Review* and *Sydney Morning Herald*, are good sources of major events such as the purchase of a company.

The interpretation of these records was assisted greatly by the personal knowledge of the author, who held senior management positions in the coal industry from 1975 to 1995, and was a member of the executive of the NSW Colliery Proprietors' Association and the Australian Coal Association. In a number of cases, personal knowledge and private company records are used, and discussions with associates in the industry were very helpful in determining the ownership of some mines.

**Entry and exit**

When a company acquires operating coal assets, and becomes an "operator" (i.e. obtains a controlling interest in a coal operation), the "entry" date is simply the date of acquisition.

When only the month of the acquisition is known, the first of the month is used, and if only the financial year of the change is known (in a few cases), July 1 is used. Ownership is traced back to the ultimate owner, rather than stopping at the first owner, as many operators own mines through subsidiary companies.

## Appendix 2

Turnbull (1974) described a method of correcting for left censoring[23], and Klein and Moeschberger (1997) gave a simple algorithm for this procedure, with the durations arranged into groups (producing a new time grid $t_j$). The Kaplan-Meier product-limit estimator for this time grid is found by ignoring left-censored data occurring at $t_i$. Modified Kaplan-Meier survivor functions are found by progressive iteration, which "estimates the probability that the event occurs at each possible time $t_i$ less than $t_j$" using the idea of "self-consistency" (Klein and Moeschberger 1997, p.127), based on the initial product-limit estimator. We use this method in our analysis of firms and find that the third iteration (which adjusts for presence of left-censored data) produces a stable survivor function that is very close to the first estimate of the survivor function determined by deleting the left-censored data (Table 1).

The Klein and Moeschberger (1997) technique is based on increasing the number of other firms extant up to the time of the exit of each left-censored firm proportionately to the change in the survivor function. This assumes that the data prior to the start of the study (the left-censored firms) are similar in form to that of the data post the start. For mines, this assumption is not valid. Prior to 1950, mines were very small and hand-worked, with little mechanisation (Figure 2 above). Of the 46 left-censored mines, we have been able to find actual start dates for 17. Their average age at 1960 was 46 years,

[23] Dunne et al. (1988), Merrell (2000) and Disney et al. (2003) handle left-censored data by including establishments that entered in the period under study only and ignoring establishments already in existence.

and using the mines' actual start dates for the analysis would have resulted in a number of mines over 100 years old.

Moffitt and Rendall (1995) and Iceland (1977) analyzed their data twice: including the left-censored data and excluding them. As there are a large number of left-censored mines, deleting them reduces the amount of information available and could introduce selection bias. Assuming that the left-censored mines are born at the start of the study has some justification because of the low prior production. The survivor functions produced by the two methods are not greatly different, and we use the average of a survivor function produced by deleting the left-censored data and one produced by including the left-censored data, using the Kaplan-Meier product limit estimator.

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**Table 1.** Firm data

| Age | Total number | Left Censor | Right censored[1] | Number of exiting firms | Observed survivor function[2] | Survivor function 3d iteration | Integrated hazard[3] |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | 1 | 1 | 0 |
| 2 | 4 | 0 | 2 | 2 | 0.969 | 0.966 | 0.034 |
| 3 | 5 | 0 | 3 | 2 | 0.936 | 0.931 | 0.071 |
| 4 | 8 | 0 | 3 | 5 | 0.851 | 0.838 | 0.176 |
| 5 | 4 | 0 | 2 | 2 | 0.815 | 0.799 | 0.225 |
| 6 | 4 | 0 | 1 | 3 | 0.758 | 0.736 | 0.306 |
| 7 | 5 | 0 | 0 | 5 | 0.661 | 0.629 | 0.463 |
| 8 | 6 | 0 | 0 | 6 | 0.544 | 0.501 | 0.691 |
| 9 | 3 | 0 | 0 | 3 | 0.486 | 0.437 | 0.829 |
| 10 | 1 | 0 | 0 | 1 | 0.467 | 0.415 | 0.879 |
| 11 | 4 | 1 | 0 | 4 | 0.408 | 0.351 | 1.047 |
| 12 | 7 | 1 | 3 | 4 | 0.350 | 0.291 | 1.235 |
| 13 | 6 | 2 | 0 | 6 | 0.257 | 0.198 | 1.619 |
| 14 | 4 | 1 | 0 | 4 | 0.187 | 0.137 | 1.990 |
| 15 | 5 | 2 | 0 | 5 | 0.117 | 0.079 | 2.539 |
| 16 | 2 | 1 | 0 | 2 | 0.093 | 0.062 | 2.785 |
| 18 | 1 | 0 | 0 | 1 | 0.070 | 0.045 | 3.096 |
| 19 | 1 | 1 | 0 | 1 | 0.093 | 0.042 | 3.170 |
| 20 | 2 | 1 | 0 | 2 | 0.062 | 0.027 | 3.621 |
| 21 | 2 | 1 | 0 | 2 | 0.031 | 0.014 | 4.288 |
| 24 | 1 | 1 | 0 | 1 | 0.031 | 0.013 | 4.343 |
| 35 | 1 | 0 | 0 | 1 | 0 | 0 | |
| 40 | 1 | 1 | 0 | 1 | | | |
| 42 | 1 | 1 | 1 | 0 | | | |
| Totals | 78 | 14 | 15 | 63 | | | |

F06

[1] there is one double-censored firm
[2] excluding left-censored data
[3] –ln(suvivor function from 3d iteration)

**Table 2**. Descriptive statistics for firm data.

| | Size | Queensland share |
|---|---|---|
| Mean | 0.032 | 0.276 |
| Standard Deviation | 0.042 | 0.180 |
| Range | 0.172 | 0.458 |
| Minimum | 0.0002 | 0.000 |
| Maximum | 0.173 | 0.458 |

| | Number |
|---|---|
| Total firms | 78 |
| Right Censored | 15 |
| Left censored | 14 |
| Foreign firms | 20 |
| In period 1 | 26 |
| In period 2 | 52 |

F07x SPSS3

**Table 3.** Mine data

| Age (years) | Total number | Number left-censored | Number exiting | Number right-censored[1] | Survivor function (incl. left-censored) | Survivor function (excl.left-censored)) | Estimated hazard[2] | Integrated hazard[2] |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 3 | 11 | 0 | 7 | 4 | 0.959 | 0.944 | 0.048 | 0.050 |
| 4 | 6 | 0 | 5 | 1 | 0.929 | 0.903 | 0.038 | 0.088 |
| 5 | 6 | 0 | 4 | 2 | 0.905 | 0.869 | 0.032 | 0.120 |
| 6 | 4 | 0 | 3 | 1 | 0.887 | 0.844 | 0.025 | 0.145 |
| 7 | 4 | 0 | 3 | 1 | 0.868 | 0.818 | 0.026 | 0.171 |
| 8 | 6 | 0 | 4 | 2 | 0.843 | 0.783 | 0.036 | 0.207 |
| 9 | 7 | 0 | 3 | 4 | 0.824 | 0.756 | 0.028 | 0.235 |
| 10 | 3 | 0 | 3 | 0 | 0.805 | 0.728 | 0.030 | 0.266 |
| 11 | 10 | 1 | 7 | 3 | 0.760 | 0.672 | 0.067 | 0.334 |
| 13 | 4 | 0 | 3 | 1 | 0.740 | 0.643 | 0.035 | 0.369 |
| 15 | 5 | 1 | 3 | 2 | 0.719 | 0.623 | 0.029 | 0.399 |
| 16 | 2 | 0 | 2 | 0 | 0.706 | 0.603 | 0.026 | 0.424 |
| 17 | 2 | 0 | 2 | 0 | 0.692 | 0.582 | 0.027 | 0.451 |
| 18 | 4 | 0 | 3 | 1 | 0.671 | 0.552 | 0.041 | 0.492 |
| 19 | 4 | 0 | 2 | 2 | 0.658 | 0.531 | 0.029 | 0.520 |
| 20 | 9 | 0 | 2 | 7 | 0.643 | 0.509 | 0.031 | 0.551 |
| 21 | 3 | 0 | 1 | 2 | 0.636 | 0.497 | 0.018 | 0.569 |
| 22 | 5 | 1 | 3 | 2 | 0.612 | 0.470 | 0.046 | 0.614 |
| 23 | 3 | 2 | 2 | 1 | 0.596 | 0.470 | 0.013 | 0.629 |
| 24 | 2 | 2 | 2 | 0 | 0.580 | 0.470 | 0.014 | 0.645 |
| 25 | 7 | 2 | 6 | 1 | 0.531 | 0.411 | 0.105 | 0.753 |
| 26 | 1 | 1 | 1 | 0 | 0.523 | 0.411 | 0.008 | 0.762 |
| 27 | 2 | 1 | 2 | 0 | 0.506 | 0.396 | 0.034 | 0.797 |
| 28 | 1 | 0 | 1 | 0 | 0.498 | 0.381 | 0.027 | 0.823 |
| 29 | 3 | 0 | 2 | 1 | 0.481 | 0.350 | 0.057 | 0.878 |
| 30 | 6 | 3 | 4 | 2 | 0.447 | 0.334 | 0.058 | 0.940 |
| 31 | 2 | 1 | 2 | 0 | 0.430 | 0.317 | 0.046 | 0.986 |
| 32 | 4 | 1 | 3 | 1 | 0.403 | 0.281 | 0.086 | 1.072 |
| 33 | 5 | 4 | 4 | 1 | 0.368 | 0.281 | 0.044 | 1.126 |
| 34 | 3 | 1 | 2 | 1 | 0.349 | 0.261 | 0.061 | 1.187 |
| 35 | 1 | 0 | 0 | 1 | 0.349 | 0.261 | 0.000 | 1.187 |
| 37 | 2 | 2 | 2 | 0 | 0.330 | 0.261 | 0.028 | 1.219 |
| 38 | 6 | 2 | 4 | 2 | 0.291 | 0.214 | 0.150 | 1.377 |
| 39 | 4 | 3 | 3 | 1 | 0.260 | 0.214 | 0.054 | 1.441 |
| 40 | 1 | 1 | 1 | 0 | 0.249 | 0.214 | 0.021 | 1.464 |
| 41 | 1 | 0 | 1 | 0 | 0.238 | 0.178 | 0.105 | 1.569 |
| 42 | 1 | 1 | 1 | 0 | 0.227 | 0.178 | 0.023 | 1.596 |
| 43 | 2 | 2 | 2 | 0 | 0.206 | 0.178 | 0.048 | 1.651 |
| 44 | 3 | 2 | 2 | 1 | 0.184 | 0.178 | 0.053 | 1.709 |
| 45 | 1 | 0 | 0 | 1 | 0.184 | 0.178 | 0.000 | 1.709 |
| 46 | 1 | 1 | 1 | 0 | 0.172 | 0.178 | 0.033 | 1.743 |
| 47 | 1 | 1 | 1 | 0 | 0.159 | 0.178 | 0.036 | 1.779 |
| 49 | 6 | 4 | 5 | 1 | 0.098 | 0.119 | 0.359 | 2.221 |
| 51 | 5 | 4 | 2 | 3 | 0.070 | | 0.143 | 3.351 |
| 52 | 2 | 2 | 0 | 2 | 0.070 | | 0.000 | |
| Totals | 171 | 46 | 116 | 55 | | | | |

F10c

[1] There are four double censored mines

[2] Calculated from the average of the two survivor functions

**Table 4**. Descriptive statistics for mine data.

| | Size underground mines | Size surface mines | Age underground mines | Age surface mines |
|---|---|---|---|---|
| Mean | 0.009 | 0.015 | 25.11 | 14.40 |
| Standard Error | 0.001 | 0.002 | 1.30 | 1.56 |
| Median | 0.009 | 0.009 | 24 | 11 |
| Standard Deviation | 0.006 | 0.016 | 14.70 | 10.23 |
| Range | 0.027 | 0.055 | 49 | 31 |
| Minimum | 0.000 | 0.001 | 3 | 3 |
| Maximum | 0.027 | 0.056 | 52 | 34 |
| Count | 128 | 43 | 128 | 43 |

F10dx

**Table 5.** Results of Cox regression for firms

| | Coefficient | SE | df | Significance |
|---|---|---|---|---|
| Size | 3.098 | 3.60 | 1 | 0.389 |
| Period[1] | 1.756 | 1.74 | 1 | 0.314 |
| Foreign | -0.129 | 0.34 | 1 | 0.699 |
| Queensland share[2] | -4.431 | 4.766 | 1 | 0.352 |

F07 spss3

[1] testing of differences between periods 1970-1985 and 1985-2001

[2] Queensland proportion of total of NSW and Queensland production

**Table 6.** Results of Cox regression for mines

| Including left-censored data | Coefficient | SE | df | Significance |
|---|---|---|---|---|
| Size | -89.77 | 16.62 | 1 | 0.000 |
| Type of mine (surface or underground) | 0.83 | 0.25 | 1 | 0.001 |

| Excluding left-censored data | Coefficient | SE | df | Significance |
|---|---|---|---|---|
| Size | -129.11 | 22.27 | 1 | 0.000 |
| Type of mine (surface or underground) | 0.42 | 0.27 | 1 | 0.117 |

**Figure 1**
**Firm duration data**

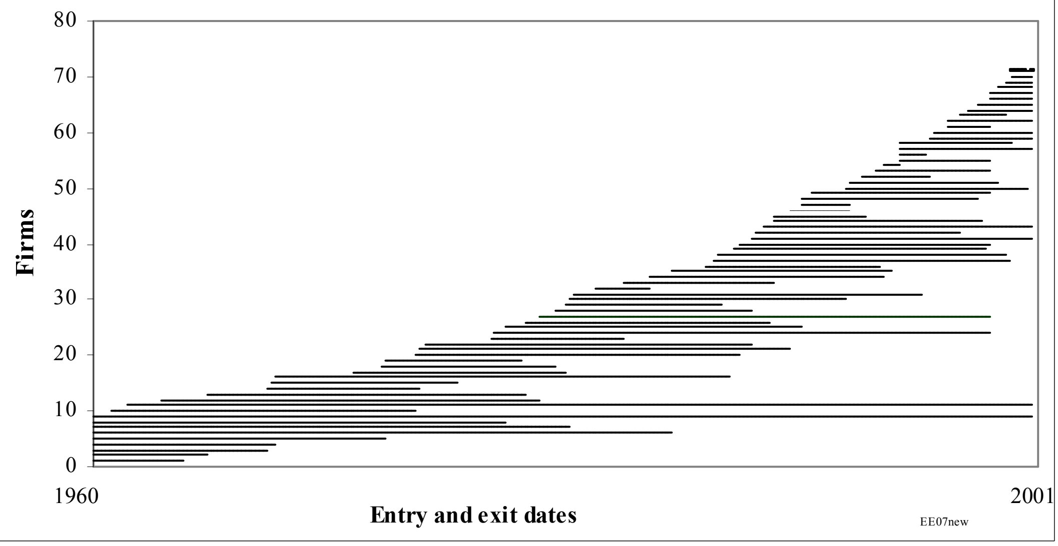


**Figure 2**
**Growth of annual average firm and mines size**

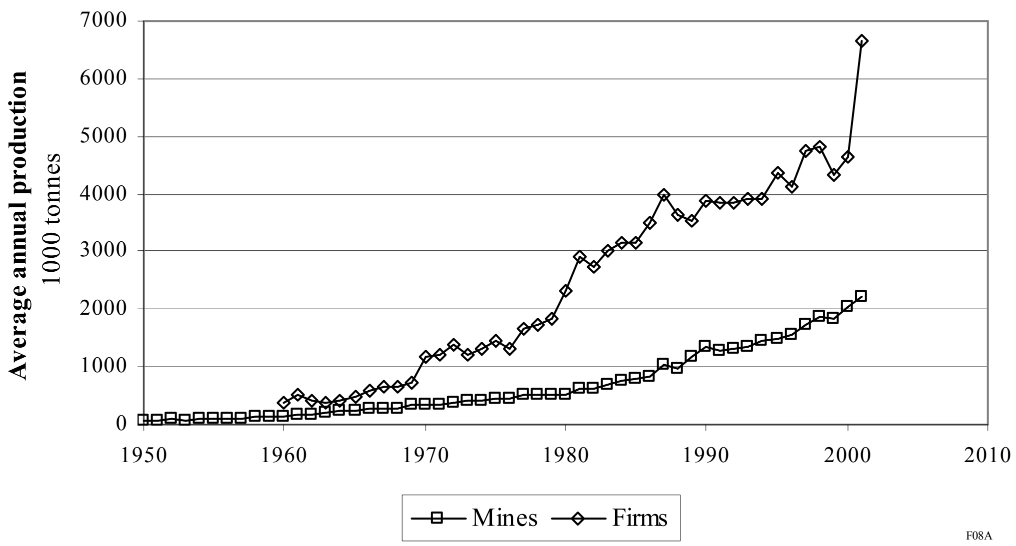

**Figure 3**
**Hazards of Firms and Mines**

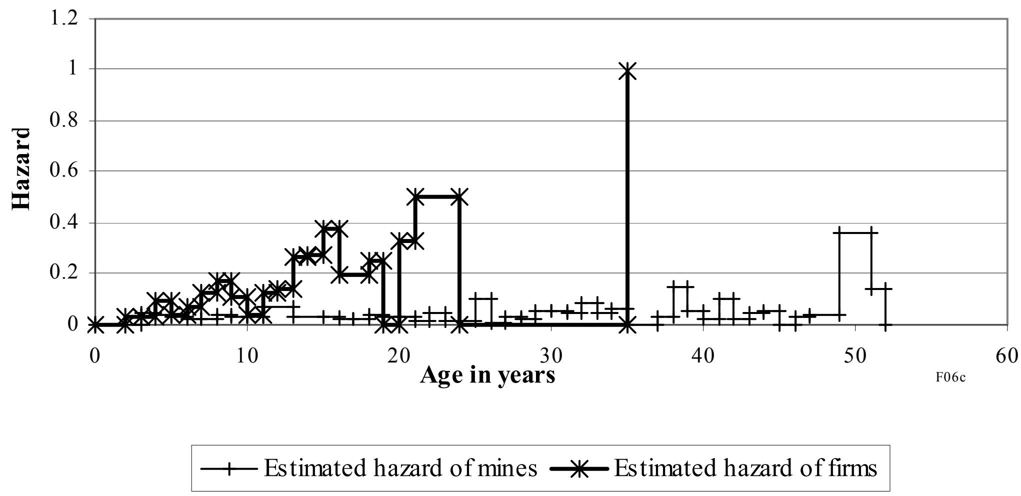


**Figure 4**
**Integrated hazards of Firms and Mines**

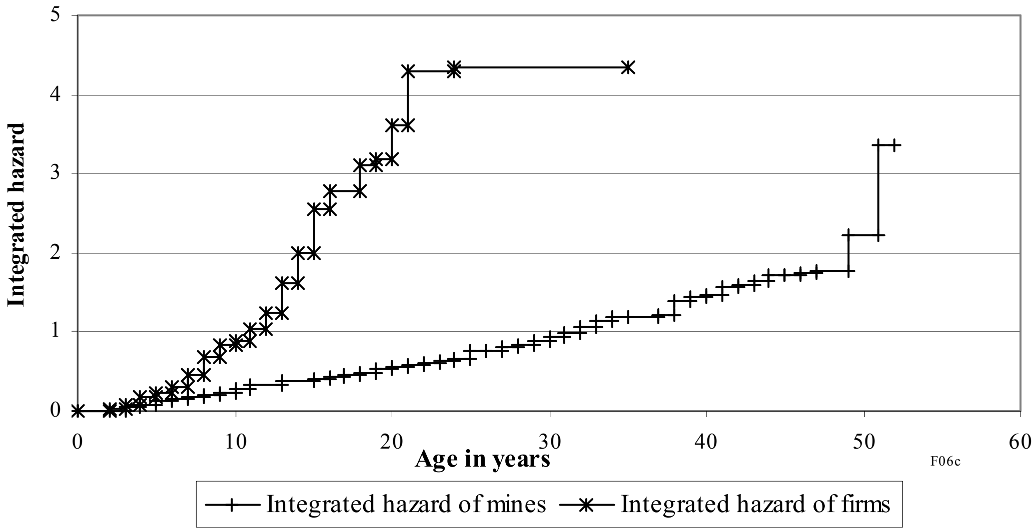

**Figure 5**
**Testing for proportional hazards**