Predicting Failure of Developmental Gold Mining Projects

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ABSTRACT

We investigate firm level financial and non-financial information and their association with project failure for a sample of pre-production gold development firms. We choose pre-revenue generating 'single project' mining companies, since project failure is synonymous with company failure for these firms. The setting is interesting due to the high information asymmetry and limitations of the GAAP-based Altman Z-score in this context. We apply a definition of project failure and compare both financial and non-financial predictors. Failure is found to be driven by whether the deposit is open pit or underground, and whether cash cost of production is disclosed at feasibility completion.

INTRODUCTION

During difficult economic times – such as the recent Global Financial Crisis [hereafter GFC] – mineral exploration and development firms in particular experience an increase in the frequency of bankruptcy, as commodity prices decline and essential development funding becomes scarce. The onset of the GFC had a predictable effect on mine closure, deferral, curtailment and company failure. Table 1 lists the name and date of Australian mining companies entering external administration following the onset of the GFC. What is interesting is that it is mainly single mine developers and early stage single mine production companies that have failed. Absent from Table 1 are the established multi mine producers who were beneficiaries of strong underlying commodity prices during the earlier mining boom, which carried over to later years through fixed prices in long-term forward contracts. The GFC still affected some of the mining producers' high-risk activities, even if bankruptcy did not result. The impact of the GFC on companies engaging in mineral production is visible in Table 2. For mining explorers and developers, the onset of the GFC meant that project failure prediction became more important as a potential risk mitigation and avoidance tool.

[Table 1 about here]

Traditionally, the Altman (1968) Z-score is utilised to estimate the likelihood of firm bankruptcy, based upon five key financial ratios. For some types of firms, non-financial information compliments (or even dominates) financial information when measuring the creation of value (Amir and Lev, 1996). It is likely that for these firms non-financial information will compliment (or even dominate) the Altman Z-score in measuring the likelihood of failure (the inability to create value). The Altman Z-score utilises ratios based on sales, earnings before interest and tax, and retained profits. For development firms that are yet to generate any sales, the Altman Z-score will not be able to distinguish value-generating from value-destroying activities. The Altman Z-score also utilises a leverage ratio, whereas most high-risk development firms do not issue debt capital.[1] Our objective is to develop a model for predicting the failure of developmental mining projects based on financial and non-financial information.

[Table 2 about here]

It is puzzling, given the cyclical nature of the mining industry and its susceptibility to exogenous shocks like the GFC, that a positive model of mining company failure has yet to be developed in the Australian financial economics literature. Moreover, this question is arguably of additional interest owing to the industry's sizeable contribution to the Australian economy. For example, a recent article in the Australian Financial Review suggests that mining company investment will account for 48.4% of total private capital expenditure in 2010-2011, compared to just 11% from manufacturing.[2] The relatively large size of the Australian mining industry compared to other industries has an additional benefit for the researcher. It means that constructing a viable sample of failed mining projects for study does not present a problem.

The definitive analytical work on mine closure is Brennan and Schwartz (1985). The propositions of Brennan and Schwartz (1985) relating to mineral *producers* were empirically examined in Moel and Tufano (2002), who focused on mine closure for gold producers in the US using a sample period from 1988-1997. Our study can be distinguished from Moel and Tufano (2002) to the extent that our focus is gold project *developers*.[3] Information asymmetry is arguably higher for these companies compared to established producers (Ferguson and Crockett, 2003), so assessing the vulnerability of early stage companies to failure will be of value to investors.

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[1] The successful ex post issue of bank debt is therefore viewed as a signal of a relatively low risk project. However, none of the sample firms have issued any ex ante project related finance prior to the feasibility completion.

[2] Australian Financial Review 26th February, 2010, p.7.

[3] For the purposes of this study, a 'developer' is defined as a mining venture that has completed a feasibility study but is yet to commence production activities.

The failure model articulated in this study features single project gold developers who in the development phase record only minor product revenues, although ultimately may or may not end up in production. The advantage of considering this type of firm is that information asymmetry is higher given the absence of an established earnings history. Further, since the focus of a development company is typically on a single project, deposit properties can be contrasted with traditional financial distress predictors such as the Altman Z-score in assessments of project outcome.

We contribute to the extant literature in three ways. Firstly, by examining developmental mining projects, we highlight a setting where applying the traditional distress prediction model, the Altman Z-score, is problematic. Further studies may consider other development settings where the accounting-based Altman Z-score is similarly inapplicable (such as start-up IT and biotechnology firms). We therefore contribute to understanding the limitations of the Altman Z-score, and encourage future research in this area.

Secondly, failure prediction is particularly important during tough economic times, such as the recent GFC. Therefore solving the problems inherent in applying the traditional Altman Z-score to pre-production mining firms has also become important. In lieu of the deficiencies of accounting-based financial ratios for development firms, we offer an alternate model that emphasises the role of context-specific non-financial information in predicting the failure of developmental mining firms.

Last, we make a contribution to managers and capital providers associated with development mining firms by empirically highlighting the information that is relevant to estimating the vulnerability of mining development projects to failure. Highlighting the information that is useful to decision-makers in this context also adds to our understanding of the importance of non-financial disclosure.

THE MINE LIFE CYCLE

In terms of structure, the Australian mining industry is typified by a large number of early-stage exploration firms, a mid-sized number of middle-stage mine developers (successful explorers) and a small number of late-stage multi-mine producers. As depicted in Table 1, the probability of a multi-mine producer failing compared to failure of a single mine developer is much lower, although it does happen from time to time (*e.g.* the failure of Sons of Gwalia in 2004).[4]

The development life cycle generally commences with a mineral explorer either applying for a mining tenement or making a tenement/project acquisition. The explorer then begins an initial evaluation phase which may include surface geochemical sampling and mapping or ground geophysics. If initial indicators look promising, sampling through either costeaning or shallow air core drilling may be undertaken. For prospects demonstrating greater potential, more expensive and deeper reverse circulation (RC) drilling is then conducted. Ideally the firm seeks a discovery, in which case the explorer will conduct further RC and diamond drilling campaigns with the objective of conducting metallurgical test work and producing a defined resource.[5]

Once a resource has been defined, the company will typically conduct a scoping study with the objective of producing some preliminary 'ballpark' or 'back of the envelope' economics in order to justify further drilling and a more intensive pre-feasibility study. Should the pre-feasibility study be successfully completed it will lead to the commencement of an often costly and lengthy 'full' or 'bankable' or 'definitive' feasibility study. The developer must then secure regulatory approvals along with mine financing before

[4] Sons of Gwalia was the victim of a toxic hedge book. Other notable hedging casualties include Pasminco.
[5] Projects that are acquired may have certain preliminary milestones such as resource definition already completed

construction and production may begin.[6] Our study examines a sample of pre-cash flow generating gold development companies that have reported the completion of a feasibility study to the Australian Securities Exchange (ASX).[7]

Given the capital constraints imposed on exploration firms, the fact that these firms have minimal product revenues (less than 5% of market capitalisation) normally implies that they are also single project firms, since developing two projects simultaneously is less common due to deposit complexities and technical and financial limitations. Consequently our sample constitutes smaller gold development firms that hold an existing deposit (normally only one) where the firm has invested in the completion of a feasibility study as a means to ultimately developing that deposit.

DEFINITION OF FAILURE

Altman (1968) includes a simple definition of failure – firms filing for bankruptcy. This definition would unnecessarily restrict our sample to total company failure (as applied in table 1 – which includes 2 firms form the study sample). Brennan and Schwartz (1985) and Moel and Tufano (2002) principally examine failure for producing mining projects, defining failure with reference to the closure and/or abandonment of a previously operating mine. For development mining projects, Brennan and Schwartz (1985) define failure as "postponing an investment decision" where an 'investment decision' relates to the decision "to proceed with construction."

[6] Junior mining exploration and development companies face many difficulties in transitioning to producer status. Despite significant exploration effort, 'greenfield' precious and base metal discoveries are surprisingly rare events in Australia. In Australia the number of recent +1million ounce gold 'greenfields' discoveries are very small. The list of projects post 2000 would include Thunderbox (DalrympleResources and Lionore Mining), Tropicana (Independence Group and Anglogold Ashanti) and McPhillamys (Alkane Resources and Newmont).

[7] We note that the majority of our announcements are referred to as feasibility completions, although some firms will subsequently undertake an additional 'optimised' or 'definitive' feasibility study. In such cases however the market has a good idea of project economics from the feasibility completion. In a small number of cases we utilise 'pre-feasibility' or 'scoping' study completions since these were the last feasibility related announcements prior to mine financing. We acknowledge the use of differing terminology by firms is a limitation in the study.

Given the sequential nature of the mine life cycle, care needs to be taken in defining 'failure' corresponding to the feasibility completion milestone. For example the definition of 'failure' is not as simple as an ultimate mine closure, since some deposits will never get to the production stage. We adopt a failure definition for development projects derived from propositions in Brennan and Schwartz (1985) and classify a project as failed if it has one of the following attributes:

1. The project fails to attract mine financing in the 5 years following feasibility completion;
2. The project is disposed of in the 5 years following feasibility completion;
3. The project is deferred or production is suspended within 5 years of feasibility completion; or
4. The company enters into external administration within 5 years of feasibility completion.

FACTORS ASSOCIATED WITH MINE FAILURE

Moel and Tufano (2002) empirically examine factors associated with mine failure for producing mines. Although these factors largely overlap with the factors associated with mine failure for developing (pre-producing) mines, there are also some differences (such as development costs). By choosing to examine pre-cash flow generating firms that are largely single project, we are able to focus on a much 'cleaner' sample (less project-firm distortions) and the attributes of gold mining projects themselves can potentially yield valuable insights into failure in this industry more generally. We compare these idiosyncratic gold deposit attributes against traditional financial distress predictors applied in the financial economics literature. Our model predictors include the following factors:

Gold price levels and gold price changes

Following Moel and Tufano (2002), we consider gold price levels and changes subsequent to the feasibility study as a potential predictor of project failure. Managers are likely to have a greater propensity to abandon a project if the commodity price environment is less favourable (Moel and Tufano, 2002). We investigate for our sample whether there is an association between project failure and gold price levels and changes subsequent to feasibility completion with our proxies *GOLD_PRICE* and *GOLD_MOVE,* respectively, which pick up levels in gold price at the completion of the feasibility study and changes in gold prices over the following 5 year period.

Nature of mining activities – underground or open pit

Mineral deposits typically come in two forms – either open pit or underground. With open pit deposits, mine overburden is removed exposing the ore body allowing removal of ore grade material to the processing plant. Open pit mining is preferred when the ore body is situated in relatively close proximity to the surface. This feature minimises the extent of costly waste material to be removed, thus lowering expected cash costs. In contrast, underground operations are higher risk with deeper ore bodies and safety issues from possible rock falls or flooding.[8] Given the higher risk and greater information asymmetry involved in complex underground mines relative to open pit mines, mine failure may be more pervasive for underground mines. We investigate whether this association is evident in our sample with our dummy variable *OPEN_PIT*. Moel and Tufano (2002) include *historic* operating costs as a factor associated with failure, but not all feasibility reports disclose *predicted* costs (as discussed later). Our *OPEN_PIT* variable can be interpreted as a proxy for a major determinant of development and operating costs. Moel and Tufano (2002) include their own open pit variable to proxy for the costs of shutting and re-opening a producing mine.

Toll Milling

[8] An example of an Australian underground mine impacted by rock falls is the Beaconsfield Mine in Tasmania. Other underground mines have been impacted by flooding such as the Browns Creek Gold mine in New South Wales.

A control for firms electing to undertake toll milling arrangements where ore from an existing deposit owned by the company is processed through third party production facilities is included in the model. Toll milling removes the necessity for the construction of an on-site processing plant and the need for associated construction financing and hence substantially lowers project risk. A dummy variable *TOLL_MILLING* is used to indicate toll milling arrangements. Our *TOLL_MILLING* variable can be interpreted as a proxy for a major determinant of development costs.

Second Hand Plant

In their feasibility studies, certain firms specify the use of second hand plant as a means to reducing the project development costs, which may signal a lower quality project. There are often issues associated with second hand plants being tailored to a new deposit. The use of second hand plant also signals capital scarcity in the sense that the firm may not be able to afford new plant as either debt or equity financing is not forthcoming. A dummy variable (coded 1 for second hand plant usage) is included in the failure model (*SECOND_HAND*).

Capitalised exploration expenditure

Exploration and development companies are allowed to defer exploration expenditure where the future of the project is uncertain under the Area of Interest Method allowed under AASB 6 through grandfathering provisions in IFRS transition.[9] Higher amounts of capitalised exploration may signal a better quality project (lower likelihood of failure). However, a lower amount may reflect accounting conservatism which may signal conservatism more broadly in terms of project development assumptions and hence greater likelihood of a successful development. Given competing arguments for the direction of the association, we pose this as

[9] IFRS transition does not affect this study due to specific grandfathering provisions in IFRS 6 which: ‘Permits entities to continue to use their existing accounting policies for exploration and evaluation assets, provided that such policies result in information that is relevant and reliable’ (Source: Deloitte IAS Plus, January 2005 – Special Edition. http://www.iasplus.com/iasplus/0501ifrs6.pdf (Link active 08/10/2010.))

an empirical question. *DEFERRED_ASSET* proxies for the stock of deferred or capitalised exploration and evaluation expenditure reported by the company in the fiscal year prior to feasibility completion.

Cash Costs

The expected cash cost of production is central to the assessment of a deposit's viability (Moel and Tufano, 2002). However, not all projects disclose cash costs upon completion of their project feasibility study. Arguably, the non disclosure of cash costs is bad news regarding project viability. Accordingly, we include a dummy variable *CASH_COST* indicating whether cash costs are released as part of the feasibility study disclosure.

Altman Z-score

Altman (1968) identifies financial ratios that predict corporate bankruptcy. Whilst financial information for developmental mining companies may be less useful in predicting project outcomes, we include the Altman Z-score (*ALTMAN_Z*) in our model consistent with prior literature – predicting a negative association between the Z-score (including its individual components) and project failure.

Company Size

Following Moel and Tufano (2002), we include company size as an additional control variable. Consistent with the notion of risk being inversely related to company size, we expect larger development companies to be less likely to fail. We include market capitalisation recorded on month end prior to the feasibility release as our proxy for firm size (*SIZE*).

Informed Shareholders

Moel and Tufano (2002) included five variables on ownership structure, but none were statistically significant. We include a measure of investor sophistication based on director's shareholding which is scaled by issued capital to provide a measure of the director's percentage ownership in a company's issued capital (*DIRSH*). We do not specify a sign on this co-efficient due to competing explanations. For example, given the high information asymmetry present in gold developers, it could be argued that higher director ownership may signal positive private information and thus director ownership is negatively related to failure. Alternatively, higher information asymmetry may allow large director shareholdings or the presence of block-holders to more effectively expropriate wealth from smaller shareholders. In this case we would expect higher director shareholding to be positively related to failure. Sensitivity tests are also conducted based on the percentage shareholding of the top 20 shareholders (*TOP_20*) which proxies for the level block-holders on the company's share register.

Cash Burn

Prior to the commencement of operations of a revenue generating project, development firms' only source of cash is from capital providers – typically the equity market (due to the high risk involved with development firms). Raising additional equity funds to pay for further project development can be difficult, particularly in tough economic times such as the GFC. Firms with relatively more cash (and other financial assets) on hand will be able to survive longer without the need to return to the equity market or generate funds internally. We expect a negative association between the ratio of cash on hand to annual cash requirements (*CASH_BURN*).

DATA

The sample comprises 85 gold projects representing the full sample of known feasibility disclosures made by pre-production single-project gold developers over the

January 1990 to December 2007 sample period.[10] The sample was hand collected from text searches of the ASX announcement archive on Huntleys Datanalysis which was cross checked on Factiva using keywords such as 'feasibility' and 'gold'. Given that mining projects are often polymetallic, to be considered a 'gold' project the feasibility study needed to report expected revenues of at least 60% gold. This was determined by utilizing feasibility report production forecasts at spot commodity prices rates at the feasibility completion date. The 60% rule conforms to industry heuristics in terms of what constitutes a 'gold' project.[11] Descriptive statistics reported in Table 3 for the proportion of gold product revenue to market capitalisation (*PRODUCT_SALES*), indicates that 72 firms or 85.7% of the sample report zero gold sales and 98.8% of firms report *PRODUCT_SALES* of 2% or less of market capitalisation.[12] This confirms that these companies are non-production companies, with some sourcing minor gold revenues from net smelter returns or royalties derived from prior project farm-outs. Sample constituents are identified through searches of ASX announcement histories.

DESCRIPTIVE STATISTICS

Summary statistics in Table 3 depict 46% meet the *FAILED_PROJECT* definition consistent with assertions that gold project development is a high risk undertaking. In terms of predictors, descriptive statistics reported in Table 3 for *OPEN_PIT* indicate that nearly 65% of projects constitute open pit as opposed to underground mines. Table 3 also indicates that the average spot gold price was $431.10 USD/oz (*GOLD_PRICE*), whilst the average

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[10] This sample period represents a 'pre-GFC' period so as to remove any effects of the GFC on the feasibility report process. The key analysis of this study relates to the 5 year (or less) period following the public release of the feasibility report, which will include the GFC for appropriate observations. Of these 85 firms, 2 are included in table 1, 5 are pre-GFC company failures, 32 met our broader definition of failure – comprising 20 disposals and 12 deferrals – and 46 are non-failure control firms.

[11] 'A sure hand at the wheel', The Australian, 4/09/2010, p. 26.

[12] The variable *PRODUCT_SALES* represents the amount of gold sales revenue scaled by market capitalisation. This data is collected to ensure that all firms in the sample are 'pre-production' firms.

change in the gold price over the five years subsequent to completion of the feasibility reports (*GOLD_MOVE*) is 75%. Cash costs are disclosed by 80% of firms (*CASH_COSTS*), whilst 13% of firms plan to produce through a mill owned and operated by another entity *(TOLL_MILLING).* Second hand plant is articulated as their preferred treatment option by 27% of projects (*SECOND_HAND*).

In terms of capitalised exploration and evaluation expenditure, the mean is $9.23 million (*DEFERRED_ASSET*). The average percentage holding by the *TOP_20* is 57.7%. Ownership by the board of directors (*DIRSH*) shows an average shareholding of 15% by all board participants, which is not surprising given that small mining companies are routinely founded by a geologist(s) who often retain(s) a large percentage of their companies issued capital post the IPO. The average market capitalisation of the sample is $17 million (*SIZE*). The average number of years of cash (and other financial assets) on hand is 1.7 years (*CASH_BURN*).

The average Altman Z-score is only 0.5 (*ALTMAN_Z*, well within Altman's < 1.81 distress zone) and the maximum is only 2.66 (outside Altman's > 2.99 safe zone). Of our sample, 91.8% of firms have a Z-score of less than 1.81 ('distress zone') although only half (46%) of our sample actually met the project failure definition within the next 5 years. To further investigate the application of the Altman Z-score to our sample of gold mining development firms, the individual components of the score are examined.

The average proportion of working capital (*WCAP*) is 20% (in between Altman's bankrupt average of -6% and non-bankrupt average of 41%). The average proportion of retained profits (*ACC_LOSS*, -151%) is well below Altman's bankrupt average (-63%), as is return-on-assets (*ROA*, -62% is well below -32%) and asset turnover[13] (*ASSET_TURN*, 6% as compared to 150%). These averages are to be expected for development firms yet to generate

[13] We note that Altman's asset turnover was limited to sales revenue whereas our measure includes total revenue as most development firms have no operating revenue.

sales revenue despite several years of development expenses. Of interest is the interpretation of the proportion of retained profits. For Altman, more retained profits is an indication of more years of business success; whereas for development firms more accumulated losses (i.e., negative retained profits) are an indication of more years of funded development activity. Therefore for development firms, the interpretation of the retained profits ratio as a measure of bankruptcy risk is the *opposite* of post-development firms.

Even after substituting Total Liabilities for Debt, the leverage ratio (*LEVERAGE;* inverse of the traditional debt-to-equity ratio) average of 7,819% is still well above Altman's non-bankrupt average of 248%. By Altman's interpretation, a low leverage ratio is a sign that the firm is close to bankruptcy as the market value of the firm's equity has declined dramatically. However for development firms, high leverage ratios are a natural consequence of the reality that they are too risky for debt capital. Therefore for development firms, the interpretation of the leverage ratio as a measure of bankruptcy risk is the *opposite* of post-development firms.[14] Overall, the traditional interpretation of the Altman Z-score does not appear to be a valid reflection of bankruptcy risk for development firms.

MODEL SPECIFICATION

We fit a logistic regression model where the dependent variable *FAILED_PROJECT* is coded 1 if it meets the aforementioned failure definition, and 0 otherwise. The model is specified as follows;

$$\begin{aligned} FAILED\_PROJECT &= \alpha_0 + \alpha_1 SIZE_{i,t} + \alpha_2 OPEN\_PIT_{i,t} + \\ &\alpha_3 GOLD\_PRICE_{i,t} + \alpha_4 GOLD\_MOVE_{i,t} + \alpha_5 TOLL\_MILLING_{i,t} + \\ &\alpha_6 SECOND\_HAND_{i,t} + \alpha_7 DEFERRED\_ASSET_{i,t} + \alpha_8 CASH\_COSTS_{i,t} + \\ &\alpha_9 DIRSH_{i,t} + \alpha_{10} CASH\_BURN_{i,t} + \alpha_{11} ALTMAN\_Z_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

[14] It should be noted that none of the firms in the sample have issued project related finance prior to feasibility completion.

ANALYSIS

We first explore the relationship between the Altman Z-score and failure by correlating *FAILED_PROJECT* with *ALTMAN_Z* and then regressing *FAILED_PROJECT* on the *ALTMAN_Z* ratio alone. In each case the *ALTMAN_Z* is insignificant at the p<.10 level with a pseudo R^2 of .008 and a Chi-square statistic of 0.673, insignificant at p=.412. The model does not correctly classify any companies as failed. We interpret these univariate results as consistent with the Altman Z-score being of less significance in this failure setting.

Logistic regression results for the full model specification in Equation (1) are reported in Table 4. Model 1 exhibits significant explanatory power with a Chi-square statistic of 24.29, significant at p<.01 and reports a pseudo R^2 of .25. Classificatory success is encouraging, with 59% of projects successfully classified by the model. In terms of significant predictors, consistent with expectations, *OPEN_PIT*, the proxy for development type, has a negative co-efficient significant at p<.10. As discussed above, underground projects involve higher information asymmetry potentially leading to a greater expected failure rate, and consequently a negative co-efficient on *OPEN_PIT*. The other significant variable in model 1 is *CASH_COSTS*. Where these are disclosed, there is lower failure (p=.006) – consistent with our prediction that the disclosure of cash costs is a signal for higher project quality.

[Table 4 about here]

Model 2 replicates Model 1 with the inclusion of the traditional Altman Z-score. Interestingly, the financial ratio-based *ALTMAN_Z* is insignificant at the p=.10 level. Whilst the sign is consistent with expectations, overall our results suggest that the *ALTMAN_Z*, on its own, is not associated with failure in this context, nor on a multivariate level with suitable other firm and deposit level controls. We interpret this as evidence that there are more important determinants of failure in this context. Reporting a negative and marginally significant co-efficient is *TOLL_MILLING*, significant at $p<.10$, suggesting failure is lower where third party production facilities are utilized.

Altman (2000) re-examined the Z-score in the more specific contexts of private firms and non-manufacturing firms, suggesting modified variable weights and classification zones. Following Altman (2000), in Model 3 we remove the traditional Altman (1968) weighting constraints included in Model 2. Model 3 therefore includes the five component variables of the Altman Z-score. The only Z-score component significant at the $p=.10$ level is the proportion of retained profits (*ACC_LOSS*), albeit with a positive coefficient. As mentioned above, the positive coefficient on *ACC_LOSS* (contradictory to Altman, 1968) is likely influenced by the high frequency of accumulated losses among development firms.[15]

CONCLUSIONS

Feasibility study completion is a key mine development milestone. Our descriptive research study aims to extend the failure prediction literature by exploring a model of failure for developer mining firms. Prior failure prediction research – such as Altman (1968), and Moel and Tufano (2002) – is difficult to apply to development firms due to the absence of cash-flow generating activities. We utilise a logistic regression model based on the success or failure of single-project gold mining firms subsequent to disclosure of a feasibility study. Results indicate that failure prediction for gold developers is primarily determined by non-financial information. Failed projects are more likely to be underground projects. Non-disclosure of cash costs of production in the feasibility completion is another key predictor of

[15] We run sensitivity tests on within sample firms jointly developing a project along with a small number of companies who attempt underground development with a separate underground feasibility study following the successful conclusion of an open pit campaign. A small number of firms fostering a second attempt at developing the same project after a prior failed attempt are also omitted in further sensitivity tests. Results of such tests are similar to those reported in Table 4. Models 1-3 are re-run with *TOP_20* as the proxy for informed shareholding as opposed to *DIRSH*. Results on all such tests are similar to those reported in Table 4.

failure. Interestingly, traditional financial predictors such as the Altman Z-score do not perform as well in terms of failure prediction in this context.

The inferences we draw may be generalisable to other settings, such as extractive development projects listed on other exchanges, extractive development projects for other commodity types, multi-project producing mining firms with significant development activities, and, on a conceptual level, development-stage-enterprises in other sectors. However, there are limitations with the approach we use relating to omitted and potentially important predictive factors; such as governance quality, a likely determinant in the long-term success of mining project development. We expect the inclusion of such factors is likely to improve the ability of our model to predict failure both for our sample, and in other settings.

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Table 1: ASX listed mining companies entering external administration between Jan 2007-Mar 2010

Date	Company Name	Main Product	Deposit Location
30/01/2007	BMA Gold	Gold	Queensland
28/04/2007	Gleneagle Gold	Gold	Western Australia
18/12/2007	Lafayette Mining Ltd	Base Metals, Gold	Philippines
8/02/2008	View Resources	Gold	Western Australia
10/07/2008	Monarch Gold	Gold	Western Australia
29/08/2008	Monto Minerals	Mineral Sands	Queensland
21/10/2008	Matilda Minerals	Mineral Sands	Northern Territory
28/10/2008	Tamaya Resources	Copper	Chile
3/11/2008	Macmin Silver	Silver	Queensland
11/11/2008	Matrix Metals	Copper	Queensland
21/11/2008	Aluminex Resources Limited	Bauxite	Western Australia
27/11/2008	Copperco	Copper	Queensland
8/01/2009	Goldstar Resources	Gold	Victoria
29/01/2009	Compass Resources	Copper	Northern Territory
27/02/2009	GBS Gold (Australia)	Gold	Western Australia
23/04/2009	Albidon	Nickel	Zambia
10/08/2009	Bounty Mining Ltd	Coal/Tech	Queensland
12/10/2009	Australian Zircon	Mineral Sands	South Australia

Table 2: Producer mine closures and project output curtailments and deferrals

Date	Company	Newswire Header (Summary)
13/01/2007	Bendigo Mining	Bendigo Mining's shock decision to shut down its $300 million-plus Kangaroo Flat mine
30/01/2007	BMA Gold	Announced the closure of Twin Hills mine, 200km west of Mackay and "a managed program of surplus asset sales
30/04/2007	Xstrata	Possible closure of Xstrata Plc.'s McArthur River lead-zinc mine
18/09/2007	Mincor / Tectonic	Closure of RAV8 mine
7/04/2008	Metals X	Metals X has announced that 100 jobs will be lost when the Collingwood Tin Mine is closed in June.
14/07/2008	Teck Cominco Ltd	Teck Cominco Ltd said to close the Lennard Shelf lead-zinc mine in western Australia in August
21/08/2008	Perilya Ltd	Australia's Perilya Ltd said to cut its zinc output by almost half due to low prices
8/09/2008	Intec Ltd	Intec Ltd said had suspended operations at its Hellyer Zinc Concentrate Project
10/09/2008	OZ Minerals Ltd	Australian miner OZ Minerals Ltd said plans to cut zinc output at its Golden Grove mine in Australia by 35-40 percent
16/09/2008	Renison Consolidated	Closes the Tom Gully Mine
18/09/2008	Newmont Mining Corp	Cost pressures are constraining development of Newmont Mining Corp's Boddington goldcopper project in Western Australia
17/10/2008	Norilsk Nickel	Norilsk Nickel said it will halt production at its Cawse laterite nickel operation in Western Australia
21/10/2008	Oz Minerals Ltd	Full or partial closure of the Century zinc mine in Australia is being considered, Oz Minerals Ltd said
29/10/2008	Newmont Mining Corp	Newmont Mining Corp said its planned start-up of the Boddington gold-copper mine in Australia has been delayed several months
30/10/2008	Kagara Ltd	Australian miner Kagara Ltd cut its 2008/09 zinc production target by 12.5 percent
30/10/2008	Mincor Resources Nl	Australian miner Mincor Resources Nl said it expects nickel ore output to be 16,000-19,000 tonnes in fiscal 2009, down from original plan
7/11/2008	CBH Resources Ltd	Australia's CBH Resources Ltd said it will cut lead-zinc mine output by a third in the 12 months to June 30, 2009
13/11/2008	BHP Billiton	BHP Billiton scraps study into developing an integrated nickel project in eastern Indonesia
18/11/2008	Thundelarra Exploration	Australia's Copernicus nickel mine has been shut indefinitely one of its owners Thundelarra Exploration Ltd says
24/11/2008	Rio Tinto	Rio Tinto cuts output temporarily by one-third at Lynemouth aluminium smelter in England
25/11/2008	OZ Minerals Ltd	Oz Minerals Ltd to cut output at Century zinc mine by 4 percent in 2009 and delay $321 million of copper and gold projects
25/11/2008	BHP Billiton	BHP Billiton to continue to review the operating performance and future value of its Ravensthorpe and Yabulu operations
25/11/2008	Norilsk Nickel	Norilsk Nickel suspends production at Waterloo and Silver Swan mines in Western Australia
26/11/2008	Straits Resources Ltd	Australian miner Straits Resources Ltd will scale back next year's production target at its Tritton copper mine to 2,200 tonnes a month
26/11/2008	Talison Minerals	Australia's Talison Minerals, which supplies about a third of the world's tantalum, suspends mining indefinitely
27/11/2008	BHP Billiton	BHP Billiton delays plans to build $120 million molybdenum processing plant at Escondida mine in Chile
3/12/2008	OceanaGold	OceanaGold puts on hold Didipio copper-gold project in the Philippines
3/12/2008	BHP Billiton	BHP Billiton temporarily cuts manganese output at Samancor operation
9/12/2008	Xstrata	Xstrata says has cut ore production by 20 percent at its McArthur River lead-zinc mine in Australia
15/12/2008	OM Holdings Ltd	OM Holdings Ltd to slash manganese output in Australia by nearly 30 percent next year
19/12/2008	OZ Minerals Ltd	Oz Minerals Ltd suspends operations at small Avebury nickel mine
7/01/2009	Aditya Birla Minerals	Aditya Birla Minerals Ltd places Mt Gordon copper mine in Queensland, Australia on care and maintenance
13/01/2009	OZ Minerals Ltd	Oz Minerals Ltd said to put Scuddles mine at its Golden Grove project on care and maintenance
13/01/2009	Rio Tinto	Rio Tinto shelves plan to extend Northparkes copper mine in Australia as it slashes capital spending
13/01/2009	Xstrata	Xstrata said it restructuring lead-zinc operations at its Mt Isa mining and processing complex in Queensland, Australia.
20/01/2009	Rio Tinto	Rio Tinto Alcan said plans to cut another six percent of aluminium output and will also cut alumina production, shed 1,100 employees to cut costs
21/01/2009	BHP Billiton	BHP Billiton will close its Ravensthorpe nickel mine in Australia and reduce activity at Mount Keith nickel mine
7/04/2009	Rio Tinto	Rio Tinto said it would cut bauxite production at its Weipa mine in northeastern Australia by about 23 percent.
9/04/2009	Xstrata	Xstrata Plc said it planned to suspend operations at its Sinclair nickel mine in Australia in August if metals prices did not rebound
24/04/2009	BHP Billiton	BHP Billiton said the viability of its Bayside aluminium smelter in South Africa was at risk following a sharp fall in demand
29/04/2009	Alcoa	Alcoa Inc said to cut aluminium production at Portland smelter in Australia by a further 38,000 tonnes to 305,000 tonnes per year
12/05/2009	BHP Billiton	BHP Billiton said planned to stop mining at the Rocky's Reward open-pit mine at the Leinster Nickel Operation in Australia
3/07/2009	BHP Billiton	BHP Billiton retreated further from high-cost nickel operations, announcing the sale of its Yabulu refinery in Australia

Table 3: Descriptive Statistics

	Mean	Std. Dev	Maximum	Minimum	Skewness	Kurtosis
GOLD_PRICE	431.1	130.86	795.25	254.6	1.05	0.36
GOLD_MOVE	0.75	0.71	1.92	-0.35	-0.35	-1.35
DEFERRED_ASSET	9.23	11.45	59.93	0	2.38	6.39
ALTMAN_Z	0.5	0.69	2.66	-0.05	2.08	3.29
WCAP	0.2	0.23	0.87	-0.18	0.96	0.67
ACC_LOSS	-1.51	1.99	0.02	-7.53	-1.89	2.88
ROA	-0.62	0.38	0.04	-1.62	-2.18	4.18
LEVERAGE	78.19	113.03	414.31	1.21	2.1	3.37
ASSET_TURN	0.06	0.08	0.31	0	2.25	4.19
SIZE	17.05	1.2	20.04	12.97	-0.45	1.64
DIRSH	0.15	0.14	0.55	0	1.12	0.45
TOP20	57.7	14.78	96.29	30.71	0.26	-0.37
CASH_BURN	1.69	2.33	10	0	2.51	5.99
PRODUCT_SALES	0	0.01	0.05	0	7.21	57.72
FAILED_PROJECT	45.88%					
OPEN_PIT	64.71%					
TOLL_MILLING	12.94%					
SECOND_HAND	27.06%					
CASH_COSTS	80.00%					

<u>Definitions</u>

GOLD_PRICE = Spot price for gold (USD/oz) at feasibility release

GOLD_MOVE = % change in gold price over 5 years after feasibility release.

DEFERRED_ASSET = Amount of deferred or capitalised exploration and evaluation expenditure in millions of dollars.

ALTMAN_Z = Altman Z-score (each of 5 components winsorised at 97th percentile).

WCAP = (Current Assets - Current Liabilities) / Total Assets

ACC_LOSS = Retained Profits (Accumulated Losses) / Total Assets

ROA = EBIT / Total Assets

LEVERAGE = Market capitalisation / Total Liabilities

ASSET_TURN = Total Revenues / Total Assets

SIZE = Log of market capitalisation sourced from SPPR measured at month end prior to feasibility release.

DIRSH = % shareholding of the board of directors.

TOP20 = Proportion of the company's shares held be the top 20 shareholders.

CASH_BURN = (Cash + Current Receivables + Current Investments) / (Cashflow from Operations, including Exploration & Development payments)

PRODUCT_SALES = Gold sales revenue divided by firm market capitalisation at feasibility release.

FAILED_PROJECT = Coded '1' if the project is failed as defined within the text, else '0'.

OPEN_PIT = Coded '1' if the project is an open pit mining operation, '0' for underground operation.

TOLL_MILLING = Coded '1' if the processing option is a toll milling arrangement, else '0'.

SECOND_HAND = Coded '1' if second hand plant nominated as preferred process option.

CASH_COSTS = Coded '1' if cash cost of production is disclosed in the feasibility release.

Table 3: Project Failure Models

		Model 1			Model 2			Model 3		
Dependent Variable		FAILED_PROJECT			FAILED_PROJECT			FAILED_PROJECT*		
Right Hand SideVariables:	Exp. Sign	Estimate	Wald -stat	Prob*	Estimate	Wald -stat	Prob*	Estimate	Wald -stat	Prob*
Intercept		9.572	4.459	0.035	9.186	4.148	0.042	11.044	4.854	0.028
SIZE	-	-0.404	2.221	0.136	-0.368	1.881	0.170	-0.422	2.040	0.153
OPEN_PIT	-	-1.276	5.034	0.025	-1.175	4.155	0.042	-1.485	5.440	0.020
GOLD_PRICE	-	-0.001	0.064	0.801	0.000	0.011	0.917	-0.001	0.155	0.693
GOLD_MOVE	-	0.112	0.081	0.776	0.013	0.001	0.975	0.241	0.294	0.588
TOLL_MILLING	-	-1.565	2.663	0.103	-1.767	3.012	0.083	-1.334	1.658	0.198
SECOND_HAND	+	-0.224	0.129	0.719	-0.223	0.125	0.724	-0.407	0.377	0.539
DEFERRED_ASSET	+/-	0.000	0.000	0.993	0.000	0.001	0.973	0.000	0.270	0.603
CASH_COSTS	-	-2.229	7.423	0.006	-2.397	7.944	0.005	-2.526	8.099	0.004
DIRSH	+/-	1.715	0.768	0.381	2.477	1.349	0.245	2.294	1.149	0.284
CASH_BURN	-	-0.077	0.376	0.540	-0.105	0.652	0.419	-0.186	1.345	0.246
ALTMAN_Z	-				-0.528	1.409	0.235			
WCAP	-							0.184	0.017	0.898
ACC_LOSS	+/-							0.479	3.749	0.053
ROA	+/-							-0.531	0.309	0.578
LEVERAGE	+/-							-0.003	1.347	0.246
ASSET_TURN	-							4.815	1.092	0.296
Chi-square (p-value)			24.29	0.007		25.70	0.007		30.78	0.009
Pseudo R^2			0.25			0.26			0.30	
% correctly classified as failed			59.0			61.5			64.1	
Sample Size			N=85			N=85			N=85	

*All p-values are two-tailed tests

Variables Descriptions

FAILED_PROJECT = Coded '1' if the project is failed as defined within the text, else '0'.

SIZE = Log of market capitalisation sourced from SPPR measured at month end prior to feasibility release.

OPEN_PIT = Coded '1' if the project is an open pit mining operation, '0' for underground operation.

GOLD_PRICE = Spot price for gold (USD/oz) at feasibility release

GOLD_MOVE = % change in gold price over 5 years after feasibility release.

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CASH_COSTS = Coded ‘1’ if cash cost of production is disclosed in the feasibility release.

DIRSH = % shareholding of the board of directors.

CASH_BURN = (Cash + Current Receivables + Current Investments) / (Cashflow from Operations, including Exploration & Development payments)

ALTMAN_Z = Altman Z score (each of 5 components winsorised at 97th percentile).

WCAP = (Current Assets - Current Liabilities) / Total Assets

ACC_LOSS = Retained Profits (Accumulated Losses) / Total Assets

ROA = EBIT / Total Assets

LEVERAGE = Market capitalisation / Total Liabilities

ASSET_TURN = Total Revenues / Total Assets