(Debt) Overhang: Evidence from Resource Extraction*

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Abstract

I study the empirical importance of debt overhang using a unique dataset on resource extraction firms, which provides ex ante measures of investment opportunities and important variation in the terms of a firm's obligations. In particular, unsecured reclamation liabilities create overhang that is costly to resolve and induces firms to forgo and postpone positive NPV investments. Traditional debt, in contrast, imposes few overhang-related investment distortions. These results show that: (i) the overhang problem is potentially large and applies more broadly to a firm's non-debt liabilities; and (ii) overhang problems associated with traditional debt can be avoided through contracting and debt composition.

JEL classification: D22, G30, G32

Keywords: Debt overhang, underinvestment, reclamation liability, general liability overhang

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1 Introduction

Debt overhang is a pillar of corporate finance theory. Myers (1977) demonstrates that existing debt obligations have the potential to induce underinvestment in valuable growth options, as the benefit of investing in such projects primarily accrues to debtholders. Establishing the importance of debt overhang in capital structure decisions is difficult, however, because contracting and debt composition mechanisms endogenously arise to mitigate its effects. In addition, fully identifying the costs of overhang requires observing the firm's investment opportunity set. This paper exploits a novel setting that allows me to both disentangle the costs of overhang from its potential solutions, and observe the firm's ex ante investment opportunity set.

I focus on a sample of Canadian resource extraction firms that provides ex ante estimates of the net present value (NPV) of a firm's new mining projects. In December 2000, the Ontario Securities Commission passed regulation that significantly increased disclosure requirements for publicly listed mining firms, notably requiring firms to file technical reports on mining projects that include an estimate of the project's NPV. These feasibility reports enable me to see exactly when firms take positive NPV projects, and more importantly, when they forgo or postpone them.

The resource extraction setting also allows me to directly compare two types of liabilities, traditional debt and mine reclamation liabilities, which differ in the costs associated with avoiding overhang.[1] The overhang-related investment distortions induced by traditional debt can be mitigated at relatively low cost by firms avoiding debt altogether, issuing short maturity debt, renegotiating the contract ex post (Myers, 1977), or securing their debt issuances (Stulz and Johnson, 1985). In contrast, applying such solutions to mine reclamation liabilities is significantly more costly. In particular, resource extraction firms cannot employ the most obvious solution to the debt overhang problem—finance projects solely through

[1] A mine reclamation liability is the obligation of a mining operator to restore disturbed mining land to a natural or economically usable state after the productive life of a mine.

equity. Rather, the production function of these firms dictates the creation of reclamation liabilities in order to extract valuable minerals from the ground. Beyond this, it is very difficult for firms to shorten the maturity of reclamation liabilities or to renegotiate the terms of the obligation ex post.

The nature of mining regulations also enables me to observe the importance of secured liabilities. Over time most jurisdictions have implemented legislation that requires mining operators to financially guarantee, or bond, their reclamation liabilities. However, the accepted forms of these guarantees vary substantially across jurisdictions. Most can be generally classified into a group that requires explicit collateral (externally-bonded) or a group that does not (self-bonded). I exploit the differences in local bonding regulations around the world to identify plausibly exogenous variation in self-bonding, and to separate reclamation liabilities into a treatment group (self-bonded) that is comparable to unsecured debt, and a control group (externally-bonded) that is comparable to secured debt.

Using the data in Table 1, I define a self-bonded mine as any mine permitted during a time self-bonding is allowed. All other mines are classified as externally-bonded. Each year, I sum the estimated reclamation liabilities of a firm's self-bonded and externally-bonded producing mines to get a total dollar amount for each type of reclamation liability. I create two sets of empirical measures of firms' exposure to the overhang problem. The first set consists of market leverage ratios, or the dollar amount of debt, self-bonded and externally-bonded reclamation liabilities, respectively, divided by the market value of assets of the firm (Frank and Goyal (2009)). The second is a group of indicator variables equal to 1 if a firm's existing liabilities exceed the potential value added by a new mining project. These indicators identify growth options that go unfunded in Myers' baseline model.

These empirical measures of overhang allow me to distinguish the impact of each respective liability on a firm's propensity to invest in new mineral projects. Mineral projects are well suited for studying overhang as they require two pre-production investments, one upfront to acquire the mining rights and a second in infrastructure and capital directly before production begins. The initial investment in the mining rights can be viewed as a growth option that expires immediately if the investment is not made. If a firm acquires the rights to extract the mineral, however, the project represents a second real option that is exercised when the firm makes the secondary investment and begins production. Myers's (1977) model shows the costs of overhang arise from firms completely forgoing investment in growth options that immediately expire, while in both Mello and Parsons (1992) and Mauer and Ott (2000), the loss of value due to debt overhang stems from firms suboptimally delaying exercise of the real option. Mineral projects allow me to test the implications of both aspects of debt overhang theory.

Consistent with both, I find that when firms are unable to avoid the overhang problem efficiently, they both forgo and postpone positive NPV mining projects. Specifically, self-bonded reclamation liabilities negatively impact the likelihood a firm acquires new positive NPV mining rights, while externally-bonded reclamation liabilities and traditional debt liabilities do not. Further, I find that only firms with large exposures to self-bonded reclamation liabilities are significantly more likely to delay construction on positive NPV mining projects. Consistent with Myers (1977), each of these effects is more pronounced when firms' liabilities are plausibly more risky.

The fact that traditional debt imposes few overhang-related distortions does not mean debt overhang is unimportant in capital structure decisions. Rather, taken together, the results highlight exactly how important the agency costs of debt overhang are and why effective solutions have endogenously arisen to avoid them. Further, if we assume that a dollar of reclamation liability imposes similar overhang as a dollar of traditional debt, the ex post costs of overhang imposed by mine reclamation liabilities provide an upper bound estimate of the ex ante contracting costs of avoiding overhang from traditional debt.

My results indicate that these costs are nontrivial. In particular, firms passing on positive NPV mining rights translates to an expected loss in value of roughly \$0.63 million each year. Additionally, for firms with self-bonded reclamation liabilities that exceed the potential value of a new project, the average delay in construction is nearly two years. In time value of money terms, this equates to an expected loss of nearly a $1.1 million each year. Given the average reclamation liability in my sample is held for 20 years, the present value of these annual costs roughly aggregated together is $17.66 million, or 6.27% of market value for the median firm with at least one producing mine.

Due to the unique nature of the resource extraction setting, I explore several tests related to the external validity of the main results. First, I verify that the results from more traditional tests of debt overhang are similar in my sample.[2] Specifically, I correlate firms' liability leverage ratios with capital expenditures. Consistent with results from a typical panel of U.S. industrial firms, I find a strong negative relation between capital expenditures and a firm's traditional debt leverage ratio. This is despite my baseline finding that traditional debt is unrelated to investment in positive NPV projects. Together, these results suggest that previous studies that find a negative relation between leverage ratios and CapEx do not identify a debt overhang effect. Instead, the negative relation may identify a decrease in the firm's investment opportunity set or even a decrease in *negative* NPV projects.

Second, I show my general results hold in two separate samples of U.S. mining firms. The first sample uses hand-collected data on U.S. mining firms that voluntarily disclose information on the amount of their reclamation liabilities and bonding methods in their 10-Ks and other reports. The second uses mine-level data from the Mine Safety and Health Administration (MSHA). I hand-match each of these samples to Compustat and find that three separate measures of a firm's self-bonded reclamation liabilities are negatively related to its capital expenditures.

My paper makes three contributions to the corporate finance literature. First, I believe mine is the closest to testing Myers's (1977) theory, and thus the importance of debt overhang, directly. In doing so I find that self-bonded reclamation liabilities, and not traditional debt, negatively impact investment in mining projects that are shown to be valuable ex ante.

[2]E.g., see Lang et al. (1996), Ahn et al. (2006), Cai and Zhang (2011), Cantor (1990), Whited (1992), Opler and Titman (1994), Sharpe (1994), and Aivazian et al. (2005).

This suggests that firms incur much of the costs of overhang ex ante through contracting and debt composition solutions rather than ex post through investment distortions. Other recent studies have also highlighted the importance of debt overhang. For example, Melzer's (2017) and Bernstein's (2018) findings imply that the overhang problem is not confined to the corporate setting. Additionally, the ex ante NPV estimates allow me to roughly estimate the costs of overhang in a reduced-form way. Much of the evidence from structural models suggests that debt overhang may not be a first-order concern in capital structure decisions as the estimated agency costs are typically 1-2% of market value.[3] My results, however, suggest that the costs (6.27% of market value) could be even larger than the structural estimates in Titman and Tsyplakov (2007) and Moyen (2007).

Second, this paper contributes to the literature on potential solutions to asset substitution and debt overhang problems. In recent empirical work, both Gilje (2016) and Denes (2017) argue that covenants, debt composition and other economic mechanisms are efficient in reducing the incentives of firms to engage in risk-shifting. These papers offer considerable insight into the struggle to identify empirical evidence of Jensen and Meckling's (1976) asset substitution problem. The evidence on avoiding debt overhang is currently more segmented. For example, a branch of literature concentrates only on renegotiation.[4] In fact, in one of the most well-executed empirical approaches, Giroud et al. (2012) show that the renegotiation of debt contracts substantially improves a firm's operating performance. My results indicate that the collective set of solutions described above reduce the inefficiencies stemming from debt overhang.

Lastly, this paper complements a growing strand of literature that focuses on the impor-

[3]E.g., see Mello and Parsons (1992), Parrino and Weisbach (1999), Mauer and Ott (2000), Hennessy (2004), and Childs et al. (2005).

[4]E.g., see Aivazian and Callen (1980), Gertner and Scharfstein (1991), Mella-Barral and Perraudin (1997), Pawlina (2010), and Chu (2016). There is also a branch that focuses only on debt maturity. For example, Barclay and Smith (1995), Guedes and Opler (1996) and Barclay et al. (2003) find a negative correlation between debt maturity and growth opportunities, while Johnson (2003) shows that short debt maturity attenuates the negative relationship between leverage and growth opportunities. Additionally, Billett et al. (2007) focus on the endogenous evolution a firm's growth options with respect to leverage, debt maturity and covenants and Diamond and He (2014) analyze the specific conditions in which short maturity debt will lead to lower overhang.

tance of a firm's non-debt obligations. Similar to prior studies on pension (Rauh (2006)) and legal (Arena and Julio (2015), Bennett et al. (2018)) liabilities, I show non-debt liabilities have a first-order effect on firm investment policy.[5] Further, both Rauh (2009) and Akey and Appel (2018) document evidence of the effect non-debt liabilities can have on managerial risk-shifting behavior. Finally, Chen et al. (2018) and Chang et al. (2018) show that operating leverage and corporate environmental liabilities, respectively, are substitutes for traditional debt liabilities.

2 Institutional Setting

2.1 Resource Extraction in Canada

Canada consistently ranks among the world leaders in the global production of minerals and metals (Marshall (2017)). Due to this rich geology, a substantial number of resource extraction firms locate in Canada and ultimately list on either the Toronto Stock Exchange (TSX) or TSX Venture Exchange (TSXV). According to the National Resource Governance Institute, the TSX and TSXV account for 31% of the world's public mining firms, and 15% of the global mining market value. Richer La Flèche et al. (2016) report that more mining companies are listed on the TSX and TSXV than on any other exchange in the world.

Beyond the size of the public resource extraction industry in Canada, this setting offers an even more significant advantage. Following the Bre-X mining scandal in the 1990s, the Ontario Securities Commission introduced the National Instrument 43-101 Standards of Disclosure of Mineral Projects, a listing requirement for both the TSX and TSXV (Fox (2017)).[6] Upon their implementation in 2003, the main tenets of National Instrument 43-101 (NI 43-101) standardized the reporting of all scientific and technical information, and required this information to be prepared by or under the supervision of a "qualified person".

[5] While Rauh (2006), Arena and Julio (2015), and Bennett et al. (2018) each have a different mechanism in mind, their results are consistent with an overhang channel.

[6] Documentation on National Instrument 43-101 Standards of Disclosure on Mineral Projects can be found at http://web.cim.org/standards/documents/block484_doc111.pdf.

The qualified person must have a mining-specific academic and career background, among other credentials, and is *liable* for the content of the NI 43-101 technical reports (Fox (2017)).

These reports are "a summary of material scientific and technical information concerning mineral exploration, development, and production activities on a mineral property that is material to an issue" (Ontario Securities Commission (2011)). They include highly detailed information on the property itself, as well as resource and reserve quantities (both proven and probable), and the potential economic viability of the project. The economic viability is analyzed in a series of reports (preliminary economic assessment (PEA), the pre-feasibility report, and the feasibility report). Each is required to include capital and operations cost estimates, estimated mine life, forecasted production and revenues, and the overall estimated NPV of extracting the mineral.

These data are extremely rich and allow me to directly test Myers's (1977) prediction that firms will pass on positive NPV projects. It is possible, however, that the NPV estimates are uninformative, inaccurate, or biased. In recent studies on voluntary disclosure of gold feasibility studies in Australia, Ferguson and Pündrich (2015) and Ferguson et al. (2013) find that the technical reports contain information used by investors, suggesting these types of reports are at least partially informative. Further, Internet Appendix Table IA1 reports linear regression results in which the dependent variables are various cumulative abnormal returns around the disclosure of the first NPV estimate in a technical report. While small, the coefficient on NPV/Market capitalization$_{t-1}$ is positive and significant, suggesting that investors believe a higher estimate means a higher project value. Finally, holding the qualified person liable for inaccuracies or forgeries helps alleviate concerns of large misrepresentations.

2.2 Mine Reclamation and Financial Assurance

Mining regulations and regulatory bodies display significant heterogeneity around the world (e.g., see Richer La Flèche (2016)). Nearly unanimously, however, regulators direct mining operators to disturb as little land as possible, and to reclaim the disturbed areas when extraction is complete. While reclamation standards vary among different jurisdictions, most include an extensive amount of work to be completed after the productive life of a mine.[7] Because this creates a substantial, long-term obligation for mining operators, most jurisdictions require mining operators to post financial assurance, or a bond, that ensures the costs of reclamation will be borne by the mining company and not by the local government and taxpayers. There are essentially four main types of financial assurance: (1) surety bonds; (2) collateral bonds; (3) letters of credit; and (4) self-bonds.[8] The types of financial assurance that are deemed acceptable vary substantially across jurisdictions and through time.

Surety bonds are the most common type of financial assurance method, particularly for mines in the United States (Gorton (2009), Nazzaro (2005)). A surety company or other type of financial institution (the surety) will agree to act as an obligor should the mining operator fail to complete the reclamation. Collateral bonds typically take the form of cash trusts or certificates of deposit and are easily accessible to the regulator. Letters of credit are heavily used outside of mining, often to reduce counter-party trade risk. Typically the buyer receives a letter from a bank guaranteeing that payment for the goods or services will arrive on time and in full. Similarly, mining operators use letters of credit to guarantee that reclamation will be completed as agreed upon during permitting.

These first three methods of bonding are costly ex ante for the mining operators. Survey evidence indicates that surety premiums in the U.S. can range from 1-3.5% (Kuipers (2000)) to 5-6% (Chelimsky (1988)) with up to a 100% collateral requirement. Recent anecdotal evidence also suggests that surety bonds can be extremely costly. Bonogofsky et al. (2015) report that Cloud Peak Energy saved upwards of $2 million per year switching from surety to self-bonds. While letters of credit often have much lower annual premiums, banks require

[7] This often includes, but is not limited to, demolition of existing mining structures; sealing and stabilization of pits and shafts; recontouring of access roads, tailing ponds, trenches, pits and shafts; revegetation; and monitoring and evaluation of the site. For a checklist that details reclamation standards in the U.S., see Bureau of Land Management (2005).

[8] This list does not include some less common forms of financial assurance accepted by certain jurisdictions. For example, some states/provinces and countries have what is called a bond pool, where mining operators each contribute to a government sponsored pool which is used to perform reclamation. For more information on reclamation bonding options, see Cheng and Skousen (2017), Gorton (2009), and Nazzaro (2005).

collateral deposits upwards of 120-200% of total estimated liability to provide the guarantee (Kirschner and Grady (2003)). Thus, there are significant liquidity costs associated with letters of credit or cash bonds.

Unlike the first three bonding methods, a self-bond does not necessitate explicit collateral. Rather a self-bond requires that an operator, its parent, or a third-party provide the guarantee for the cost of reclamation. Because of financial and credit-worthiness criteria, as well as contracting costs with a third party, most self-bonds are parent guarantees, often called company or corporate guarantees (Nazzaro (2005)).[9]

2.3 Contracting Costs

There are several potential, yet costly, solutions to the overhang problem. First, a firm can simply choose to finance its projects through equity rather than debt and avoid the overhang problem altogether. Additionally, Myers (1977) notes that debt overhang can be resolved through a policy of (non-automatically) rolling over short maturity debt claims, or ex post through renegotiation. Finally, Stulz and Johnson (1985) suggest that the use of secured debt can mitigate the underinvestment problem.

Reclamation liabilities offer a unique instrument to study these potential solutions as the costs of implementing the first three listed above are significantly higher than they are for traditional debt.[10] For example, while not costless to finance solely through equity, the option nevertheless exists and is often exercised by firms (e.g., see Strebulaev and Yang (2013)). This option, however, is not applicable to reclamation liabilities. For any resource extraction firm wishing to extract minerals from the ground, a reclamation liability is simply part of the production function that cannot be avoided.

[9] Additionally, many jurisdictions that allow self-bonds only explicitly allow parent guarantees. For example, Missouri's metal mining statute, MO Rev. Stat. §444.368.1 states, "...the operator shall file a demonstration of financial assurance in the form of a bond, certificate of deposit, letter of credit, insurance, *company guarantee* [emphasis added], escrow agreement or other form of financial assurance as approved by the director."

[10] Additionally, my identification strategy (discussed below in Section 3.1) allows me to separate unsecured mine reclamation liabilities

Diamond (1991, 1993) and Sharpe (1991) point out that short maturity debt contracts impose costs due to liquidity risk. Even so, firms continue to issue large amounts of short maturity bonds. For example, Xu (2017) finds that the average maturity for U.S. corporate bonds over a sample period of 1997-2012 is 10.5 years. Additionally, Custódio et al. (2013) report that less than 20% of the median firm's total debt outstanding has a remaining maturity greater than five years. Both of these studies highlight that firms regularly issue and hold effectively short maturity debt, suggesting the potential overhang costs of long maturity debt exceed the costs of liquidity risk from short maturity debt.

On the other hand, the average mine in my sample has a productive life greater than 20 years, creating a liability with twice the maturity as the average bond. Strategically choosing short-life mines ex ante is likely to be extremely costly, as the life of a mine is highly correlated with the amount of mineral contained in the deposit and thus the NPV of the project. Additionally, because "retiring" a mine reclamation liability involves closing and reclaiming a mine, shortening the maturity of current a mine reclamation liability even by a few years could mean sacrificing millions of dollars in valuable resource extraction and production.

The best evidence of the costs of renegotiating debt contracts is the sheer prevalence with which renegotiation takes place. For example, Roberts (2015) finds that the average bank loan is renegotiated 3.5 times, while Roberts and Sufi (2009) report that 90% of private credit agreements are renegotiated prior to their original maturity. Further, Nikolaev (2017) finds that the unconditional probability a firm renegotiates at least one contract in a given year is 37%. Taken together, the results in these studies suggest that the overall costs of renegotiation for traditional debt are likely not prohibitive. This does not mean, however, that renegotiating debt contracts is never costly. For example, Chu's (2016) findings imply that syndicate loans with many lenders are more costly to renegotiate. This suggests that there is heterogeneity in the costs of avoiding overhang even in the cross-section of traditional debt contracts. Indeed, Internet Appendix Table IA2 supports this hypothesis using the sample from Table 4 below.

Mine reclamation liabilities, on the other hand, appear significantly more difficult to renegotiate ex post in a way that mitigates overhang. First, while traditional debt contracts can be renegotiated on price, level, maturity, or specific covenants, mine reclamation liabilities can only be renegotiated on level. Second, adjusting the level of a mining firm's liability down requires local regulators to transfer the obligation from large mining firms to local taxpayers. Third, it is unclear if regulators have the authority to renegotiate in all jurisdictions (e.g., see Socalar (1988)). Lastly, while reclamation liabilities and their associated bonds are often negotiated up, (e.g., see Walsh (2017)), using a comprehensive news search, I cannot find evidence of a single anecdote in which a reclamation liability is renegotiated down to a point that it no longer accurately represents the expected costs. All of this evidence supports the argument that reclamation liabilities have renegotiation costs that exceed those of traditional debt.

3 Empirical Strategy and Data

3.1 Identifying Reclamation Liabilities

The difference in contracting costs between traditional debt and reclamation liabilities allows me to assess the importance of debt overhang through a direct comparison of the different liabilities' impact on investment policy. While traditional debt is defined simply as the sum of a firm's book value of total long-term debt and the book value of debt in current liabilities, defining a firm's exposure to reclamation liabilities is more complex. Estimated reclamation liabilities are reported in project technical reports; however, even with the high disclosure standards, firms are not required to disclose the manner in which their reclamation liabilities are bonded. Rather, I exploit the cross-section and time-series variation in self-bonding regulations to identify quasi-exogenous variation in firms' ability to self-bond their mine reclamation liabilities. This variation allows me to separate reclamation liabilities that must be backed by explicit collateral.

There are two main endogeneity concerns with this identification strategy. The first is that the passage of self-bonding regulations is influenced by the prevailing political economy or specific firms that lobbied for or otherwise motivated the laws (e.g., see Karpoff and Wittry (2018)). Because the collection of lobbying expenditures and reports is a relatively new phenomena, the majority of law changes precede the beginning of databases such as Open Secrets. In any case, I can only identify 4 cases in which a single firm reports it is "monitoring the status of self-bonding legislation." Further, I cannot find a single news article that credits a specific firm for a change in the financial assurance provision in any jurisdiction's mining regulation.

The second concern arises from the fact that firms choose where and when to purchase new mining rights and which mining projects to move forward with permitting. This could potentially introduce a selection bias in which firms decide to purchase or permit mining projects in accord with the prevailing self-bonding regulations. While this firm-mine matching problem cannot be completely ruled out, Internet Appendix Table IA3 analyzes the number of new mining rights acquired and the number of new mining projects permitted in a jurisdiction surrounding the passage of a self-bonding provision. The results indicate that, on aggregate, self-bonding provisions do not influence firms' decisions to buy new rights or start the permitting process in one director or the other.[11]

Table 1 displays all self-bonding regulations for which I can locate documentation. These regulations cover over 90% of the permitted mines in my sample. In Australia and Canada, individual states and provinces, respectively, set bonding laws, while the U.S. federal government regulates financial assurance provisions that are specific to the mineral to be extracted.

[11] Internet Appendix Table IA3 mitigates not only this particular selection concern, but also a confounding variables problem based on geographic clustering. Specifically, if there are location economies, firms may choose to locate several mines in the same jurisdiction. Then, if the passage of self-bonding provisions is correlated with negative local economic or industry-specific shocks, it could be the case that firms with several mines located in such a jurisdiction will also have high levels of self-bonded reclamation liabilities and will invest less in the future due to the shock, not the amount of their reclamation liabilities. The results in Internet Appendix Table IA3 strongly suggest this is not the case.

Namely, the Surface Mining Coal Reclamation Act (SMCRA) of 1977 regulates coal mining, while 43 C.F.R §3809, passed in 2001, amended legislation for hardrock and metal mining. However, both federal provisions give states the option to be *more* stringent, that is, to prohibit self-bonding if the federal law allows it.[12] Like 43 C.F.R §3809, most of the mining regulations in Table 1 are part of a country's or state's mining reform, where previous legislation had required mines to be reclaimed without requiring financial assurance. I assume the time periods preceding reform, and jurisdictions with a reclamation requirement yet without a financial assurance provision, explicitly allow self-bonding, as the incentive to fulfill the obligation in all cases is very similar.

Under these assumptions, I define a mine as self-bonded if it was permitted in a state, province, or country, and in a year in which a self-bond or corporate guarantee was considered an acceptable form of financial assurance. All other mines are classified as externally-bonded. This definition is analogous to assuming that mining companies choose to self-bond whenever they are able. This seems reasonable for a few reasons. First, the other forms of financial assurance are costly ex ante. Annual premiums and collateral requirements can add millions of dollars to estimated reclamation costs. Second, the evidence supports that the option to self-bond is heavily exercised (e.g., see Interstate Mining Compact Commission (2014) and Nazzaro (2005)). Finally, the fact that some mines defined as self-bonded in my sample are not actually guaranteed through a self-bond should bias me against finding significant results.

Each self-bonded and externally-bonded mine in some stage of production contributes to a firm's overall self-bonded and externally-bonded reclamation liabilities, respectively. Using the definition of a self-bonded mine above, a firm's self-bonded liabilities in a given year are comprised of the estimated reclamation liabilities for all of its producing self-

[12]43 C.F.R §3809 amended the law to prohibit new self-bonds but explicitly grandfathered existing self-bonded mines to that form of financial assurance. Thus, producing hardrock and metal mines were not required to provide additional financial assurance after the change. In other legislative changes around the world, it is much more difficult to discern the existence of and details regarding a grandfather provision. In this paper, I assume all current self-bonded mines are grandfathered in at the point of the law change, only needing to be re-bonded with a new form of financial assurance if the mine owner changes.

bonded mines. I use the short-hand notation SB to represent the total U.S. dollar amount of a firm's self-bonded reclamation liabilities in a given year. Formally, this is $\text{SB}_t = \sum_{i \in \text{P,S}} E[\text{Reclamation liability}_{it}]$, where P represents mines in production, S represents mines defined as self-bonded, and the estimated reclamation liability is reported in the technical reports prior to the mine being permitted. Similarly, EB represents the total U.S. dollar amount of a firm's externally-bonded reclamation liabilities in a given year. Formally $\text{EB}_t = \sum_{i \in \text{P,E}} E[\text{Reclamation liability}_{it}]$, where again P represents mines in production, but E represents mines defined as externally-bonded. These definitions of a firm's self-bonded and externally-bonded liabilities assume that once a mine is closed, the firm is no longer exposed to the liability.[13] This assumption alleviates concerns due to a particular financial constraint in which firms with self-bonded reclamation liabilities cannot fund new investment due to their ongoing clean-up costs.

Figure 1 presents an example of three coal mines located near the border of British Columbia and Alberta, Canada. Transalta permitted Highvale Coal Mine in Alberta in 2007. Because Section 21 of the Alberta Conservation and Reclamation Regulation, passed in 1993, permits self-bonds, the \$42.1M in estimated reclamation costs for Highvale is is added to SB for Transalta when Highvale entered production in 2008.

Teck Resources permitted the other two mines, Greenhills Coal Mine and Elkview Coal Mine, in British Columbia in 1992 and 2008, respectively. Section 30 of British Columbia's Bonding Act, passed in 1996, prohibits self-bonding. Because of the timing of the regulation in British Columbia, the \$153.2M in estimated reclamation costs for Greenhills is added to SB for Teck Resources when Greenhills began production in 1993, and the \$53.4M in estimated reclamation costs for Elkview is added to EB when Elkview continued production in 2009 after being acquired by Teck Resources.[14] All three of these mines are still in production

[13]This is equivalent to making the assumption that mining firms begin reclamation as soon as a mine is closed. The results are robust to alternative assumptions, such as the liability persists for 1, 2, or 3 years after ceasing production.

[14]Because of the time-series variation in regulations, even the same mine can be defined as self-bonded and externally-bonded over different parts of the sample if ownership changes following the passage of new regulation. For example, Highvale Coal Mine could be defined as externally-bonded if Teck Resources

today and so are still considered liabilities for the respective companies at the end of my sample in 2016.

3.2 Empirical Measures

In an ideal empirical setting to test debt overhang, a researcher would use exogenous variation in the value of a firm's option to default on their obligation (Merton (1974)) to study the impact on investment. Unfortunately, the value of a firm's put option is not directly observable. Thus, to facilitate the comparison between traditional debt and mine reclamation liabilities and analyze their impact on investment, I use two separate empirical measures that should be positively correlated with the value of the firm's option to default.

The first measure can essentially be thought of as a "leverage" ratio. For traditional debt, it is the market debt leverage ratio as defined in Frank and Goyal (2009). That is, debt leverage is a firm's total debt divided by the market value of its assets.[15] For reclamation liabilities, the denominator of market value of assets remains the same, but total debt is replaced by SB or EB, the total dollar amounts of a firm's respective reclamation liabilities. Thus, the "leverage" ratios for self-bonded and externally-bonded reclamation liabilities are SB/MV and EB/MV, respectively. While leverage ratios are commonplace in studying debt overhang, there is no strong theoretical basis for why debt or other obligations would impact firms' option to default, and ultimately investment policy in a linear way. Rather, it is much more likely that firms are impacted by overhang only after crossing some threshold.

The second empirical measure I use attempts to account for this nonlinearity. In doing so, I take advantage of the richness of the project-level data extracted from the NI 43-101 technical reports. I define indicator variables that take a value of 1 if a firm has existing liabilities—traditional debt, SB, or EB—that exceed the potential value created by the new mineral project. For example, if SB exceeds the estimated NPV of a potential mining project, $\mathbb{1}_{\text{SB}\geq\text{NPV}} = 1$. Ultimately, this measure is also imperfect. While it exactly identifies

transferred the rights to a new owner after 1996.

[15] See Appendex Table A1 for the details of this ratio.

the "wedge" in the baseline model, Myers (1977) provides a generalization of the problem for firms that hold more than one asset. In this model, the investment decision is slightly more complicated as the firm compares the NPV of the project ($\Delta V(s) - I(s)$ in Myers's notation) against the capital gain to bondholders if the option is exercised ($\Delta V_D(s)$). In this framework, using the entire liability (P) assumes the bondholders would get nothing if the firm does not exercise the option. This is unlikely the case for firms with assets in place. However, using the entire liability allows me to avoid making assumptions about asset allocations in bankruptcy. It also represents a necessary (but insufficient) condition for firms to be exposed to overhang (i.e. it must be the case that $\Delta V_D(s) \leq P$).

3.3 Data and Summary Statistics

The vast majority of mine-level data used in this paper are contained in public company filings. Extensive mine-level information is disclosed in regularly filed reports such as the Management Discussion and Analysis (MD&A) report. The NI 43-101 technical reports also contain detailed data on a company's mineral projects. A mining research firm called Mining Intelligence aggregated the information in these filings and provided me a database of nearly 800 publicly traded Canadian mining firms owning over 3,600 mining projects worldwide during my sample period of 1990-2016.[16] The data includes historical mine status and ownership, mine type and location, cost of acquisitions, and information extracted from the NI 43-101 technical reports on feasibility. I supplement the data provided by Mining Intelligence with hand-collected estimates of a mine's reclamation liabilities for each permitted mine in my sample.[17]

Table 2 reports summary statistics for the mining projects in my sample. Panel A shows that only 14% of the 22,379 mine-year observations are in some phase of production. The

[16]Mining Intelligence is a division of InfoMine, Inc., a private data intelligence firm that provides data solutions and services to mining companies, suppliers, educators and financiers. The company claims to cover over 14,000 resource extraction companies and 36,000 mining properties worldwide, while collecting data from over 1.8 million publicly filed documents.

[17]Estimates for the reclamation liabilities are most often found in the NI 43-101 technical reports filed prior to production and thus are not updated through time.

vast majority of mining projects in this sample are in the earlier stages of development, with two-thirds of the observations in prospecting, exploration or feasibility. Figure 2 displays these different stages for a typical mining project and highlights important milestones such as when different feasibility studies are often disclosed.

Panel B of Table 2 displays summary statistics for only mines that enter production at some point during the sample. These mines would have been required to submit a bond for their reclamation liabilities to the appropriate local authorities. The average liability of $27.7 million and maximum of $558 million highlight that reclamation liabilities are non-trivial. Using the self-bonded definition described in Section 3.1, I classify nearly 40% of the producing mines in my sample as self-bonded. The remainder of Panel B shows the distribution of mines by mine type, primary mineral extracted, and mine location. The mines in my sample are most likely to extract gold and be located in North America, byproducts of using Canadian mining firms.

Panel C of Table 2 reports the descriptive statistics for the data from the NI 43-101 technical reports and the NPV calculated for the acquisition of mining rights. The mean project (acquisition) NPV is over $400 ($200) million while the median is $172 ($68.5) million. Due to the high costs of exploratory drilling and the commissioning of the technical reports, it is reasonable to assume that firms only pursue feasibility studies on mining projects that are almost certainly positive NPV. This biases the sample towards including only valuable projects. However, this sample composition allows me to precisely test Myers's (1977) theory that firms will forgo *positive* NPV projects. Panel C also highlights the frequency at which firms are exposed to Myers's (1977) wedge. Of the 269 projects, nearly 18% are owned by a firm with debt liabilities that are greater than the estimated value of the project at the time of disclosure. Far fewer firms have enough exposure to self-bonded reclamation liabilities to surpass the estimated project NPV. However, as I show in Section 4, these liabilities have a large impact on investment decisions.

Table 3 summarizes firm-level variables on reclamation liabilities and the number of mining projects in various stages of development for the Canadian mining firms over the sample period of 1990 through 2016. This data is aggregated to the firm-year level from the mine-level data described above. The average firm in my sample with at least one mine in production has just under \$70 million in reclamation liabilities while the median firm has \$11.9 million. This suggests that reclamation liabilities, while typically smaller, are of the same order of magnitude as traditional debt liabilities. Table 3 also displays a firm's liability leverage ratios. The maximum values of SB/MV (10.54) and EB/MV (72.41) indicate that certain firms have very high exposure to reclamation liabilities. These statistics match evidence from the U.S. coal mining industry that indicates huge amounts of reclamation liabilities, self-bonded and otherwise, can be concentrated in a small number of firms (Hein et al. (2016)).

Finally, Table 3 displays the summary statistics for the firms' accounting variables taken from Compustat—North America. Compared to the typical U.S. industrial sample, the average Canadian mining firm tends to be smaller in terms of book (\$856.8M) and market (\$925M) value of assets, have lower leverage (0.109) and much more variable operating performance. They hold a comparable amount of cash as a percentage of book value of assets (0.243) and have similar growth opportunities (Tobin's $Q = 3.3$).

4 Results

4.1 Acquisition of Mining Rights

My first set of empirical tests analyzes firms' propensity to make an initial investment in a new project. For mining firms, the initial investment in a mining project is acquiring the rights to extract the mineral in a specific deposit. I view the option to purchase new mining rights as an auction. Thus, the option immediately expires upon completion of the auction for all but the highest bidder.[18] This framework allows me to test Myers's (1977) main

[18] In reality, it is possible the option to purchase new mining rights does not expire immediately. For example, two mining firms may have protracted negotiations regarding the transfer of rights that extends

empirical prediction that firms will completely forgo investing in positive NPV projects in some states of the world.

Table 4 reports the results of linear probability models (LPMs) in which the dependent variable takes a value of 1 if the firm acquires new mining rights in a given year, and 0 otherwise.[19] The sample consists of firms located in Canada and listed on the TSX or TSXV exchanges from 1990 through 2016. This first set of tests uses firm-year observations and because I am not analyzing a firm's decision with respect to a specific mineral project, I am constrained to using the first empirical measure, the liability leverage ratio. Each model includes both firm and year fixed effects and I cluster the standard errors at the firm level.

Firm fixed effects present a trade-off between controlling for firm-specific characteristics and perhaps limiting the exogenous variation in the reclamation liabilities. Specifically, when using firm fixed effects, the entire effect is identified by time-series variation within a given firm. Because the estimated reclamation costs are not updated through time, the majority of the variation in my measures of reclamation liabilities comes from starting new mines and closing old ones—both arguably endogenous to the decision to invest in new mines. Notwithstanding, I use firm fixed effects in all LPM specifications in my empirical tests for a few reasons. First, this does not limit the plausibly exogenous variation in defining liabilities as self-bonded or externally-bonded. If the results were driven completely by opening and closing mines, there should be no difference between self-bonded and externally-bonded reclamation liabilities. Second, the survival analysis in Section 4.2.2 should alleviate this concern completely as all of the identification in those tests comes from the cross-section of reclamation liabilities at the time of the first NPV estimate.

Models (1) and (2) of Table 4 analyze the acquisition of any mining project in my sample—not just those that are NPV positive. Model (1) reports the results without controls, while Model (2) adds covariates for a firm's size (log of book assets), internal capital con-

the life of the option.

[19]I use the LPM as it allows me to include high-dimensional year and firm fixed effects. See Angrist and Pischke (2008) for a discussion on the advantages of the LPM. My results remain largely unchanged when using a logistic or probit model without firm fixed effects.

straints (cash), profitability (ROA), growth opportunities (Tobin's Q and firm projects in each stage of development), and lifecycle effects (log of firm age). The results suggest that both self-bonded reclamation liabilities and traditional debt have a significant and negative impact on a firm's propensity to acquire new mining rights. In fact, the magnitude of the coefficient for traditional debt (-0.057) is nearly two times as large as that of self-bonded reclamation liabilities (-0.035). However, because it is unclear whether these mining projects are value increasing, there are several alternative explanations for the negative correlations reported for traditional debt. For example, one such explanation is that debt acts as a governance mechanism, limiting costly overinvestment due to Jensen's (1986) free cash flow problem.

In order to rule out these alternative explanations, Models (3) and (4) restrict the new mining rights to those that look to be NPV positive. I define the NPV of the mining rights as the initial NPV estimate in the NI 43-101 technical reports (or the remaining NPV estimated by this report if the mine is already producing) less the cost the paid for the individual mine at acquisition.[20] Thus, the dependent variable in Models (3) and (4) takes a value of 1 in a year the firm acquires new mining rights in which this NPV is positive, and 0 otherwise.

The inference from these models differs substantially from the first two. For example, in Model (4), the coefficient on SB/MV remains similar in magnitude at -0.025 and significant at the 1% level. The coefficient on the market debt leverage ratio, in contrast, is cut in half and not significant at conventional levels. The results in Models (3) and (4) support Myers's (1977) empirical prediction that firms with existing obligations will forgo positive NPV growth options in some states of the world, however only for firms with self-bonded reclamation liabilities.

The costs of this investment distortion are non-trivial. For a one standard deviation

[20]This mining rights NPV measure is noisy as individual mines are often sold in package deals as assets in the sale of a mining operator and it is difficult to assess the value of the mine without the operator's capital assets. However, in using the entire acquisition cost, once again I'm biasing the sample toward the *more* valuable projects. I exclude sales of mining operators that own more than one mining project. I control for the incidence of these multi-project acquisitions, as well as the acquisitions of mining rights that have no NI 43-101 technical report NPV estimate, in Model (4).

increase in SB/MV, the average firm is 12.3% less likely to acquire positive NPV mining rights relative to the baseline likelihood for firms with at least one producing mine. In expectation, this amounts to a $-0.123 \times 0.057 \times 89.1 = \$0.63$ million loss in value each year the firm maintains high exposure to self-bonded reclamation liabilities. Given the average reclamation liability in my sample is held for 20 years, the present value of these annual costs is $6.38 million, or 2.27% of market value for the median producing firm.[21] Overall, the results in Table 4 highlight that (1) overhang imposes meaningful costs, and (2) contracting mechanisms allow firms with traditional debt liabilities to avoid these costs, at least ex post. Ultimately, the costs imposed by mine reclamation liabilities offer an upper-bound estimate of the contracting costs firms pay ex ante to avoid traditional debt overhang.

4.2 Mining Projects as Real Options

Section 4.1 analyzed the impact of a mining firm's liabilities on its propensity to acquire *new* NPV positive mining rights in an auction framework in which the option to invest expires. Once a firm acquires the rights to mine a particular deposit, however, it has the exclusive right to extract the mineral for a considerable time period. The firm can choose to immediately make capital and infrastructure investments, or the firm can choose to delay construction until a future date. Thus, these existing mining projects represent real options for the firm.

Mello and Parsons (1992) and Mauer and Ott (2000) model debt overhang in a real options framework in which the firm's growth option does not simply expire. Both studies, using resource extraction for the setting of their contingent claim models, make similar empirical predictions—mainly the agency cost of debt overhang arises from suboptimal operating decisions. In particular, Mello and Parsons (1992) show that firms will delay opening (or reopening) a mine past the optimal trigger point when mineral prices are low. Similarly, Mauer and Ott (2000) find that firms will delay exercising the option to expand mining

[21] These calculations use the median NPV of $89.1 million for the mining rights and a market value $281.8 million (median for firms with at least one producing mine).

operations past the point which maximizes firm value.

In this section, I further utilize the data in the NI 43-101 technical reports to study these predictions. Specifically, I analyze the impact that liabilities have on firms' decision to start construction on positive NPV mining projects. The NI 43-101 technical reports allow me to use detailed data on project specifics in an attempt to control for the optimal trigger point. These controls include the NPV and capital costs associated with the mining project, the expected life of the mine, the primary mineral price, futures prices and implied volatility, among other things. Additionally, these data allow me to use Myers's wedge, the second empirical measure, which arguably does a better job classifying firms exposed to overhang.

The sample in this section is slightly different from the sample used in the previous section. While the analysis uses the same Canadian mining firms listed on the TSX or TSXV, it uses project-year observations rather than firm-year observations. Thus the sample uses annual data from the time a mineral project is estimated to have a positive NPV value (time t=0) until either the firm begins construction on the project or the sample period ends in 2016. The first year in which NPV estimates were provided in technical reports was 2003, creating a sample of over 800 project-year observations, covering almost 180 firms and over 200 mining projects from 2003 through 2016.

4.2.1 Linear Probability Model

Table 5 displays the results using a linear probability model in which the dependent variable takes a value of 1 if the project starts construction and 0 otherwise.[22] Once again, the models include year and firm fixed effects in the baseline specification, with robust standard errors clustered at the firm level.[23] Panel A continues to use the liability leverage ratios. Model (1) presents the results without additional control variables. Models (2) through (5)

[22] There is an additional advantage to using the LPM with the Myers's wedge indicators as Angrist and Pischke (2008) point out that models with categorical regressors do not satisfy the assumptions of the logistic or probit model as they are not continuous.

[23] Table IA3 in the Internet Appendix examines the robustness of Table 5 to the inclusion of alternative fixed effects, such has location, mine type, and primary mineral by year fixed effects.

in Table 5, Panel A, add a host of control variables. These covariates are meant to control for factors in a firm's decision to optimally exercise its real option to construct the mine. For example, Model (2) adds the standard accounting control variables that were used in Table 4, as well as project level controls for the NPV, capital costs, expected mine life, and number of projects in each developmental stage. Models (2) through (5) also attempt to control for a firm's investment opportunity set. Specifically, Model (2) controls for the total NPV of a firm's alternative projects and whether or not the firm begins construction on one of those alternative projects. Model (3) adds a control for the annual percentage change in the mineral price of the primary mineral to be extracted from the mine, Model (4) controls for the 12-month futures price, and Model (5) adds the implied volatility from historical 1-month at the money put-call straddles.

Consistent with the results from Section 4.1, each model in Panel (A) suggests that only self-bonded reclamation liabilities have a significant impact on firms' investment decisions. The economic magnitude of each coefficient is large, as Model (3) implies a one standard deviation increase in SB/MV leads to nearly a 25% decrease in the likelihood (relative to the baseline likelihood) a firm decides to begin construction on a positive NPV mining project in that year. While all insignificant, the coefficients on a firm's debt leverage ratio are negative in Models (2) through (5), while the coefficients on the externally-bonded reclamation liability ratio are positive.

Panel B of Table 5 switches to the second empirical measure—an indicator that equals 1 if the liability exceeds the estimated value of the mineral project and 0 otherwise. Once again, Model (1) examines the impact of the firm's liability on its propensity to begin construction without additional control variables, and the final four models repeat the analyses in Panel A with control variables that are firm-, project-, or mineral-specific and attempt to control for a firm's optimal trigger point. In each model, the coefficient on self-bonded reclamation liabilities is negative and significant while those on traditional debt and externally-bonded reclamation liabilities are near zero and insignificant. For example, the coefficient on Myers' wedge for self-bonded reclamation liabilities in Model (3) is -0.269 and is significant at the 5% level. This suggests firms with self-bonded reclamation liabilities that exceed the NPV of a mining project are nearly 27% less likely to begin construction on the mine in that year than otherwise similar firms.

A potential alternative explanation for the results in Table 5 is that a firm's existing self-bonded reclamation liabilities make it politically difficult for the firm to obtain permits for new mining projects. This explanation would be consistent with the negative relationship between the firm's liabilities and investment in new projects but has a very different interpretation than debt overhang. Table IA4 in the Internet Appendix addresses this concern by using the fact that many projects have a time gap between the permitting stage and the construction stage. These results show there is no discernible impact of a firm's self-bonding reclamation liabilities on the likelihood the firm obtains new permits.

Overall, the results in Table 5 are consistent with the predictions in Mello and Parsons (1992) and Mauer and Ott (2000) and suggest firm liabilities do impact a firm's decision to trigger the real option. However, as with the results in Table 4, this impact is concentrated in liabilities in which the contracting costs are high. In particular, a firm's ability to shorten the maturity of its debt or renegotiate it ex post limits the costs of the overhang problem. Further, the stark difference between self-bonded and externally-bonded reclamation liabilities in these tests offers support for the efficacy of secured obligations in mitigating overhang.

4.2.2 Survival Analysis

A second way to examine the effect of a firm's liabilities on its propensity to begin or delay construction is with survival analysis, which in this case, offers two advantages. First, survival analysis allows me to more directly test the empirical predictions in Mello and Parsons (1992) and Mauer and Ott (2000) that firms will delay the exercise of the real option. Additionally, I am able to roughly calculate an average delay imposed by a firm's liabilities. Second, survival analysis allows me to avoid the issue created by using firm fixed effects in the linear probability models. In particular, the variation in the Cox regressions comes from cross-sectional differences in firms' reclamation liabilities at the time of the initial NPV estimate, which is presumably a very similar point in development for each mine. To make this concrete, the liability leverage ratios and indicator variables are fixed at the time the NPV is estimated. Thus, the overhang measures are time-invariant across all observations for a specific project, from the point the NPV is estimated to the end of the sample in 2016, or when the event (construction) occurs, whichever comes first.

Figure 3 displays Kaplan-Meier nonparametric survivor functions for each of the three indicator variables identifying Myers's wedge. Consistent with earlier results, the delay for projects in which self-bonded reclamation liabilities exceed the estimated NPV is stark, while the survivor functions for externally-bonded reclamation liabilities and traditional debt show no discernible differences between projects in which the liabilities exceed the NPV and those that it does not.[24] It is possible, however, the nonparametric tests do not adequately account for factors relating to the optimal exercise date. Table 6 presents the results from Cox exponential proportional hazard regressions.[25] Each model includes year and primary mineral fixed effects.[26]

Panel A of Table 6 uses liability leverage ratios, while Panel B uses the indicator for Myers's wedge. Model (1) in Panel A displays the hazard ratios for the liability leverage ratios without additional control variables. The hazard ratio for SB/MV is 0.344 and is significant at the 10% level. The hazard ratio for EB/MV is also well under 1, but not significant at conventional levels. Finally, the hazard ratio for the market debt leverage ratio

[24]Further, the observed survivor functions for externally-bonded reclamation liabilities cross, a violation of the proportional hazard assumption.

[25]In unreported tests, I verify that the results are not sensitive to the assumed exponential proportional hazards distribution and remain qualitatively (and quantitatively) similar for the Weibull and Gompertz proportional hazards distributions.

[26]Firm fixed-effects are excluded from the Cox regressions in exchange for primary mineral fixed effects. Just as Kalbfleisch and Sprott (1970) find that logistic and probit models suffer from "incidental parameter bias" when using a large number of parameters, Allison (2002) uses simulations to show this same bias is nearly as severe in Cox regressions.

is very close to 1 and is insignificant, suggesting that a firm's traditional debt obligations are unrelated to its decision to exercise the real option.

Models (2) through (5) add the same additional control variables in the same progression as Table 5. The estimated project NPV, capital costs, and mine life are included as static covariates, while the rest are time-varying. Models (2) through (5) report results similar to those in Model (1) in that both self-bonded and externally-bonded reclamation liabilities seem to impact a firm's exercise decision. The main difference in these models is the hazard ratio for self-bonded reclamation liabilities is not significant at conventional levels. The biggest loss of significance happens when adding mineral-specific time-varying coefficients to the Cox models. This could reflect that when better controlling for factors that influence a firm's optimal trigger point, reclamation liabilities lose explanatory power. Alternatively, it could be the case that the time-varying coefficients make identifying true exposure to overhang, a tail event, more difficult for the liability leverage ratios.

Panel B of Table 6 displays the results using indicators for Myers's wedge with the same progression of static and time-varying control variables. The hazard ratios for self-bonded reclamation liabilities range between 0.329 and 0.476, and in contrast to Panel A, remain significant at the 5% level when including the additional control variables. This provides support for the argument that the linear measure for overhang struggles to properly identify when firms should be exposed to overhang. Again consistent with earlier results, externally-bonded reclamation liabilities and traditional debt do no impact the timing of the construction decision, suggesting that overhang is an important ex post concern only for liabilities that have high contracting costs.[27] These results provide direct support for the empirical predictions in Mello and Parsons (1992) and Mauer and Ott (2000).

The costs of the delay imposed by reclamation liabilities are significant. I use a back of the envelope calculation to approximate the delay induced by self-bonded reclamation liabilities.

[27]Even for liabilities with high contracting costs, other market mechanisms may arise to mitigate the costs of overhang. For example, Internet Appendix Table IA 6 shows that firms with high self-bonded reclamation liabilities attempt to sell positive NPV projects more often than otherwise similar firms.

Specifically, I calculate the difference in the survival function between $\mathbb{1}_{\text{SB}\geq\text{NPV}} = 1$ and $\mathbb{1}_{\text{SB}\geq\text{NPV}} = 0$ at each percentile of mining projects beginning construction. Firm-project pairs in which self-bonded reclamation liabilities exceed the NPV begin construction, on average, 1.9 years later than otherwise similar pairs. For the median project constructing nearly two years later, the new NPV is $172/1.075^{1.9}$ = \$149.9 million, which represents a time-value-of-money loss of \$22.1 million. Because the baseline likelihood of starting construction on a positive NPV mining project is 5.01%, firms with large self-bond reclamation liabilities face an expected loss each year of \$1.1 million. The present value of holding this liability for 20 years (typical life of mines in my sample) is \$14.6 million or 4.00% of market value for the median producing firm.

4.3 Risky Liabilities

One of the main assumptions in Myers's (1977) model is that the firm's existing liability is *risky* debt. Thus it seems that a debt overhang effect should be concentrated in firms with riskier liabilities. Once again, studying the mining industry offers an inherent advantage—the energy sector is extremely volatile. For example, S&P Global Ratings (2019) reports that Energy & Natural Resource's weighted average default rate from 1981-2018 is over 3%, placing it just behind Leisure Time/Media for highest defaulting industry. The fact that oil & gas and mining, in general, are prone to default suggests that a large percentage of the firms in my sample do indeed have risky liabilities.

Table 7 considers this prediction from Myers's model more directly. I take two approaches to mitigate the impact of safe cash flows and liabilities on my results. First, for each of my main tests (Model (4) from Table 4, and Model (2) from Panels A and B in Table 5), I exclude any firm that receives an investment grade security rating at any point in my sample period. These results appear in Models (1), (3), and (5). Second, I interact each overhang measure from my main tests with an indicator variable that equals one in the year of, and the year prior to, a security rating downgrade from either S&P or Moody's.[28] The interaction results appear in Models (2), (4), and (6).

Models (1), (3), and (5) of Table 7 very closely resemble the main tests using the full sample of firms as the coefficient on self-bonded reclamation liabilities is negative and significant at the 1% level in each. The point estimates are each slightly larger than those with the full sample, suggesting that the safest firms are mitigating the average effect of overhang from self-bonded reclamation liabilities. Models (2), (4), and (6) indicate that the likelihood for firms with self-bonded reclamation liabilities to acquire new rights or begin construction on NPV positive mining projects is significantly lower in downgrade periods. This effect is quite large. For example, the interaction term in Model (4) is -0.368, nearly 7 times as large as the average effect of -0.054.

The results in Table 7 confirm two points. First, the mining industry overall is considerably risky. For example, only a handful of firms earn an investment grade security rating over any sample period used. Further, while the interaction of self-bonded reclamation liabilities with the downgrade period is negative and significant, self-bonded reclamation liabilities on their own are significantly related to underinvestment. Second, the results are consistent with the hypothesis that overhang is more pronounced for riskier liabilities.[29]

5 External Validity

Studies on firm decisions from niche industries like resource extraction reasonably raise questions on external validity. My use of mine reclamation liabilities as an instrument to study debt overhang may amplify these concerns. However, while mine reclamation liabilities are certainly unique to resource extraction, other general liabilities exist that could induce similar investment behavior. In fact, Rauh (2006), and Arena and Julio (2015) and Bennett

[28] The rationale for using the year prior to, as well as the year of, a rating downgrade is that most times the downgrade significantly lags the precipitating event.

[29] Internet Appendix Table IA7 shows similar results for both U.S. samples discussed in the following section.

et al. (2018) find results consistent with an overhang effect when studying pension and legal liabilities, respectively.

Furthermore, resource extraction and in particular, resource extraction in Canada is a nontrivial economic sector. Worldwide, resource extraction is a multitrillion dollar industry and Section 2.1 argues that the mining in industry in Canada is among the world's largest. This mitigates a portion of external validity concerns. However, to go a step further, this section reports the results of several additional empirical tests exploring the effect reclamation liabilities have on firm investment.

5.1 Replicating the Negative Correlation Between Liabilities and Capital Expenditures

The first set of tests aims to use my sample on Canadian mining firms to replicate past results in the literature that have examined the effect of a firm's traditional debt liabilities on its capital expenditures. A firm's capital expenditures has become a standard proxy for investment in this literature (E.g., see Lang et al. (1996), Aivazian et al. (2005), Ahn et al. (2006), and Cai and Zhang (2011)). Each model includes year and firm fixed effects and robust standard errors are clustered at the firm level.

Model (2) of Table 8 examines the effect of debt, self-bonded and externally-bonded reclamation liabilities on the level of capital expenditures, including the standard control variables. Similar to prior results, the market debt leverage ratio is negatively related to capital expenditures and is significant at the 5% level. The coefficients on both self-bonded and externally-bonded reclamation liabilities are also negative and significant at the 1% level, although the size of the externally-bonded coefficient is an order of magnitude smaller than those of self-bonded reclamation or traditional debt liabilities. Next, Model (3) includes an interaction term between market leverage and Tobin's Q. The coefficient on this term is negative and significant at the 5%, suggesting that the decrease in capital expenditures among highly levered firms is concentrated in high growth firms. This result is consistent with prior studies and is often interpreted as evidence of debt overhang.

Overall, the results in Table 8 are consistent with panel regression results found in a typical U.S. industrial sample. Market leverage is negatively correlated with capital expenditures and this effect seems to be concentrated in high growth firms, even though in the same sample, traditional debt is unrelated to a firm's investment in positive NPV mining projects. These results imply that previous results showing a decrease in proxies for investment (CapEx, etc.) may be identifying a decrease in firms' overall investment opportunity sets, or a decrease in *negative* NPV projects. For example, it could be the case that financial covenants restrict Jensen's (1986) free cash flow problem. Additionally, these results provide some measure of reassurance that the results in Section 4 are not simply due to a unique sample.

5.2 Overhang and Investment in the U.S.

This set of empirical tests takes advantage of two different samples from the U.S. First, some mining firms voluntarily disclose the amount of their reclamation liabilities and the method in which these liabilities are bonded. I hand-collect this information from firms' 10-Ks and other reports over a sample period of 1992-2016. This yields just over 40 firms and around 350 firm-year observations. Second, I used data from the U.S. Mine Safety and Health Administration (MSHA) that reports mine-level information such as mine location and status through time. This sample yields nearly 5,000 mining firms, including 120 I can match to Compustat, over a period of 1983-2016.

Table 9 displays the results of these regressions where the dependent variable is capital expenditures in Models (1) through (6), and the incidence of a new mine in Model (7). Models (1) and (2) report the results using the firm's leverage liability ratios constructed from the hand-collected data. Consistent with earlier results, the coefficient on SB/MV is negative and significant in both cases. Models (3) and (4) confirms the negative relation using an indicator variable for firms that disclose any use of self-bonds. Finally, Models (5) through (7) use the MSHA data to create a measure that counts the number of self-bonded mines owned by each firm and show that this measure is negatively related to CapEx (Models (5) and (6)) and the likelihood a firm starts a new mine (Model (7)).

The results in Table 9 are consistent with the idea that self-bonded reclamation liabilities negatively impact firm investment and that this result is not unique to Canadian resource extraction firms. Furthermore, the results help ease concerns about the assumptions made for the identification of self-bonding reclamation liabilities in Section 4.

6 Conclusion

Debt overhang is a clearly modeled inefficiency that plays a central role in capital structure theory. However, contracting and debt composition mechanisms exist that could make debt overhang difficult to identify empirically. In addition, fully identifying the effects of overhang requires observing the firm's opportunity set. To mitigate these identification challenges, I exploit novel data on resource extraction that provides ex ante NPV estimates and firms that carry two major types of liabilities, traditional debt and reclamation liabilities, each with different costs associated with avoiding the overhang problem.

Consistent with debt overhang, I find that firms' investment decisions are significantly affected by the overhang imposed by unsecured mine reclamation liabilities. In particular, firms with such liabilities are more likely to forego the acquisition of new positive NPV mining rights, and to postpone construction in existing positive NPV mining projects than firms without such liabilities.

Firms' traditional debt, in contrast, is unrelated to investment in such positive NPV projects, consistent with the proposition that contracting and debt composition mechanisms exist that enable firms to avoid the debt overhang problem. This in true even in a sample in which firms' leverage ratios are negatively correlated with capital expenditures. Together, these results suggest that previous studies which use capital expenditures as a proxy for investment may identify a decrease in the overall opportunity set or even a decrease in negative NPV projects.

My findings imply that traditional debt, by itself, imposes few overhang-related investment distortions. This does not mean, however, that debt overhang is unimportant. Rather, my unique settings highlights exactly how important debt overhang is in capital structure decisions and why such effective solutions have endogenously arisen to mitigate it. Specifically, the overhang imposed by mine reclamation liabilities suggests that the costs of these ex ante solutions for traditional debt could be as large as 6.27% of firm value.

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Figure 1: SB vs EB example. This figure displays three coal mines on the border of British Columbia and Alberta, Canada as an example of the specifics of my empirical strategy. The data on estimated reclamation liabilities were hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1.

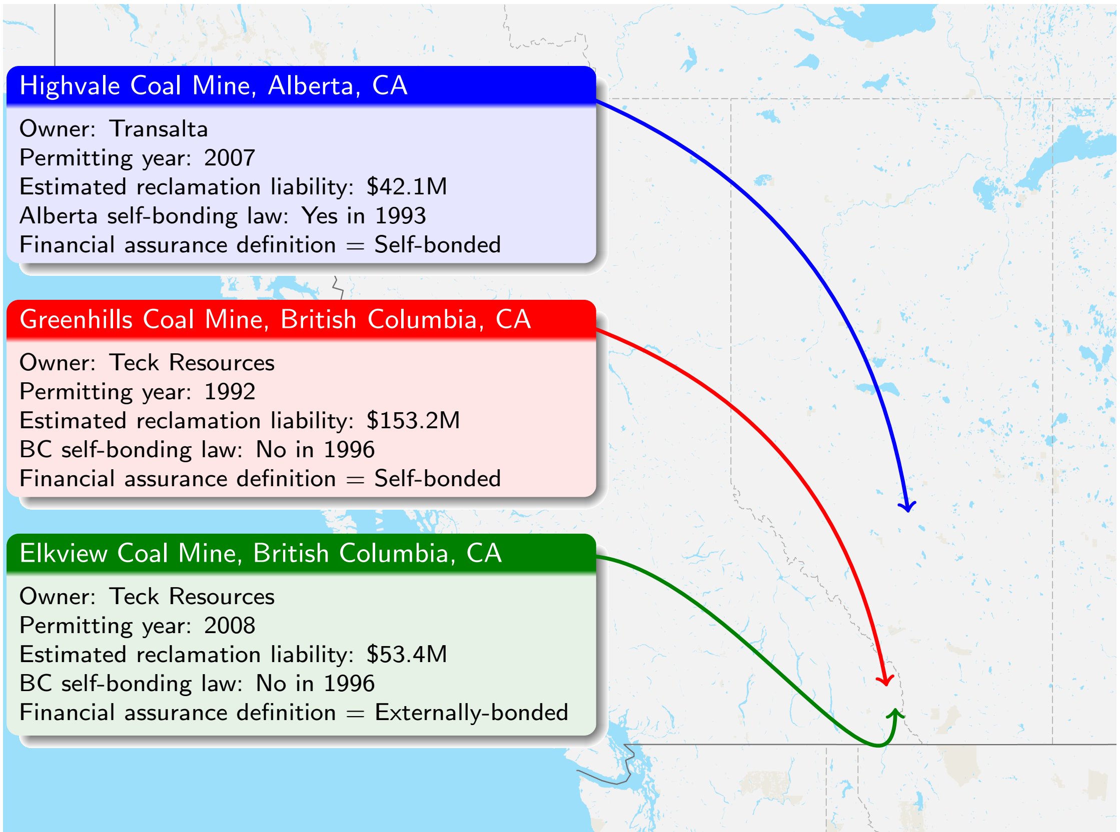

Figure 2: The life cycle of a typical mining project. This figure displays the life cycle of a typical mining project. The source for this figure is KPMG International 2012. This figure also highlights the main milestones at each stage for a mining project. The mines in my sample match very closely with the ranges given for the various stages. The median and mean numbers for mining projects spent in exploration (prospecting and exploration) in my sample are 6 and 7.5 years, respectively. The median and mean numbers for mining projects spent in evaluation (feasibility) in my sample are 5 and 5.2 years, respectively. The median and mean numbers for mining projects spent in development (construction/permitting) in my sample are 3 and 4.75 years, respectively. The median and mean numbers for mining projects spent in production in my sample are 12 and 19.9 years, respectively. Finally, the median and mean numbers for mining projects spent in closure in my sample are 10 and 11.1 years, respectively. It is, however, very difficult to discern when a mining project finishes the closure stage.

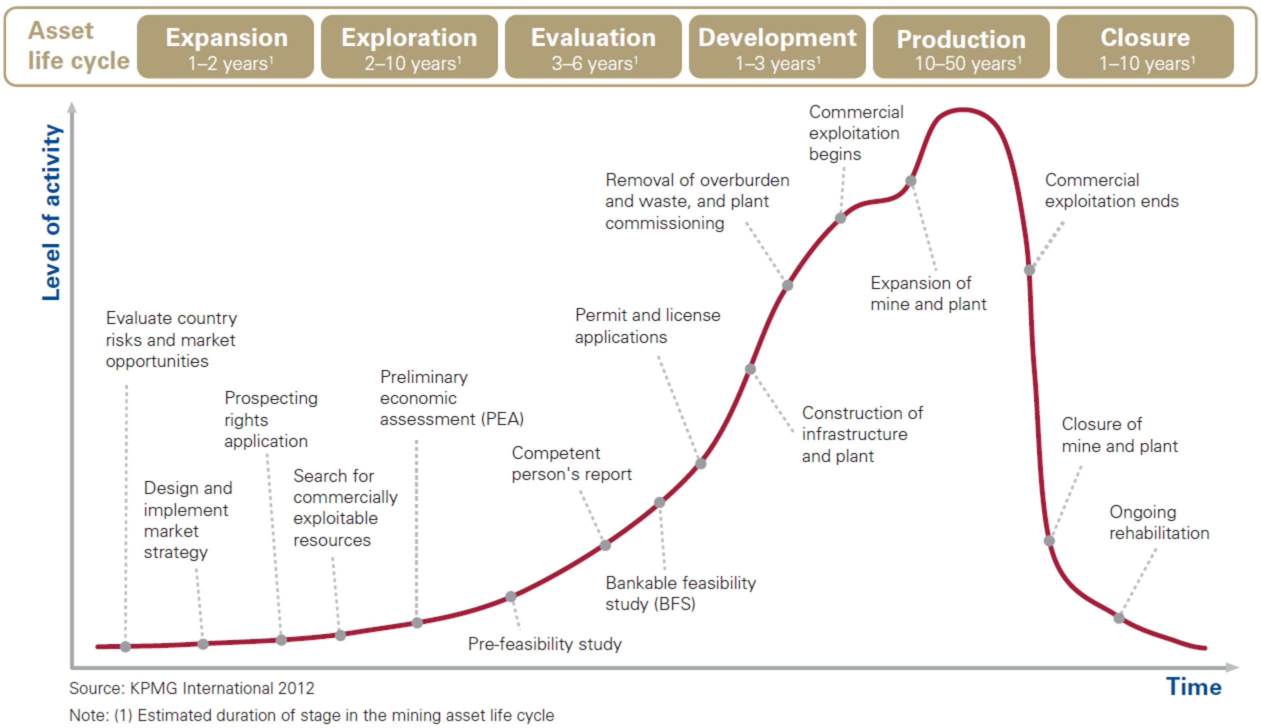

Figure 3: Survival analysis. This figure displays Kaplan-Meier survival functions. The sample is comprised of project-year observations for mining projects from the year the firm publicly discloses the NI 43-101 technical report that includes the initial NPV estimate to the year the firm begins construction on the mine, or the sample period ends, whichever comes first. The sample consists of firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 2003 to 2016. A project experiences an "event" when it begins construction. Solid lines represent the observed non-parametric survival functions while dashed lines depict the predicted functions. Each sub-figure is split on whether the liability—self-bonded reclamation liabilities, externally-bonded reclamation liabilities, or total debt—exceeds the initial NPV estimate. The data on estimated reclamation liabilities was hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1.

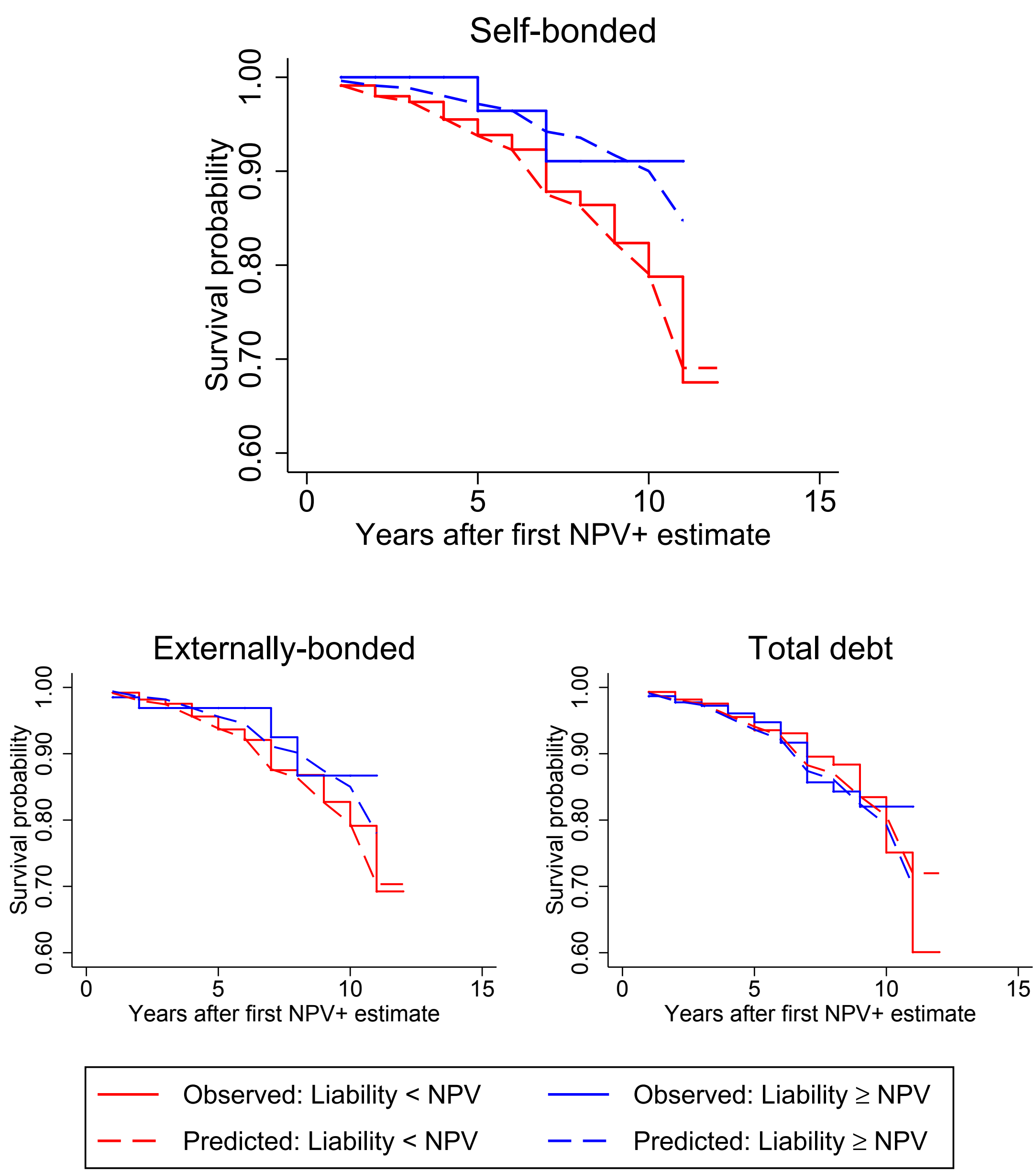

Table 1: Self-bonding mining regulations. This table displays the self-bonding regulations for the United States (panel A) and the rest of the world (panel B). The sources for the mining regulations are the various annotated state statutes and country legislative acts. While this is not an exhaustive list, the regulations listed in this table cover over 90% of the permitted mines in my sample. For the purposes of this paper, states and countries without a bonding regulation, and those time periods before a law is passed to allow (or disallow) self-bonding, are treated as if they explicitly allow self-bonding.

Panel A: United States

	Coal Mining			**Hardrock and Metal Mining**		
State	**Federal or State Statute**	**Year**	**Self-bonding allowed**	**Federal or State Statute**	**Year**	**Self-bonding allowed**
All	Surface Mining Control and Reclamation Act (SMCRA)	1977	Yes	43 C.F.R. §3809.555, .571(c)	2001	No
Alabama	ALA. CODE §§9-16-89(c)	1982	Yes	ALA. CODE §§9-16-8	1969	No
Alaska	ALASKA STAT. §§27.21.160	1982	Yes	ALASKA STAT. §§27.19.040(e)	1990	Yes
Arizona				ARIZ. REV. STAT. §§27-991	1994	Yes
Arkansas	ARK. CODE ANN. §§15-58-509	1979	Yes	ARK. CODE ANN. §§15-57-317	1991	Yes
California				CAL. PUB. RES. CODE §2773.1	1975	Yes
Colorado	COLO. REV. STAT. §34-33-113(3)	1979	Yes	COLO. REV. STAT. §34-32-117(3)(f)	1977	Yes
Delaware				DEL. CODE ANN. tit. 7 §6115	1953	Yes
Florida				FLA. STAT. ANN. §§253.571	1969	Yes
Georgia				GA. CODE ANN. §§12-4-75(3)	1968	No
Hawaii	HAW. REV. STAT. §§182-3	1963	Yes	HAW. REV. STAT. §§182-3	1963	Yes
Idaho				IDAHO CODE §47-1512 (surface)	1955	No
				IDAHO CODE §47-1317 (dredge)	1971	Yes
Illinois	225 ILL. COMP. STAT. 720/6.01(b)	1981	Yes	225 ILL. COMP. STAT. 715/8	1983	No
Indiana	IND. CODE 14-34-7	1982	Yes	IND. CODE 14-36-1-24	1995	Yes
Iowa	IOWA CODE §207.10	1985	No	IOWA CODE §208.23	1985	No
Kansas	KAN. STAT. ANN. §§49-615(a)	1994	No	KAN. STAT. ANN. §§49-615(a)	1994	No
Kentucky	KY. REV. STAT. ANN. §350.064(2)	1980	No			
Louisiana	LA. REV. STAT. ANN. §§30:909(c)	1978	No			
Maine				ME. REV. STAT. ANN. tit. 38 §490-RR(3)	1979	Yes
Maryland	MD. CODE ANN., ENVIR. §§15-612	1976	No	MD. CODE ANN., ENVIR. §§15-507, 15-823	1975	No
Michigan				MICH. COMP. LAWS §§324.63211	1968	Yes
Minnesota				MINN. STAT. §§93.49	1969	Yes
Mississippi	MISS. CODE ANN. §§53-9-31	1979	Yes	MISS. CODE ANN. §§53-7-37	1977	Yes
Missouri	MO. ANN. STAT. §§444.950	1982	Yes	MO. ANN. STAT. §§444.368 (metals)	1989	Yes
				MO. ANN. STAT. §§444.778 (other)	1971	No
Montana	MONT. CODE ANN. §§82-4-223	1971	No	MONT. CODE ANN. §§82-4-338	1971	Yes
Nebraska						
Nevada				NEV. REV. STAT. §§519A.160(4)	1989	Yes
New Hampshire				N.H. REV. STAT. §12-E:6	1979	Yes
New Mexico	N. M. STAT. ANN. §§69-25A-13	1979	Yes	N. M. STAT. ANN. §§69-36-7(q)	1994	No
New York				N.Y. ENVTL. CONSERV. LAW §§23-2701	1976	Yes
North Carolina				N.C. GEN. STAT. §§74-54	1971	Yes
North Dakota	N.D. CENT. CODE §§38-14.1-16.8	1979	Yes	N.D. CENT. CODE §§38-14.1-16.8	1979	Yes
Ohio	OHIO REV. CODE ANN. §§1513.01(W)	2000	Yes	OHIO REV. CODE ANN. §§1514.04	2002	No
Oklahoma	OKLA. STAT. tit. 45 §§745.6(e)	1979	Yes	OKLA. STAT. tit. 45 §§728(e)	1982	No
Oregon				OR. REV. STAT. §§517.810	1971	Yes
Pennsylvania	25 PA. CONS. STAT. §§86.159	1982	Yes	25 PA. CONS. STAT. §§77.222	1990	No
South Carolina	S.C. CODE ANN. §§48-20-110	1990	Yes	S.C. CODE ANN. §§48-20-110	1990	Yes
South Dakota				S.D. CODIFIED LAWS §§45-6B-23	1982	No
Tennessee	TENN. CODE ANN. §§59-8-408	1987	No	TENN. CODE ANN. §§59-8-207	1972	No
Texas	TEX. NAT. RES. CODE ANN. §§134.123	1995	Yes	TEX. NAT. RES. CODE ANN. §§134.123	1995	Yes
Utah	UTAH CODE ANN. §§40-10-15(3)	1979	Yes	UTAH CODE ANN. §§40-8-14(3)	1975	Yes
Virginia	VA. CODE ANN. §§45.1-241	2014	No	VA. CODE ANN. §§45.1-183	1968	No
Washington				WASH. REV. CODE §§78.56.110(1) and 78.44.087(3)	1994	No
West Virginia	W. VA. CODE §§22-3-11(c)	1987	Yes			
Wisconsin				WIS. STAT. §§295.59 and 293.51	1973	No
Wyoming	WYO. STAT. ANN. §§35-11-417	1973	Yes	WYO. STAT. ANN. §§35-11-417	1973	Yes

Table 1—*Continued*

Panel B: Non-US Countries

Country	State or Province	Regulation	Year	Bonding Regulation	Self-bonding allowed
Argentina		1997 Mining Code	1997	No	
Australia		Mining regulations at the state level			
	New South Wales	Protection of the Environment Operations Act 1997 No 156 Part 9.4	1997	Yes	Yes
	Queensland	Environmental Protection Act 1994 (EM1010)	1994	Yes	No
	South Australia	Opal Mining Act	1995	Yes	Yes
	Tasmania	Mineral Resources Development Act 1995 Sec 14, 53, and 75	1995	Yes	No
	Victoria	Mineral Resources (Sustainable Development) Act 1990 (MR(SD)A) Sec 78	1990	Yes	No
	Western Australia	Mining Act 1978 Sec 126	1978	Yes	Yes
Bolivia		1997 Mining Code	1997	No	
Botswana		Mines and Minerals act of 1999	1999	Yes	Yes
Burkina Faso		The Mining Code, Article 12 of Decree No. 2017-068	2017	Yes	No
Brazil		NRM 20 and DN 127	2001, 2009	No	
Canada		Mining regulations at the province level			
	Alberta	Conservation and Reclamation Regulation Sec 21	1993	Yes	Yes
	British Columbia	Bonding Act (RSBC 1996) Chapter 30	1996	Yes	No
	Manitoba	Mine Closure Regulation, 1999 (Mines and Mineral Act)	1999	Yes	Yes
	New Brunswick	Mining Act	1989	Yes	No
	Newfoundland	Mining Act Chapter M-15.10	1999	Yes	No
	Northwest Territories	NWT Waters Act	1992	Yes	No
	Nova Scotia	Minerals Resources Act S.N.S. 1990, c.18 Sec 77	1990	Yes	Yes
	Nunavut	Nunavut Water Regulations Sec 10.3	2013	Yes	No
	Ontario	Ontario Mining Act	2000	Yes	Yes
	Quebec	Quebec Mining Act	1998	Yes	Yes
	Saskatchewan	The Mineral Industry and Environmental Protection Regulations	1996	Yes	No
	Yukan Territory	Yukon Water Act	1992	Yes	Yes
Chile		1983 Mining Code	1983	No	
Colombia		Law No. 685 (The Mining Code)	2001	No	
Congo		Law No. 007/2002 (The Mining Code)	2002	Yes	No
Dominican Republic		Environmental Law (Law No. 64-00)	2000	Yes	No
Ethiopia		Environmental Protection Authority Establishment Proclamation No. 9/1995	1995	Yes	No
Finland		Environmental Protection Act Section 43a (647/2011)	2011	Yes	No
Ghana		EPA Act 494 and LI 1652	1999	Yes	No
Indonesia		R.I. Government Regulation No. 78	2010	Yes	No
Mali		The Mining Law	1999	No	
Mexico		NOM-141-SEMARNAT-2003	2003	Yes	No
Mongolia		Mongolia Minerals Law	1997	Yes	No
Panama		Code of Mineral Resources, Law 13 of 2012	2012	Yes	No
Papua New Guinea		Mining Act of 1992	1992	No	
Peru		Law No. 28090, Law that Rules the Closing of Mines (Ley que Regula el Cierre de Minas)	2003	Yes	No
Philippines		DENR Administrative Order No. 2010-21 (Mining Act IRR)	2010	Yes	No
South Africa		National Environment Management Act (NEMA)	1998	Yes	No
Tanzania		The Mining Act	2010	Yes	Yes
Turkey		Regulation on Reclamation of Lands Disturbed by Mining	2007	No	
Vietnam		Mineral Law	1996	Yes	No
Zambia		Mines and Minerals Development Act No. 7 of 2008	2008	Yes	No
Zimbabwe		Environmental Management Act [Chapter 20:27]	2002	Yes	No

Table 2: Mine-level summary statistics. This table displays summary statistics for mines owned by firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada during the period 1990 to 2016. Observations in Panel A are at the mine-year level, and observations in Panel B and Panel C are at the mine-level. Data on firms' mines, including mine status, mine type, primary mineral extracted, mine location, and project-level data on estimated NPV, capital costs, discount rates, and mine life were provided by Mining Intelligence. Other mining data, including estimated reclamation liabilities and the surface area to be reclaimed were hand-collected from firms' public disclosures. Self-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. All monetary variables are reported in U.S. dollars, using historical exchange rates from OFX when values are reported in other currencies.

Panel A: All mining projects (mine-year observations)					
Variable	**Obs.**	**Mean/ Percentage**	**Median**	**Min**	**Max**
Mine status (in %)					
Prospect/exploration	22,379	0.623			
Feasibility	22,379	0.041			
Construction/Permitting	22,379	0.015			
Production	22,379	0.142			
Closed	22,379	0.027			
Panel B: Permitted mines (mine observations)					
Surface area to be reclaimed (in km^2)	580	106.5	42.5	0.04	2663
Estimated reclamation liabilities (in $Ms)	580	27.7	6.6	0	558
Self-bonded mines (in %)	580	0.398			
Estimated self-bonded reclamation liabilities (in $Ms)	188	24.2	6.5	0.0	400
Mine type (in %)					
Open-pit or surface	580	0.553			
Underground	580	0.436			
Primary mineral extracted (in %)					
Gold	580	0.478			
Copper	580	0.083			
Coal	580	0.071			
Silver	580	0.045			
Zinc	580	0.045			
Uranium	580	0.043			
Other or combination	580	0.236			
Mine location (in %)					
Canada	580	0.288			
United States	580	0.200			
Mexico	580	0.112			
Australia	580	0.047			
Chile	580	0.036			
Brazil	580	0.029			
Other	580	0.290			

Table 2—*Continued*

Panel C: Projects with Estimated NPV (mine observations)					
Variable	**Obs.**	**Mean/ Percentage**	**Median**	**Min**	**Max**
Initial NPV estimate ($Ms)	269	402.4	172	-48.9	7114.6
Initial capital costs estimate ($Ms)	269	535.7	223	1.2	7899.0
Discount rate (%)	269	6.8	7.5	5	15
Estimated mine life (years)	269	14.1	11	1	50
Projects undertaken by 2016 (%)	269	0.283			
$\mathbb{1}_{\mathrm{SB} \geq \mathrm{NPV}}$	269	0.043	0	0	1
$\mathbb{1}_{\mathrm{EB} \geq \mathrm{NPV}}$	269	0.072	0	0	1
$\mathbb{1}_{\mathrm{TD} \geq \mathrm{NPV}}$	269	0.177	0	0	1
Acquisition of mining rights					
Total acquisition cost ($Ms)	191	38.5	9.1	0.9	532.0
NPV of mining rights ($Ms)	191	200.6	68.5	-115.8	1129.0
Primary mineral extracted (in %)					
Gold	269	0.442			
Copper	269	0.171			
Silver	269	0.041			
Uranium	269	0.041			
Other or combination	269	0.305			
Mine location (in %)					
Canada	269	0.428			
United States	269	0.112			
Mexico	269	0.112			
Peru	269	0.045			
Other	269	0.303			

Table 3: Firm-level summary statistics. This table reports firm-level summary statistics for firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 1990 to 2016. Data on firms' mines, including the number of mining projects, were provided by Mining Intelligence. The data on estimated reclamation liabilities, as well as the surface area to be reclaimed, were hand-collected from firms' public disclosures. *SB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as self-bonded divided by the market value of the firm's assets. *EB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) divided by the market value of the firm's assets. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. Accounting data is from Compustat—North America. Variable definitions are located in Appendix A1. All monetary variables are reported in U.S. dollars, using historical exchange rates from OFX when values are reported in other currencies. All ratio variables are winsorized at the 1% and 99% levels.

Variable	**Obs.**	**Mean**	**Median**	**Min**	**Max**
Mining variables					
Estimated reclamation liabilities (in \$Ms)	7,986	10.2	0.0	0.3	1,609
SB/MV	7,079	0.010	0.000	0.000	10.540
EB/MV	7,079	0.058	0.000	0.000	72.410
Surface area to be reclaimed (km^2)	7,986	38.4	0.0	0.0	3,109
Self-bonded surface area (%)	7,986	0.07	0.00	0.00	1.00
Likelihood of acquiring new mining rights (all)	7,986	0.194	0	0	1
Likelihood of acquiring new mining rights (NPV+)	7,986	0.037	0	0	1
Prospect/exploration	7,986	1.6	0	0	73
Feasibility	7,986	0.1	0	0	4
Construction/permitting	7,986	0.0	0	0	6
Production	7,986	0.3	0	0	15
Closed	7,986	0.1	0	0	7
Mining variables (firms with producing mines)					
Estimated reclamation liabilities (in \$Ms)	1,182	68.7	11.9	0.3	1,609
SB/MV	1,094	0.062	0.004	0.000	10.540
EB/MV	1,094	0.373	0.009	0.000	72.410
Surface area to be reclaimed (km^2)	1,182	259.3	87.1	0.0	3,109
Self-bonded surface area (%)	1,182	0.48	0.34	0.00	1.00
Likelihood of acquiring new mining rights (all)	1,094	0.265	0	0	1
Likelihood of acquiring new mining rights (NPV+)	1,094	0.057	0	0	1
Prospect/exploration	1,094	2.9	1	0	73
Feasibility	1,094	0.2	0	0	4
Construction/permitting	1,094	0.2	0	0	6
Production	1,094	2.4	1	1	15
Closed	1,094	0.3	0	0	7
Accounting variables					
Capital expenditures (% of book assets)	7,498	0.132	0.081	0.000	0.824
Book value of assets (BV) (in \$Ms)	7,609	856.8	21.0	0.0	76,467
Market value of assets (MV) (in \$Ms)	7,079	925.0	23.3	0.0	61,511
Short-term debt (STD) (in \$Ms)	7,601	18.1	0.0	0.0	7,338
Long-term debt (LTD) (in \$Ms)	7,604	155.5	0.0	0.0	13,173
Market leverage (%)	7,079	0.109	0.000	0.000	0.911
Return on assets (ROA) (%)	7,516	-0.795	-0.098	-21.182	0.314
Cash (% of book assets)	7,603	0.243	0.134	0.000	0.988
Tobin's Q	7,077	3.3	1.1	0.1	64.5
Annual stock return (%)	6,685	0.435	-0.100	-0.907	11.750

Table 4: Firm liabilities and the likelihood of acquiring the rights to new positive NPV mining projects. This table reports the results of linear probability models in which the dependent variable is the likelihood a firm acquires the rights to a new positive net present value (NPV+) mining project. The NPV of the mining rights is defined as the value of the NPV estimate in the NI 43-101 technical reports discounted back to the acquisition year, less the cost the acquiring firm paid for the individual mine at acquisition. The sample consists of firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 1990 to 2016. *SB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as self-bonded divided by the market value of the firm's assets. *EB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) divided by the market value of the firm's assets. The data on estimated reclamation liabilities were hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. *Acquire mining rights (other)* is an indicator variable that equals 1 if a firm acquires rights to a mine that I cannot calculate an NPV number for. Accounting variables (defined in Appendix Table A1) are constructed using data from Compustat—North America and the data on firms' mining projects were provide by Intelligence Mining. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Dependent variable =	Likelihood of acquiring rights to any project		Likelihood of acquiring rights to NPV+ projects	
	(1)	(2)	(3)	(4)
SB/MV	-0.030***	-0.035**	-0.022***	-0.025***
	(0.009)	(0.015)	(0.008)	(0.006)
EB/MV	0.002	0.003	0.001	0.001
	(0.003)	(0.003)	(0.001)	(0.001)
Market leverage	-0.046	-0.057*	-0.014	-0.027
	(0.031)	(0.032)	(0.015)	(0.019)
Log of book assets		0.018***		0.004*
		(0.005)		(0.002)
Cash		0.013		0.010
		(0.023)		(0.011)
ROA		0.000		0.000
		(0.002)		(0.001)
Tobin's Q		0.001		0.000
		(0.001)		(0.000)
Log of firm age		0.001		-0.025**
		(0.021)		(0.011)
# of mines in exploration		0.026***		0.002
		(0.007)		(0.002)
# of mines in feasibility		0.015		0.013
		(0.023)		(0.018)
# of mines in construction/permitting		0.024		0.047**
		(0.030)		(0.019)
# of producing mines		0.008		0.014**
		(0.016)		(0.007)
# of closed mines		0.024		0.045**
		(0.030)		(0.020)
Aquire mining rights (other)				-0.071***
				(0.007)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Number of firms	790	775	790	775
Observations	7,083	6,747	7,083	6,747
R^2	0.275	0.301	0.128	0.166

Table 5: Firm liabilities and the likelihood of beginning construction on positive NPV projects. This table reports the results of linear probability models in which the dependent variable is the likelihood of beginning construction on a positive net present value (NPV+) project. The sample is comprised of project-year observations for mining projects from the year the firm publicly discloses the NI 43-101 technical report that includes the initial NPV estimate to the year the firm begins construction on the mine, or the sample period ends, whichever comes first. The sample consists of firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 2003 to 2016. SB/MV is the sum of estimated reclamation liabilities of all of a firm's mines defined as self-bonded divided by the market value of the firm's assets. EB/MV is the sum of estimated reclamation liabilities of all of a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) divided by the market value of the firm's assets. $\mathbb{1}_{\text{SB}\geq\text{NPV}}$ is an indicator variable that equals 1 if the sum of estimated reclamation liabilities of all of a firm's mines defined as self-bonded exceeds the initial NPV estimate of the mining project. $\mathbb{1}_{\text{EB}\geq\text{NPV}}$ is an indicator variable that equals 1 if the sum of estimated reclamation liabilities of all of a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) exceeds the initial NPV estimate of the mining project. $\mathbb{1}_{\text{TD}\geq\text{NPV}}$ is an indicator variable that equals 1 if the firm's total debt exceeds the initial NPV estimate of the mining project. The data on estimated reclamation liabilities were hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. Accounting variables (defined in Appendix Table A1) are constructed using data from Compustat—North America, the project data were provide by Intelligence Mining and futures data is from Bloomberg. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Panel A: Liability ratios

Dependent variable =	Likelihood of beginning construction on an NPV+ project				
	(1)	(2)	(3)	(4)	(5)
SB/MV	-0.046***	-0.054***	-0.055***	-0.048**	-0.124***
	(0.014)	(0.014)	(0.016)	(0.020)	(0.024)
EB/MV	0.020	0.003	0.011	0.012	0.122
	(0.061)	(0.062)	(0.125)	(0.132)	(0.137)
Market leverage	0.010	-0.007	-0.030	-0.038	-0.070
	(0.058)	(0.056)	(0.057)	(0.060)	(0.069)
Log of book assets		0.018	0.023	0.023	0.017
		(0.014)	(0.016)	(0.017)	(0.019)
Cash		0.043	0.034	0.042	0.042
		(0.058)	(0.072)	(0.074)	(0.079)
ROA		-0.015	-0.021	-0.022	-0.018
		(0.012)	(0.016)	(0.016)	(0.017)
Tobin's Q		0.000	-0.001	-0.002	-0.002
		(0.005)	(0.007)	(0.007)	(0.008)
Log of firm age		-0.055	-0.049	-0.059	-0.037
		(0.064)	(0.074)	(0.078)	(0.074)
Project NPV ($100Ms)		0.014**	0.016*	0.013	0.012
		(0.007)	(0.009)	(0.009)	(0.008)
Project Capital Costs ($100Ms)		-0.014**	-0.012*	-0.009	-0.008
		(0.007)	(0.007)	(0.008)	(0.007)
Expected mine life		-0.002	-0.002	-0.004	-0.009
		(0.004)	(0.005)	(0.010)	(0.012)
Total NPV of alternative projects ($100Ms)		-0.014	-0.013	-0.013	-0.012
		(0.011)	(0.011)	(0.011)	(0.011)
Start alternative NPV+ project		-0.042	-0.032	-0.017	-0.013
		(0.111)	(0.117)	(0.114)	(0.113)
Primary mineral price (% ch.)			-0.001		
			(0.064)		
Futures price				0.007	-0.009
				(0.015)	(0.012)
Options-implied volatility					-0.058
					(0.065)
Controls for projects in each stage	No	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Primary mineral FE	No	No	No	Yes	Yes
Number of firms	177	174	143	140	126
Observations	838	822	679	662	589
R^2	0.289	0.299	0.294	0.296	0.306

Table 5—*Continued*

Panel B: Liability indicators					
Dependent variable =	Likelihood of beginning construction on an NPV+ project				
	(1)	(2)	(3)	(4)	(5)
$\mathbb{1}_{\text{SB} \geq \text{NPV}}$	-0.232**	-0.264**	-0.269**	-0.243**	-0.378*
	(0.116)	(0.109)	(0.106)	(0.106)	(0.222)
$\mathbb{1}_{\text{EB} \geq \text{NPV}}$	0.013	-0.019	0.001	0.024	0.046
	(0.072)	(0.082)	(0.086)	(0.097)	(0.104)
$\mathbb{1}_{\text{TD} \geq \text{NPV}}$	-0.018	-0.034	-0.028	-0.043	-0.040
	(0.066)	(0.070)	(0.071)	(0.074)	(0.075)
Log of book assets		0.022	0.025	0.025	0.014
		(0.014)	(0.017)	(0.017)	(0.018)
Cash		0.049	0.042	0.047	0.054
		(0.058)	(0.070)	(0.072)	(0.076)
ROA		-0.015	-0.020	-0.021	-0.016
		(0.012)	(0.016)	(0.016)	(0.017)
Tobin's Q		0.000	-0.001	-0.001	-0.003
		(0.005)	(0.007)	(0.007)	(0.008)
Log of firm age		-0.052	-0.047	-0.059	-0.042
		(0.064)	(0.074)	(0.078)	(0.075)
Project NPV ($100Ms)		0.012*	0.012	0.012	0.012
		(0.006)	(0.008)	(0.009)	(0.009)
Project Capital Costs ($100Ms)		-0.013*	-0.011	-0.009	-0.007
		(0.007)	(0.007)	(0.007)	(0.008)
Expected mine life		-0.004	-0.005	-0.006	-0.009
		(0.004)	(0.005)	(0.009)	(0.012)
Total NPV of alternative projects ($100Ms)		-0.015	-0.015	-0.014	-0.011
		(0.011)	(0.011)	(0.011)	(0.011)
Start alternative NPV+ project		-0.023	-0.014	-0.003	0.012
		(0.109)	(0.114)	(0.111)	(0.110)
Primary mineral price (% ch.)			0.016		
			(0.061)		
Futures price				0.010	0.005
				(0.015)	(0.013)
Options-implied volatility					-0.081
					(0.064)
Controls for projects in each stage	No	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Primary mineral FE	No	No	No	Yes	Yes
Number of firms	177	174	143	140	126
Observations	838	822	679	662	589
R^2	0.290	0.300	0.295	0.297	0.300

Table 6: Firm liabilities and time until beginning construction on positive NPV projects. This table reports the results of Cox proportional hazards model regressions. The reported coefficients are the hazard ratios. The sample is comprised of project-year observations for mining projects from the year the firm publicly discloses the NI 43-101 technical report that includes the initial NPV estimate to the year the firm begins construction on the mine, or the sample period ends, whichever comes first. The sample consists of firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 2003 to 2016. The "event" is when the firm begins construction on the project. *SB/MV* is the sum of estimated reclamation liabilities of all of a firm's mines defined as self-bonded divided by the market value of the firm's assets. *EB/MV* is the sum of estimated reclamation liabilities of all of a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) divided by the market value of the firm's assets. $\mathbb{1}_{\text{SB}\geq\text{NPV}}$ is an indicator variable that equals 1 if the sum of estimated reclamation liabilities of all of a firm's mines defined as self-bonded exceeds the initial NPV estimate of the mining project. $\mathbb{1}_{\text{EB}\geq\text{NPV}}$ is an indicator variable that equals 1 if the sum of estimated reclamation liabilities of all of a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) exceeds the initial NPV estimate of the mining project. $\mathbb{1}_{\text{TD}\geq\text{NPV}}$ is an indicator variable that equals 1 if the firm's total debt exceeds the initial NPV estimate of the mining project. The data on estimated reclamation liabilities were hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. In both Panels A and B, the unreported time-varying coefficients used in Model (2) are log of book assets, cash, ROA, and Tobin's Q, log of firm age, the number of projects in each mining stage, the total NPV of the firm's alternative mining projects, and a dummy variable if the firm starts construction on an alternative project. The unreported time-varying coefficients used in Model (3) include those in Model (2), as well as the annual percentage change in the price of the primary mineral extracted. Models (4) and (5) add the 12-month futures price and the implied volatility from historical put-call straddles, respectively. These variables (defined in Appendix Table A1) are constructed using data from Compustat—North America, Mining Intelligence, and Bloomberg. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Panel A: Liability ratios

	Survival analysis				
	(1)	(2)	(3)	(4)	(5)
SB/MV	0.344*	0.657	0.699	0.707	0.646
	(0.191)	(0.328)	(0.296)	(0.300)	(0.300)
EB/MV	0.552	0.725	0.746	0.759	0.143
	(0.449)	(0.402)	(0.416)	(0.367)	(0.306)
Market leverage	0.926	1.347	1.043	1.096	0.925
	(0.405)	(0.717)	(0.539)	(0.572)	(0.461)
Project capital costs ($100Ms)		0.978	0.973	0.985	1.006
		(0.033)	(0.035)	(0.052)	(0.049)
Project NPV($100Ms)		1.026	1.018	1.016	1.017
		(0.023)	(0.025)	(0.025)	(0.023)
Expected mine life		1.027	1.043	1.041	1.011
		(0.046)	(0.046)	(0.048)	(0.032)
Year FE	Yes	Yes	Yes	Yes	Yes
Primary mineral FE	Yes	Yes	Yes	Yes	Yes
Time-varying coefficients	No	Yes	Yes	Yes	Yes
Number of firms	191	189	158	155	144
Observations	955	944	823	811	754
Pseudo-R^2	0.108	0.127	0.114	0.115	0.143

Table 6—*Continued*

Panel B: Liability indicators

	Survival analysis				
	(1)	(2)	(3)	(4)	(5)
$\mathbb{1}_{\text{SB}\geq\text{NPV}}$	0.329***	0.433**	0.467**	0.476**	0.470**
	(0.121)	(0.162)	(0.167)	(0.173)	(0.163)
$\mathbb{1}_{\text{EB}\geq\text{NPV}}$	0.709	0.800	0.864	0.889	0.643
	(0.380)	(0.447)	(0.479)	(0.496)	(0.373)
$\mathbb{1}_{\text{TD}\geq\text{NPV}}$	0.917	0.834	0.867	0.866	0.866
	(0.289)	(0.307)	(0.314)	(0.313)	(0.315)
Project capital costs ($100Ms)		0.951	0.949	0.956	0.945
		(0.043)	(0.042)	(0.049)	(0.051)
Project NPV($100Ms)		1.035	1.027	1.025	1.032
		(0.024)	(0.024)	(0.024)	(0.022)
Expected mine life		1.023	1.041	1.041	1.029
		(0.040)	(0.038)	(0.039)	(0.037)
Year FE	Yes	Yes	Yes	Yes	Yes
Primary mineral FE	Yes	Yes	Yes	Yes	Yes
Time-varying coefficients	No	Yes	Yes	Yes	Yes
Number of firms	191	189	158	155	144
Observations	955	944	823	811	754
Pseudo-R^2	0.108	0.126	0.113	0.114	0.125

Table 7: Risky firm liabilities and positive NPV projects. This table reports the results of linear probability models to analyze how more plausibly risky firm liabilities affect investment in positive NPV projects. The dependent variable and additional control variables for Models (1) and (2) match those of Table 4, Model (5). The dependent variable and additional control variables for Models (3) and (4) match those of Table 5, Model (2). Finally, the dependent variable and additional control variables for Models (5) and (6) match those of Table 6, Model (2). The additional control variables (defined in Appendix Table A1) are constructed using data from Compustat—North America, Mining Intelligence, and Bloomberg. Models (1), (3), and (5) exclude firms that have an investment grade bond rating at some point over the sample period. For Models (2), (4), and (6), the independent variables of interest are the measures of a firm's liabilities (self-bonded and externally-bond reclamation liabilities, and traditional debt), and the interaction of these measures with an indicator variable that equals one in the year a firm receives a credit downgrade from S&P or Moody's, and the year directly preceding the downgrade. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Dependent variable =	Acquire rights		Begin construction			
	(1)	(2)	(3)	(4)	(5)	(6)
SB/MV	-0.023***	-0.021***	-0.058***	-0.054***		
	(0.007)	(0.008)	(0.012)	(0.014)		
EB/MV	0.001**	0.002***	-0.004	0.004		
	(0.001)	(0.001)	(0.063)	(0.061)		
Market leverage	-0.026*	-0.018	-0.004	-0.006		
	(0.015)	(0.017)	(0.055)	(0.062)		
$\mathbb{1}_{SB \geq NPV}$					-0.414***	-0.284*
					(0.157)	(0.148)
$\mathbb{1}_{EB \geq NPV}$					-0.019	0.013
					(0.097)	(0.086)
$\mathbb{1}_{TD \geq NPV}$					0.003	-0.052
					(0.132)	(0.121)
SB/MV × downgrade period		-0.102**		-0.368**		
		(0.045)		(0.141)		
EB/MV × downgrade period		0.056***		0.052		
		(0.017)		(0.174)		
Market leverage × downgrade period		-0.006		-0.002		
		(0.005)		(0.037)		
$\mathbb{1}_{SB \geq NPV}$ × downgrade period						-0.170*
						(0.097)
$\mathbb{1}_{EB \geq NPV}$ × downgrade period						0.092
						(0.197)
$\mathbb{1}_{TD \geq NPV}$ × downgrade period						0.137
						(0.138)
Downgrade period		0.003		0.005		0.028
		(0.003)		(0.020)		(0.085)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	756	775	170	174	170	174
Observations	6,361	6,747	791	822	791	822
R^2	0.133	0.135	0.312	0.300	0.312	0.302

Table 8: Firm liabilities and capital expenditures. This table reports the results of linear regression models in which the dependent variable is capital expenditures (as a percentage of a firm's total book assets). In Models (1) through (3) the sample consists of firms listed on the Toronto Stock Exchange (TSX) or Toronto Stock Exchange Venture (TSXV) and located in Canada over the sample period of 1990 to 2016. The sample period in Model (4) is 2003 to 2016 to match the sample used in the project-level analysis. *SB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as self-bonded divided by the market value of the firm's assets. *EB/MV* is the sum of estimated reclamation liabilities of all a firm's mines defined as externally-bonded (guaranteed with a surety bond, letter of credit, etc.) divided by the market value of the firm's assets. The data on estimated reclamation liabilities were hand-collected from firms' public disclosures. Self-bonded and externally-bonded mines are classified using the self-bonding regulations in Table 1 according to the description in Section 3.1. Accounting variables (defined in Appendix Table A1) are constructed using data from Compustat-North America and the data on firms' mining projects were provide by Intelligence Mining. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Dependent variable =	Capital expenditures			
	(1)	(2)	(3)	(4)
SB/MV	-0.023***	-0.022***	-0.022***	-0.021***
	(0.003)	(0.003)	(0.003)	(0.003)
EB/MV	-0.004***	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Market leverage	-0.022	-0.038**	-0.028	-0.033*
	(0.017)	(0.017)	(0.017)	(0.018)
Market leverage × Tobin's Q			-0.003**	
			(0.001)	
Log of book assets		0.004	0.004	0.010***
		(0.004)	(0.004)	(0.004)
Cash		-0.085***	-0.086***	-0.101***
		(0.013)	(0.013)	(0.014)
ROA		-0.012***	-0.012***	-0.013***
		(0.002)	(0.002)	(0.002)
Tobin's Q		-0.002**	-0.001*	-0.002***
		(0.001)	(0.001)	(0.001)
Log of firm age		-0.034***	-0.034***	-0.039***
		(0.010)	(0.010)	(0.010)
# of mines in exploration		0.001	0.001	0.000
		(0.001)	(0.001)	(0.001)
# of mines in feasibility		0.002	0.002	0.002
		(0.006)	(0.006)	(0.006)
# of mines in construction/permitting		0.025**	0.025**	0.024**
		(0.011)	(0.011)	(0.011)
# of producing mines		-0.002	-0.002	-0.002
		(0.003)	(0.003)	(0.004)
# of closed mines		0.000	0.000	0.003
		(0.006)	(0.006)	(0.009)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Number of firms	790	775	775	764
Observations	7,029	6,697	6,697	5,904
R^2	0.354	0.387	0.388	0.415

Table 9: Reclamation liabilities and investment in the U.S. This table reports the results of linear regression models in which the dependent variable of interest is either capital expenditures (as a percentage of a firm's total book assets) or the incidence of a new mine (Model (7)). In Models (1) through (4), the sample consists of mining firms incorporated in the United States over the sample period of 1992 to 2016 that self-disclosed reclamation liabilities in their annual reports. *SB/MV* is total amount of disclosed self-bonded reclamation liabilities divided by the market value of the firm's assets. *EB/MV* is total amount of disclosed externally-bonded (guaranteed with a surety bond, letter of credit, etc.) reclamation liabilities divided by the market value of the firm's assets. $\mathbb{1}_{\text{SB}\geq 0}$ is an indicator variable that equals 1 if the firm has a positive amount of self-bonds. In Models (5) through (7), I use data from the Mine Safety and Health Administration (MSHA) on the location and permitting of a firm's mines to calculate the number of mines defined as self-bonded and externally-bonded using the self-bonding regulations in Table 1 according to the description in Section 3.1. Accounting variables (defined in Appendix Table A1) are constructed using data from Compustat-North America. Robust standard errors, clustered at the firm level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Dependent variable =	Capital expenditures						New mine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SB/MV	-0.080*	-0.112**					
	(0.040)	(0.043)					
EB/MV	-0.016	-0.011					
	(0.014)	(0.008)					
$\mathbb{1}_{\text{SB}\geq 0}$			-0.016***	-0.022***			
			(0.004)	(0.008)			
# of self-bonded mines					-0.003*	-0.003*	-0.015**
					(0.002)	(0.001)	(0.006)
# of externally-bonded mines					0.003*	0.003**	0.016***
					(0.001)	(0.001)	(0.006)
Market leverage	-0.037	-0.002	-0.040	-0.015	-0.026**	-0.009	
	(0.028)	(0.032)	(0.026)	(0.028)	(0.012)	(0.012)	
Log of book assets		0.011		0.010		-0.004	
		(0.016)		(0.015)		(0.003)	
Cash		-0.080**		-0.035		-0.092***	
		(0.035)		(0.037)		(0.017)	
ROA		-0.043*		-0.040*		0.043	
		(0.024)		(0.023)		(0.027)	
Tobin's Q		0.028***		0.024***		0.015***	
		(0.006)		(0.005)		(0.005)	
Log of firm age		-0.001		-0.000		0.001	
		(0.001)		(0.001)		(0.005)	
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data used	10-k	10-k	10-k	10-k	MSHA	MSHA	MSHA
Number of firms	39	39	42	42	120	120	4,983
Observations	338	338	359	359	1,453	1,453	33,876
R^2	0.621	0.680	0.629	0.682	0.559	0.585	0.238

Table A1: Data Appendix. This table defines the variables used in the empirical tests in the main portion of the paper and lists the data source(s) for each variable.

Variable name	**Source**	**Definition**
SB	Technical reports, Mining Intelligence	Sum of estimated reclamation liabilities of producing mines defined as self-bonded
EB	Technical reports, Mining Intelligence	Sum of estimated reclamation liabilities of producing mines defined as externally-bonded
SB/MV	Technical reports, Mining Intelligence, Compustat	SB/((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)
EB/MV	Technical reports, Mining Intelligence, Compustat	EB/((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)
Market leverage	Compustat	(dltt+dlc)/((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)
$\mathbb{1}_{\text{SB} \geq \text{NPV}}$	Technical reports, Mining Intelligence	Indicator for SB that exceed the estimated project net present value
$\mathbb{1}_{\text{EB} \geq \text{NPV}}$	Technical reports, Mining Intelligence	Indicator for EB that exceed the estimated project net present value
$\mathbb{1}_{\text{TD} \geq \text{NPV}}$	Technical reports, Mining Intelligence	Indicator for total debt liabilities that exceed the estimated project net present value
Log of book assets	Compustat	log(at)
Capital expenditures	Compustat	capx/at
Return on Assets (ROA)	Compustat	ebitda/at
Cash	Compustat	che/at
Tobin's Q	Compustat	((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)/at
Log of firm age	Datastream	Log of years since firm listed on TSX or TSXV
Project NPV	Mining Intelligence	Initial estimate of project net present value
NPV of mining rights	Mining Intelligence	NPV estimate from NI 43-101 techinical report (or the remaining NPV estimated by this reported if the mine is already producing), less the cost the acquiring firm paid for the individual mine at acquisition
Project capital costs	Mining Intelligence	Initial estimate of project capital costs
Total NPV of alternative projects	Mining Intelligence	The total NPV of the firm's alternative mining projects in a given year
Start alternative NPV+ project	Mining Intelligence	Indicator for firm starting an alternative NPV + project in a given year
Primary mineral price (% ch.)	FRED global price series or producer price indices	$(\text{P}_t - \text{P}_{t-1})/\text{P}_{t-1}$, where P is the January price in year t
Futures price	Bloomberg	12-month futures prices for the primary mineral mined
Options-implied volatility	Bloomberg	Volatility implied by historical 1-month, at the money put-call straddles
Mine status	Mining Intelligence	Status (exploration, feasibility, production, etc) of mining project
Mine type	Mining Intelligence	Type (Surface, open pit, or underground) of mining project
Primary commodity	Mining Intelligence	Primary mineral to be extracted
Downgrade period	Compustat, Moody's reports	Indicator for the year of, and year prior to, a security rating downgrade from S&P or Moody's
From Table 8		
SB/MV	10-k's, Compustat	Self-disclosed self-bonded reclamation liabilities/((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)
EB/MV	10-k's, Compustat	Self-disclosed externally-bonded (surety bond, letter of credit, etc) reclamation liabilities/((prcc_f*cshpri) + dlc + dltt + pstkl − txditc)
$\mathbb{1}_{\text{SB} \geq 0}$	10-k's	Indicator for positive levels of self-bonded reclamation liabilities
# of self-bonded mines	Mine Health & Safety Administration	Number of mines permitted in a jurisdiction and at a time when self-bonding was allowed
# of externally-bonded mines	Mine Health & Safety Administration	Number of mines permitted in a jurisdiction and at a time when self-bonding was not allowed