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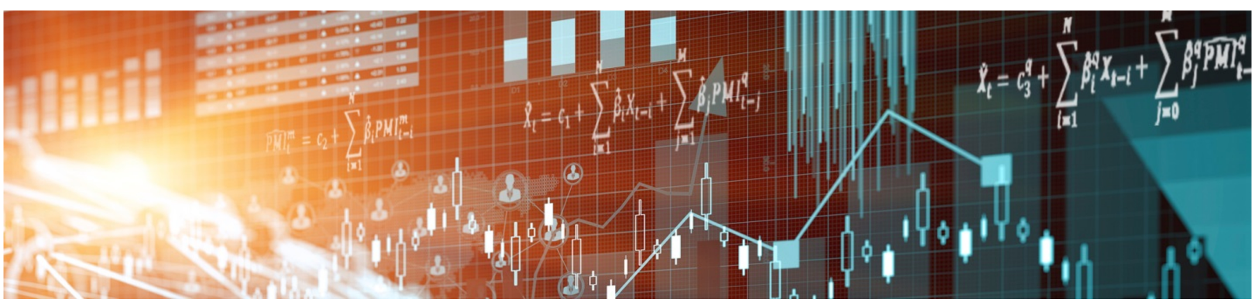
Financial Distress and Hedging: Evidence from Canadian Oil Firms



by Kun Mo, Farrukh Suvankulov and Sophie Griffiths

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Financial Distress and Hedging: Evidence from Canadian Oil Firms

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Abstract

The paper explores the link between financial distress and the commodity price hedging behaviour of Canadian oil firms. Specifically, we argue that the expected costs of financial distress have been associated with the hedging behaviour for Canadian oil firms between 2005 and 2015. We use firm-level annual data for 92 Canadian-based, publicly traded oil extraction companies. Results from Honore's semiparametric model for panel data with fixed effects and Heckman's two-step model show that firms with higher short-term and long-term debt tend to hedge more. Furthermore, an increase in the Altman bankruptcy score by one is associated with the decline of the hedge ratio by 1.2 to 1.7 percentage points.

Bank topic: Firm dynamics; Financial markets
JEL codes: G32, Q40

Résumé

Dans cette étude, nous examinons la relation entre les difficultés financières des pétrolières canadiennes et leurs activités de couverture contre les fluctuations des prix des produits de base. Plus précisément, nous soutenons que les coûts anticipés de ces difficultés ont été associés aux activités de couverture des pétrolières canadiennes de 2005 à 2015. Nous utilisons des données annuelles sur 92 sociétés d'extraction pétrolière canadiennes cotées en bourse. Les résultats du modèle semi-paramétrique d'Honoré pour données de panel avec effets fixes ainsi que du modèle à deux étapes de Heckman montrent que les sociétés plus endettées à court et à long terme ont tendance à avoir davantage recours aux opérations de couverture. De plus, une augmentation d'une unité de l'indice de faillite d'Altman est associée à une baisse de 1,2 à 1,7 point de pourcentage du ratio de couverture.

Sujet : Dynamique des entreprises; Marchés financiers
Codes JEL : G32, Q40

1 Introduction

Properly implemented hedging strategies help reduce the volatility of revenues and shareholder returns (Bartram, Brown and Conrad 2011; Gay, Lin and Smith 2010; Nelson, Moffitt and Affleck-Graves 2005; and Guay 1999). Hedging can help ensure a firm's ability to meet investment commitments and maintain production and employment levels. It also lowers the cost of debt and helps prevent shareholders from incurring additional risk due to insolvency concerns. While hedging is now a commonly used risk-management strategy, the degree to which hedging programs are implemented varies across firms. The literature proposes several potential explanations for cross-firm variations in hedging strategies. This paper adds to the discussion by providing empirical evidence on the most salient factors contributing to different hedging strategies within the Canadian oil sector.

The potential reduction in the expected cost of financial distress is frequently cited as an important determinant of a firm's hedging decision. Mayers and Smith (1982) and Smith and Stulz (1985) provide a theoretical framework for the link between hedging and the expected cost of financial distress. When a firm's financial standing deteriorates, raising capital becomes more difficult and expensive for the firm. In this context, firms expecting high costs resulting from financial distress and those paying high risk premiums have more incentive to hedge risks to reduce their risk premiums. Most empirical studies obtain a positive relationship between hedging and the various measures of expected financial distress (Dolde 1993; Haushalter 2000; Dionne and Garand 2003). Chen and King (2014) find that firms with a hedging program do indeed incur relatively lower costs of debt by reducing bankruptcy risks and related information asymmetry.

Other explanations have also been given in the literature for cross-firm variations in hedging decisions. Firms with greater investment opportunities are more likely to employ hedging strategies (Nance, Smith and Smithson 1993; Smith and Watts 1992). This hypothesis stems primarily from the literature on the agency problem and underinvestment problem in the presence of costly external financing (Bessembinder 1991; Froot, Schafstein and Stein 1993; Spano 2004). There is also some empirical evidence that larger and more mature firms tend to hedge more (Guay and Kothari 2003; Bartram, Brown and Conrad 2011). A possible explanation is the economies of scale. Specifically, it is argued that the per-unit cost of hedging declines when the overall size of a firm's hedging program is larger. However, a counter argument is that smaller firms have a greater incentive to hedge because they are more vulnerable to commodity price risks. Various studies based on surveys with firms also find that oil firms' speculations of future prices of the underlying asset play a role in hedging decisions. Bodnar, Hayt and Marston (1998) survey 350 non-financial US firms and find many firms consider the market outlook before choosing a hedging strategy. Similarly, Dolde (1993) finds that 90 per cent of firms surveyed consider the prices of the underlying assets when choosing hedging strategies. Mnasri, Dionne and Gueyie (2013) suggest that, since the goal of hedging by commodity firms is to ensure the stability of future revenue, the incentive to do so is greater when oil price volatility is perceived to be high. They find that hedging strategies strongly correlate with price volatility and the shape of the futures curve.

Our study adds to the discussion by applying the various proposed explanations to explain hedging strategies by Canadian oil producers. In particular, we hypothesize that expected financial distress is an especially important consideration for Canadian oil producers in choosing their hedging strategies. The Canadian oil sector experienced a boom from the mid-2000s on the back of oil sands, but many oil producers also incurred significant debt during that period. At the same time, certain types of production of Canadian oil sands sit high on the oil supply cost curve, and these producers are especially susceptible to financial distress during periods of falling oil prices. Our main contribution to the literature lies in applying empirical approaches that have rarely been applied to oil price hedging studies in the Canadian context. We construct a comprehensive dataset of hedging activities by Canadian oil producers, which includes details on firm characteristics and hedging programs over 2005–15. We then apply tools from the finance literature to derive the proper hedge ratio for hedges that are implemented using financial options. Our empirical framework tests whether changes in expected costs of financial distress—as proxied by the debt ratios, credit ratings or Altman's bankruptcy score (Altman 1968, 2013; Altman and Hotchkiss 1993)—are associated with hedging behaviour.[1] More specifically, we use Honoré's semiparametric model for panel data with fixed effects (Honoré 1992) and Heckman's two-step model (Heckman 1979) to enable us to control for clustered observations at a level of zero hedging and firm-specific unobservable characteristics.

Our empirical results mostly show a significant positive relationship between expected financial distress and hedging by Canadian producers, even after accounting for other firm characteristics and oil market conditions, as proposed in the literature. Firms with higher short- and long-term debt and lower credit ratings tend to have a higher hedge ratio. Specifically, a percentage point in the ratio of long-term debt to total assets is associated with an increase in the hedge ratio of 0.29 to 0.36 percentage points. Furthermore, an increase by 1 in the Altman Z-score is associated with the

[1] See Appendix 3 for details on the computation of Altman's Z-score.

decline of the hedge ratio by 1.17 to 1.68 percentage points. Overall, our findings suggest that the expected costs of financial distress have been strongly associated with hedging behaviour by Canadian oil firms.

This paper is organized as follows: Section 2 offers a conceptual framework for the relationship between the expected financial distress and hedging activity. Section 3, documents our data collection methods, calculation of proper hedge ratios and sample selection routine. Section 4 reviews our modelling approach. Section 5 includes the main estimation results. Section 6 reviews the limitations of the study and concludes.

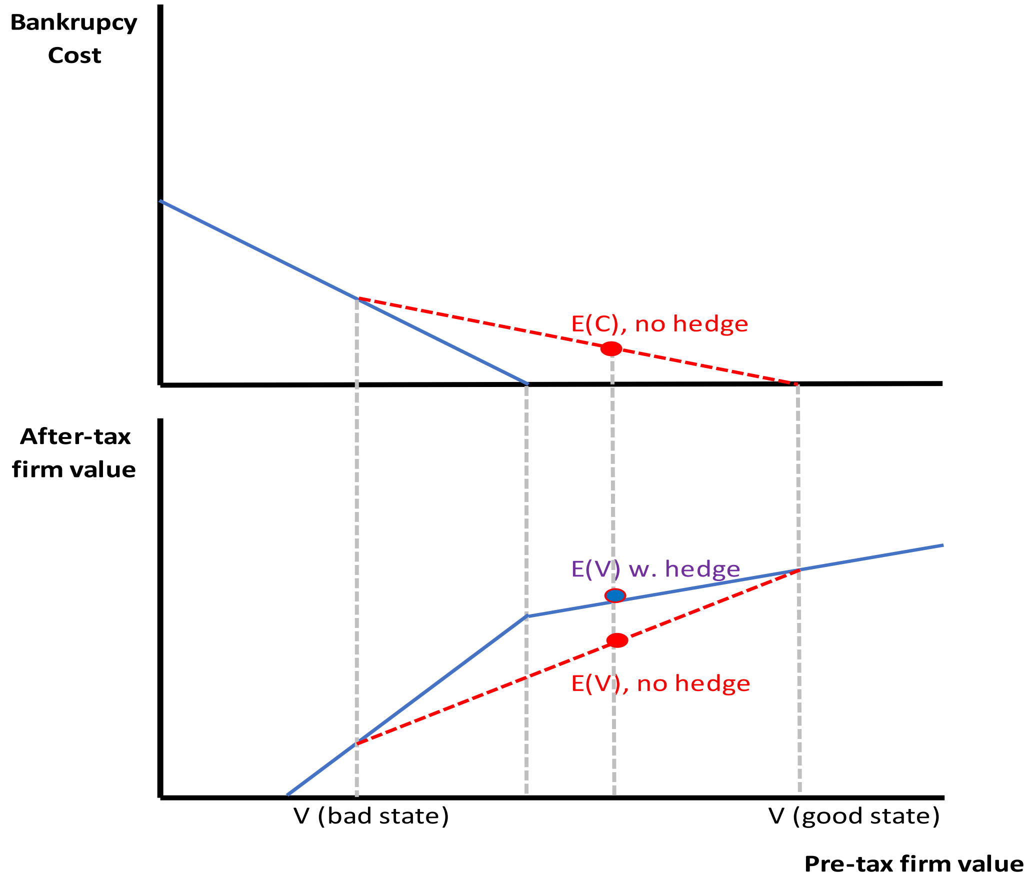
2 Conceptual framework: financial distress and hedging activity

In a perfect capital market scenario, such as the classic Modigliani–Miller settings within which no information asymmetries, taxes or transaction costs exist, hedging should not add any value to a firm or to its investment envelope since shareholders can undo—or replicate on their own—any risk-management portfolio. Yet, in practice, imperfections in capital markets, such as the direct and indirect costs of financial distress and the costs of external financing, create incentives for lowering the volatility of earnings and thus implementing a hedging strategy.

We follow Smith and Stulz (1985) and document a state preference model that discusses the impact of hedging on the present value of a firm's after-tax cash flow. Under this framework, one of the key benefits of hedging is reducing the expected costs associated with financial stress. Direct costs are more explicit, easily measurable and include court, lawyer and other legal fees associated with insolvency. Indirect costs are more multi-faceted and stem from changes in operational performance and access to financing. More specifically, customers frequently become reluctant to do business with a distressed firm because they doubt the reliability of supplies or after-sale services. Employees of a distressed firm also become skeptical about career prospects and look for other opportunities. In turn, competitors take advantage of the situation by intensifying poaching of customers and employees.

In the presence of financial stress, hedging can enhance the value of the firm from a shareholder's perspective. This can be shown in a simple illustration (**Figure 1**). Suppose a firm has debt with face value denoted by F. If the value of the firm (denoted by V) is below the debt level upon maturity, then the firm incurs bankruptcy costs (denoted by C), and only the bondholders receive the face value of the debt less the bankruptcy costs ($F - C$). If the value of the firm is above the debt level upon maturity, then the bondholders are paid back the full amount of debt and shareholders are also compensated with the value of the firm less debt and tax payments ($V - F - T$).

Figure 1: Firm values in the presence of bankruptcy cost



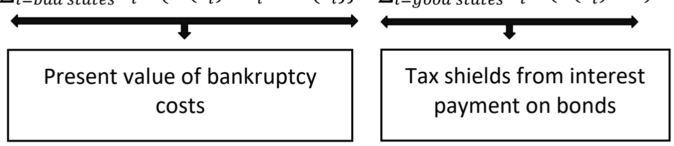
Consider a two-state example where the states are such that $V_{bad} < F < V_{good}$. In a scenario where the firm does not hedge, it is expected that the after-tax valuation is the average of $E(V_{bad})$ and $E(V_{good})$, which is denoted by *E(V, no hedge),* and the expected bankruptcy cost of $E(C, no\ hedge)$ is positive. In a scenario where the firm can implement a hedge such that its expected valuation will be $E(V, w.\ hedge)$, regardless of which state occurs, the expected bankruptcy cost is zero because the valuation of the firm is hedged at a point that is higher than F. This example shows that firms can eliminate, or at least reduce, the probability of incurring bankruptcy costs by hedging, which benefits shareholders and is therefore considered a value-enhancing strategy.

The benefits of hedging in the presence of bankruptcy costs can also be derived in a numerical framework. We set up a model where a firm's pre-tax valuation is determined by the state of the world (V_i), P_i denotes the probability of being in state of the world $i = 1, \dots, S$, and $T(V_i)$ is the tax rate if the before-tax value of the firm is V_i. Equations 1 and 2 show the expected after-tax value for an unleveraged and a leveraged firm, respectively. The face value of debt issued by the leveraged firm is denoted by F such that $V_{bad} < F < V_{good}$. The costs of bankruptcy are given by $C(V_i) \leq V_i$. Taking the difference between these two equations yields a breakdown of the benefits and costs for a firm to issue debt. Equation 3 suggests that issuing debt provides the firm tax savings related to interest payments. However, the valuation of a leveraged firm is also negatively affected by the present value of expected bankruptcy costs.

$$V(0) = \sum_{i=1}^{S} P_i * (V_i - T(V_i) * V_i) \quad (1)$$

$$V(F) = \sum_{i=bad\ states} P_i * \left(V_i - C(V_i)\right) + \sum_{i=good\ states} P_i * (V_i - (T(V_i) * (V_i - F)) \quad (2)$$

$$V\ (F) - V(0) = \sum_{i=bad\ states} P_i * (\ T(V_i) * V_i - \ C(V_i)) + \sum_{i=good\ states} P_i * (T(V_i) * F) \quad (3)$$



A firm may choose to implement a hedge to reduce the expected bankruptcy costs. Again, consider a world with two possible states, with the unhedged firm facing bankruptcy in the bad state. Let H denote payouts from a firm's hedging contracts, which can be either positive or negative. Assume the firm can set up a costless hedge whereby the firm pays in the good state (i.e., H_{good} <0) but receives compensation in the bad state (i.e., H_{bad} >0), such that $P_{good}H_{good} + P_{bad}H_{bad} = 0$.[2] With this hedge, the firm is guaranteed to avoid bankruptcy in either state, with $V_{good} + H_{good} > F$ and $V_{bad} + H_{bad} > F$. The expected valuation of a leveraged firm that hedges its future cash flow V^{Hedged} is given by equation 4.

$$V^{hedged}(F) = P_{bad} * \left(V_{bad} + H_{bad} - T(V_{bad} + H_{bad}) * (V_{bad} + H_{bad} - F)\right)$$
$$+P_{good} * \left(V_{good} + H_{good} - T\left(V_{good} + H_{good}\right) * \left(V_{good} + H_{good} - F\right)\right) \quad (4)$$

$$V^{hedged}(F) - V(F) = P_{bad} * C(V_{bad}) + P_{bad} * T * (F - V_{bad}) \quad (5)$$

After making the simplifying assumption that tax rates are constant, we derive the benefits of hedging for a leveraged firm, which is given in equation 5. Because $P_{bad} * C(V_{bad})$ and $F - V_{bad}$ are both positive by construction, there is clear indication that hedging is a value-enhancing strategy for leveraged firms. Furthermore, this simple model suggests that the benefits of hedging—and therefore the desire to do so—are greater for firms that face higher expected bankruptcy costs and

[2] An example of the costless hedge is the collar option, where a firm simultaneously buys a put option (receives payments if oil price falls below the strike price) and sells a call option (pays if oil prices rise above the strike price). In this illustration the transaction cost of implementing the hedge is assumed to be zero.

for those that face greater volatility in their expected cash flows. If this model holds true in the data, we should expect a firm's hedging decision to be positively correlated with its level of financial stress.

3 Data source and construction

3.1 Data sources

We collected annual data on Canadian oil producers for the period from 2005 to 2015. Our time frame is wider compared with existing studies (e.g., Dan et al. 2005) and is chosen for two reasons. First, it allows us to explore how firms may respond to common oil market shocks. On this point, we note that our dataset covers two periods of high oil price volatility: the 2008 financial crisis and 2014 oil price collapse. Second, a longer time frame helps to provide insights on how a firm's hedging decisions may change as its own structure and financial positions evolve.

We first obtained a list from D&B Hoovers of 104 oil firms with headquarters in Canada. We then collected annual financial statements for these firms from Compustat, which we accessed through the Wharton Research Data Services. Only 95 of the 104 firms from the D&B Hoovers dataset were matched in Compustat. We obtained detailed financial information for these firms from these statements, including size of the firm, debt breakdown, cash flow and earnings. Next, we collected information on oil hedging activities from annual reports stored at the System for Electronic Document Analysis and Retrieval (SEDAR).[3] In many instances, the annual report documents volumes of oil production hedged and types of hedging instruments used. We found that some firms' annual reports explicitly state that the company does not have a hedging program in place, prompting us to assign the hedging volumes as 0. For 3 of the 95 firms, information on hedging activity was absent. We excluded these firms from our sample.

Our panel dataset ultimately contains 636 firm-year observations for 92 firms. The number of firms in the sample steadily increases from 31 in 2005 to 74 in 2015. To a certain extent, the sample expansion reflects the organic growth of the Canadian oil industry over that decade. The decade saw a significant increase of publicly traded firms, linked with the expansion of oil sands operations and their supply chains, including the production of natural gas and other liquids. Given the unbalanced settings of our sample, we carried out a BGLW test (Becketti et al. 1988) to test for attrition. The test results point to the lack of selection on observables at conventional levels of statistical significance,

[3] Filing on SEDAR is mandatory for Canadian Securities Administrators filings. SEDAR does not contain information on four firms that are not listed on the Toronto Stock Exchange. For these firms, we accessed their annual reports from firm websites.

allowing us to proceed with the panel analysis. Despite spells of missing data, overall our sample represents the industry well. In terms of production measured by barrels per day on a yearly basis, firms in our dataset account for more than 80 per cent of annual crude oil production in Canada in every year of the estimation time frame of 2005 to 2015.

3.2 Effective hedge ratio

The variable of interest in our study is the hedge ratio. In the simplest form, the hedge ratio is the notional volume of oil stated in hedging contracts as a share of a firm's total production. This simple definition can be easily applied in the case of linear instruments, such as fixed contracts and swaps, since every barrel of oil hedged will result in physical transaction upon maturity. However, it requires greater consideration when non-linear financial options are used as the hedging instrument because the effective amount of oil hedged is sensitive to the perceived likelihood that the option will be activated (i.e., the price of oil will exceed the specified strike price). Following the literature, we use the Black–Scholes option price model to compute the effective hedge ratio for hedging through financial options (Black and Scholes 1973).

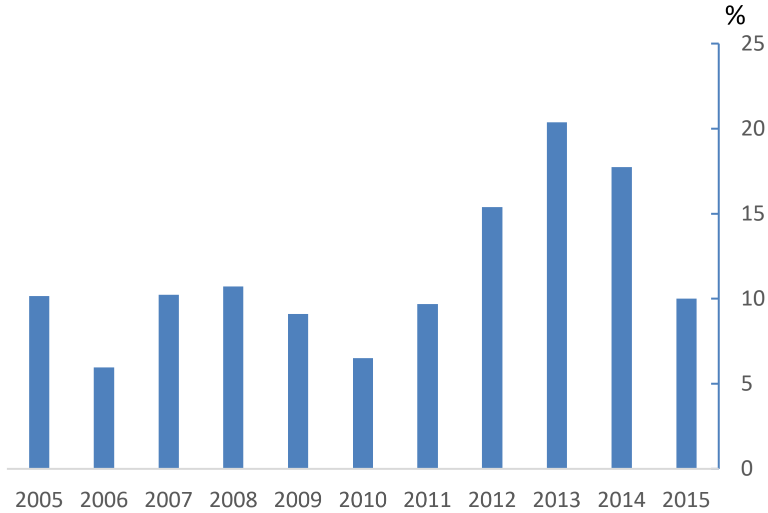
In the context of the Black–Scholes model, the delta of a financial option represents the sensitivity in the option value with respect to a change in the price of the underlying asset. Implicitly, fixed contracts and swaps carry a delta of one. It can be loosely interpreted as the likelihood that the financial option will be activated (or in the money) given market conditions at a specific point in time (i.e., current expected futures price versus the strike price, perception of volatility in the market and the interest rate). Appendix 1 contains more details on the calculation of the delta.

We multiply the delta with the notional amount of oil (in barrels) specified in the associated financial contracts to obtain the effective amount of oil hedged. To obtain the overall effective hedge ratio for a firm in a specific year, we sum the effective hedged amount across all contracts and calculate their share of total production:

$$Effective\ Hedge\ Ratio = \frac{\sum_i^M Notional\ volumes\ (Fix\ \&\ swap)_{(i)} + \sum_j^N delta_j * Notional\ volumes\ (Financial)_j}{Oil\ Production} \qquad (6)$$

Summary statistics for firm characteristics are presented in Table A-1 in Appendix 1. Overall, just under half of the firm-year observations in our sample had hedging activities, ranging from 41.8 per cent in 2014 to 66.7 per cent in 2010. More than two-thirds of the firms hedged their production in at least one of the years in the sample. On average, between 2005 and 2015, Canadian oil producers hedged 12.4 per cent of their production.

Chart 1: Evolution of effective hedge ratios



Source: Author's calculations

Chart 1 shows the average effective hedge ratio across Canadian oil producers, which appears to have trended up from 10 per cent in the second half of the 2000s to a peak of around 20 per cent in 2013.[4] This growth has been driven, to a certain extent, by small and medium-sized firms that have hedged an increasingly larger share of their production. For smaller producers, the cost of hedging has likely declined in recent years due to greater liquidity in the Canadian oil futures market and the development of futures trading for Western Canadian Select (WCS).

3.2 Indicators of expected financial distress

The primary objective in our paper is to explore the link between expected financial distress and hedging behaviour across firms. The bankruptcy-cost theory suggests that, *ceteris paribus*, highly leveraged firms and firms with lower credit ratings tend to hedge more. In this context, our expectations are a positive and significant relationship between indicators of expected financial stress and the hedge ratio.

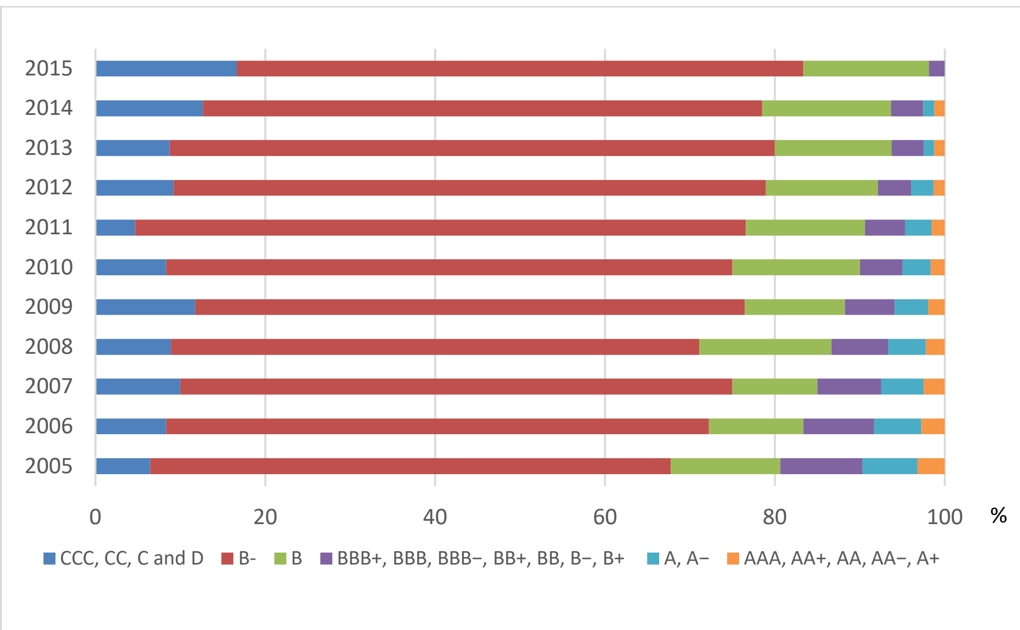
Expected financial distress is not directly observable, but previous literature proposes various proxies for expected financial distress. In our paper, we test our hypothesis using three different measures of expected financial distress: the leverage ratios, credit ratings and Altman's bankruptcy score.

[4] The hedge ratio shown in **Chart 1** is calculated by assigning equal weight to each firm in the sample. If firms are weighted by output, the effective hedge ratio for Canadian oil producers overall was relatively more stable at between 10 and 15 per cent between 2005 and 2015.

The leverage ratio has been used in existing studies as an indicator for the likelihood of financial distress (Mayers and Smith 1982; Smith and Stulz 1985; Rawls and Smithson 1990; Dolde 1993; Stulz 1996; Raposo 1999). Specifically, we compute the share of short- and long-term debt to total assets.

The literature also considers credit ratings as a measure of a firm's financial health and argues that changes in credit ratings are likely to affect the likelihood of financial distress over and above the distress caused by poor fundamentals (Bongaerts, Cremers and Goetzmann 2012; Ellul, Jotikasthira and Lundblad 2011; Kisgen and Strahan 2009; Opp, Opp and Harris 2013; Manso 2013). We employ Standard & Poor's (S&P) domestic long-term issuer credit ratings available through the Wharton Research Data Services. **Chart 2** depicts the evolution of credit ratings for the sample of our firms. For the empirical estimation, values of the S&P domestic long-term issuer credit ratings have been converted into ordered numerical values (see Appendix 2 for detailed methodology).

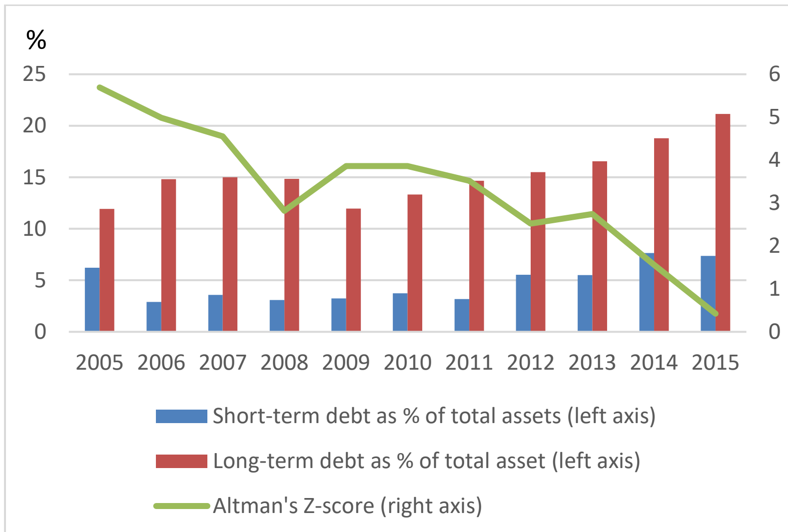
Chart 2: Credit ratings for Canadian oil firms



Source: Standard & Poor's

Our third and final measure of expected financial distress is Altman's bankruptcy index (Z-score), calculated using a set of financial ratios, based on balance sheet and income statement data (Altman 1968, 2013; Altman and Hotchkiss 1993). The score signifies the state of a firm's financial fundamentals and is frequently used in the literature to predict financial distress or bankruptcy for a given firm. The details on how we estimate the score are available in Appendix 3. According to the literature, Z-scores above 2.99 tend to be financially sound. Firms with Z-scores in the "ignorance zone," the interval between 1.81 and 2.99, must be considered with caution. Finally, firms with a Z-score below 1.81 are likely to be in financial distress with a significant probability of defaulting on their debt. **Chart 3** depicts the evolution of the average Z-score for our sample of firms. The average Z-score for Canadian oil firms saw a steady decline toward the end of our sample period, largely driven by increases in the debt ratios. In fact, for 2015 the average index is at 0.4, pointing to significant financial distress in the industry in the wake of a precipitous decline in oil prices.

Chart 3: Evolution of Altman Z-score in our sample



Source: Author's calculations

3.3 Control variables

In addition to expected financial stress, other firm characteristics may also be correlated to a decision to hedge. First, evidence from Guay and Kothari (2003) and Bartram, Brown and Conrad (2011) suggests that larger firms tend to hedge more. A possible explanation is an economy of scale because a per-unit cost of hedging declines when the overall size of a firm's hedging program is larger. We control for this effect using a firm's total asset size, as obtained from its annual financial statement. Second, the literature on agency issues and underinvestment problems suggests that investment opportunities may also affect hedging decisions (Nance, Smith and Smithson 1993; Smith and Watts 1992). In fact, there is evidence that firms with greater investment opportunities tend to be less leveraged but may also hedge more. It is important to control for this effect to obtain the true relationship between expected financial stress and hedging. We collect data on the price-earnings ratio and use this variable as a proxy for investment opportunities.

We also collect data on current and expected conditions in the oil market. Specifically, we obtain future prices for West Texas Intermediate (WTI) from the New York Mercantile Exchange (NYMEX) and construct the level of oil prices, volatility of oil prices and the shape of the oil price futures curves. The conventional narrative suggests that under low and volatile oil prices, properly implemented hedging strategies can reduce the volatility of revenues and ensure an ability to meet spending commitments, repay debt and prevent shareholders from incurring unexpected losses. Since commodity firms hedge to ensure stability of future revenue, the incentive to do so is likely greater when oil price volatility is perceived to be high. Mnasri, Dionne and Gueyie (2013) find that hedging strategies strongly correlate with price volatility and the shape of the futures curve. Survey-based results, such as Bodnar, Hayt and Marston (1998), also confirm that a firm's view of market conditions can alter either the size or the timing of hedges.

The set of control variables also includes the Canadian dollar (CAD) exchange rate relative to the US dollar (USD). Output prices for the industry are frequently denominated in USD, whereas the cost structure of Canadian oil producers tends to be in CAD. Firms in the industry, as any other Canadian exporters, benefit from a weaker CAD to a certain extent.

4 Modelling approach

4.1 Honoré's semiparametric model with fixed effects

Many firms in our sample did not hedge oil production for certain years. As a result, the value of the dependent variable, a hedge ratio, is zero for 342 firm-year observations. Treatment of these zero-hedge observations is a major consideration in our modelling framework. We take a twofold approach to this. First, we assume that firms with no hedging positions can be treated as corner solutions that indicate that these firms did not choose to exercise an opportunity to hedge, resulting in clustering of hedge ratios at zero. Thus, we proceed with panel model for censored data.

Given the panel characteristics of our sample, one of the options is to fit a random-effects Tobit model as summarized by Cameron and Trivedi (2005). However, the conditions underlying the proper estimation of the random-effects models are restraining because one must assume that firm effects from time-invariant unobservable characteristics are orthogonal to other explanatory variables, which is hard to confirm empirically. Furthermore, due to the incidental parameters problem, parametric fixed effects estimation of coefficients also leads to inconsistent estimates (Honoré 1992). Given these considerations, we instead employ Honoré's (1992) semiparametric model for panel data censored regression that includes control for firm fixed effects.[5] In contrast to the random-effects model, in Honoré's model the distribution of errors remains unspecified. In other words, it is

[5] We estimate the model using pantob version 0.6 routine in Stata.

not necessary to maintain parametric assumptions on the error terms. The resulting estimators are consistent and asymptotically normal (Honoré 1992). To check the robustness of the results from the semiparametric model with fixed effects, we also estimate a random-effects Tobit model.

The conventional setup for panel models with censored data is as follows:

$$y_{it}^{*} = \beta X + \varepsilon_{it} \tag{7}$$

$$y_{it} = \begin{cases} y_{it}^{*} & \text{if } y_{it}^{*} > 0 \\ 0 & \text{if } y_{it}^{*} \leq 0\text{'} \end{cases} \tag{8}$$

where y_{it}^{*} is a latent dependent variable, y_{it} is an observed dependent variable and X is vector of explanatory variables. Equation 9 displays the model specification that we employ for our data.

$$HedgeRatio_{it} = \begin{cases} HedgeRatio_{it}^{*} = \beta_0 + \beta_1\, short\_debt_{it-1} + \beta_2\, long\_debt_{it-1} + \beta_3 cr_{it-1} + \beta_4 WTI_{t-1} \\ \quad + \beta_5 WTI\_futures_{t-1} + \beta_6 WTI\_var_{t-1} + \beta_7 er_{t-1} + \beta_8 \ln asset_{it-1} \\ \quad + \beta_{11} pe_{it-1} + \varepsilon_{it} & \text{if } hedge\_ratio_{it}^{*} > 0 \\ 0 & \text{if } hedge\_ratio_{it}^{*} \leq 0 \end{cases} \tag{9}$$

where

- $HedgeRatio_{it}$ is the hedge ratio for firm i in year t

financial distress explanatory variables

- $short\_debt_{it-1}$ is a sum of short-term notes and the current portion of long-term debt (normalized to total assets) for firm i year $t-1$
- $long\_debt_{it-1}$ is long-term debt (normalized to total assets) for firm i in year $t-1$
- cr_{it-1} is the S&P domestic long-term issuer credit rating of firm i at the end of year $t-1$

control variables

- WTI_{t-1} is an average value of the WTI benchmark price in year $t-1$
- $WTI\_futures_{t-1}$ is a ratio of an average WTI 12-month futures price to the WTI spot price in year $t-1$
- WTI_var_{t-1} is a coefficient of variation of daily WTI prices in year $t-1$
- er_{t-1} is a daily average of CAD/USD nominal exchange rate in year $t-1$
- $asset_{it-1}$ is total assets of firm i at the end of year $t-1$
- pe_{it-1} is a price earnings ratio for firm i at the end of year $t-1$
- ε_{it} are error terms

Our review of annual reports indicates that, to a large extent, hedging contracts with delivery date in year t are secured in a preceding year $t-1$. Chang, Gu and Xu (2005) and Jin and Jorion (2006) also suggest that, while firms enter hedging contracts on a rolling basis, in most cases the majority of their hedging contracts are locked in by the end of the previous calendar year. Therefore, variables on the right-hand side of equation 9 are lagged by one year.

4.2 Heckman's two-step model

Our second modelling approach addresses the sample selection problem more directly. Several authors recently argued that the true hedge ratios for some firms with zero hedges are unobservable (e.g., see Sheppard 2015; Zhdannikov and Bousso 2015; and Chyong and Reiner 2017). Integrated firms are frequently cited in this context. They argue that, for these firms, significant volumes of crude production are internally hedged despite the lack of use of external risk-management contracts. Under this assumption, treatment of such cases as zero-hedge observations leads to a sample selection problem, necessitating the sample correction procedure. We opt for a Heckman parametric two-step model (Heckman 1979) to correct for the sample selection bias. More specifically, we implement a pooled panel version of the Heckman model with clustered panel corrected standard errors to account for repeated observations in the dataset.

To satisfy an exclusion restriction of the Heckman model, we include a dummy variable for whether a firm is an integrated oil producer in the first-stage regression and exclude this variable in the second-stage regression.[6] Integrated firms are those with a combination of midstream and downstream operations that act as a natural hedge against commodity price volatility. As such, integrated firms are less likely to hedge in any particular year given their ability to partially offset any losses from a decline in commodity prices through higher margins on refining and retail operations. For integrated firms that do have hedging programs, however, the share of production hedged may not depend on their status of being an integrated producer.[7]

Cameron and Trivedi (2005), Adkins and Hill (2011) and Greene (2003, 873–880) provide a good overview of a two-step Heckman estimator. More recently, Adam, Fernando and Salas (2017) used similar methodology to explore the drivers for hedging by gold mining firms in the United States. We follow the Adam, Fernando and Salas (2017) setup for the Heckman model. The first-step estimation models a decision to hedge, which is a dummy variable for hedging activity, using a standard panel

[6] For the Heckman model to generate credible estimates, there must be at least one variable that is statistically significant in the first-step selection equation but not statistically significant in the equation of interest. This is generally known as the shifter variable.

[7] To check the validity of the dummy variable for integrated firms as a shifter in the first-step regression, we regress it on the hedging dummy and find a statistically significant correlation. We also find no significant correlation between the dummy variable for integrated firms and the hedge ratio, an outcome variable in the second stage regression.

probit model conditional on explanatory variables identified in equation 9 and a shifter dummy variable for an integrated oil producer I_{it} (equation 10)

$$Prob\ (Hedging = 1|X, I) = \ \phi(\beta X + I\gamma) \tag{10}$$

Following Adam, Fernando and Salas (2017), in the second step we model the hedge ratio using panel pooled ordinary least squares against explanatory variables X, inverse Mills ratio λ[8] as an additional regressor to correct for the sample selection bias, and time dummy variables.

$$E[HedgeRatio|Hedging = 1] = \beta X + \theta\,\lambda \tag{11}$$

The resulting estimators from two-step Heckman equations are consistent with Wooldridge (2002) and Cameron and Trivedi (2010).

As discussed earlier, Honoré and Heckman models treat zero observations differently. The Honoré model treats zero hedges as zeros, while the Heckman model considers them as non-zero and unobserved. However, results from these models can be comparable because they include the same set of dependent and explanatory variables. To make a comparison more straightforward, we present results from equation 9 and equation 11 in marginal effects format.[9]

5 Results

We first display results from Honoré's fixed-effects model for panel censored data. **Table 1** lists the marginal effects for financial distress variables as well control variables. Columns I and III display estimated regressions that include only the financial distress constructs as explanatory variables. Estimates in columns II and IV are appended by the set of control variables. The estimated coefficient for financial stress variables—short-term debt, long-term debt and Altman's Z-score—are statistically significant, both with parsimonious specifications (columns I and III) and enriched ones (columns II and IV). The coefficient for firm's credit rating becomes significant once control variables are added to the equations. Most variables of financial distress seem to be important and robust to specifications, pointing to a solid evidence of correlation with hedge ratios.[10] Since **Table 1** lists marginal effects, the interpretation of estimates is straightforward. A percentage point increase in short-term debt, defined as a ratio (percentage) of short-term notes and the current portion of the

[8] The inverse Mills ratio is calculated as $\widehat{\lambda_{it}} = \frac{\phi(w_{it}\widehat{\gamma})}{\Phi(w_{it}\widehat{\gamma})}$.

[9] To derive the marginal effects in the semiparametric model for the panel data censored regression that controls for firm fixed effects in the two-step Heckman model, we scaled the coefficients by multiplying them to the relative frequency of positive responses in the dataset. (See https://www.statalist.org/forums/forum/general-stata-discussion/general/1377619-marginal-effects-after-pantob)

[10] Table A.3 in the appendix displays largely comparable results from the random-effects Tobit model.

ratio of long-term debt to total assets, is associated with a 0.19 to 0.2 percentage point increase in the hedge ratios in the subsequent year. Similarly, a percentage point increase of the long-term debt, defined as the ratio of long-term debt to total assets, is associated with a 0.28 to 0.33 percentage point increase in hedge ratios for the subsequent year. From column II, a unit improvement on the credit rating scale increases hedge ratios by 6.8 percentage points. Finally, a unit increase in Altman's Z-score is associated with a decrease in the hedge ratio of 1.17 to 1.18 percentage points.

Table 1: Results from the Honoré fixed-effects model for panel censored data

Variable (t-1)	**Hedge ratio**			
	I	II	III	IV
Short-term debt	0.191***	0.203***		
	(-0.079)	(-0.078)		
Long-term debt	0.325**	0.278*		
	(-0.165)	(-0.168)		
Credit ratings	-5.070	-6.844*		
	(-3.815)	(-3.983)		
Altman's Z-score			-1.176**	-1.165**
			(-0.526)	(-0.579)
WTI prices		-4.106		-5.582*
		(-3.033)		(-3.370)
WTI futures curve slope		-1.900		-2.630
		(-1.490)		(-1.649)
WTI price volatility		-1.601		-2.216*
		(-0.966)		(-1.109)
CAD/USD exchange rate		-0.670**		-0.683**
		(-0.274)		(-0.294)
Size of firm (assets)		2.941		1.762
		(-2.505)		(-2.575)
Price-earning ratio		-0.001		-0.003
		(-0.002)		(-0.004)
Prob > chi2	0.00	0.00	0.00	0.00
Observations	522	522	494	494
Number of firms	90	90	88	88

Note: *, ** and *** denote significance at the 1, 5, and 10 per cent confidence level, respectively. Marginal effects are displayed. Numbers in parentheses refer to the standard error. Intercepts and coefficients for year dummies in each column are omitted for brevity. WTI means West Texas Intermediate.

Now we turn to findings from Heckman two-step model (**Table 2**). Columns I, III, V and VII display first-step estimations. The key takeaway from these columns is the fact that our shifter dummy variable for integrated oil producers is correlated with the decision to hedge in all four first-step regression specifications. It has a negative sign, in line with our prior estimations that oil producers with access to refining and retail assets are less likely to hedge because they can recoup loss on the upstream segment from gains from midstream and downstream operations.

Table 2: Results from the Heckman two-step model

Variable (t-1)	I Hedging dummy (probit)	II Hedge ratio (second	III Hedging dummy (probit)	IV Hedge ratio (second	V Hedging dummy (probit)	VI Hedge ratio (second	VII Hedging dummy (probit)	VIII Hedge ratio (second step)
Short-term debt	0.020***	0.172	0.023***	0.213				
	(0.007)	(0.166)	(0.008)	(0.174)				
Long-term debt	0.028***	0.343*	0.016***	0.357**				
	(0.005)	(0.201)	(0.005)	(0.143)				
Credit ratings	0.090	-	-0.172	-				
	(0.080)	(1.471)	(0.105)	(2.333)				
Altman's Z-score					-0.075***	-1.673*	-0.078***	-1.682**
					(0.018)	(0.942)	(0.018)	(0.719)
WTI prices			-0.302	-10.808			-0.324	-11.863
			(0.366)	(7.109)			(0.366)	(7.823)
WTI futures curve slope			-0.142	-5.104			-0.151	-5.639
			(0.176)	(3.410)			(0.176)	(3.765)
WTI price volatility			-0.135	-3.247			-0.151	-3.797
			(0.113)	(2.240)			(0.112)	(2.415)
CAD/USD exchange			-0.017	-			-0.015	-1.573**
			(0.032)	(0.619)			(0.033)	(0.650)
Size of firm (assets)			0.227***	0.508			0.184***	-0.687
			(0.048)	(1.497)			(0.034)	(0.907)
Price-earning ratio			-0.000	0.002			-0.000	0.004
			(0.000)	(0.010)			(0.001)	(0.010)
Integrated producer	-0.848**		-		-0.702***		-1.308***	
	(0.348)		(0.352)		(0.266)		(0.299)	
Inverse mills ratio		-3.302		-2.269		-4.973		-4.235
		(10.678)		(9.703)		(13.383)		(7.202)
Prob > chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	522	252	522	252	494	522	248	248
Number of	90	64	90	88	88	90	63	63

Note: *, ** and *** denote significance at the 1, 5, and 10 per cent confidence level, respectively. Marginal effects are displayed. Numbers in parentheses refer to the standard error. Intercepts and coefficients for year dummies in each column are omitted for brevity. WTI means West Texas Intermediate.

Columns II, IV, VI and VIII display results from second-step equations that include inverse Mills ratio as one of regressors. The estimated marginal effects for some financial stress variables—namely, long-term debt, credit ratings and Altman's Z-score—are statistically significant in parsimonious and expanded specifications (columns I and III) and enriched ones (columns II and IV). In contrast to findings from the Honoré specifications, the coefficient for the short-term debt is not statistically significant. That said, the credit rating becomes significant in both parsimonious and extended specifications.

Combining results from the Honoré and Heckman models, it looks like the ratio of long-term debt to total assets and Altman's Z-score variable are consistently correlated to hedge ratio. These results are robust to the model selection as well as specifications. These results offer some evidence that a firm's motivation to reduce the costs associated with bankruptcy and financial distress is associated with its hedging behaviour. This is in line with previous studies by Smith and Stulz (1985), Raposo (1999) and Stulz (1996) that suggest that firms hedge to reduce the volatility of their cash flow and maintain an ability to pay for current expenditures, including wages and salaries, as well as debt repayments, since the interest rate and principal payments of debt constitute obligations to which bondholders are legally entitled.

In contrast to some previous studies, we fail to identify consistently significant relationships between hedging behaviour and oil market conditions. First, the level of oil prices and the shape of the futures curve do not have a statistically significant impact on hedging behaviour for firms in our sample. We also find mixed results for how price volatility (measured as the coefficient of variation of daily WTI prices) affects hedging behaviour.[11] In the expanded Honoré model, the parameter estimate is negative and significant, while in the Heckman model it loses the significance. While at first glance the negative relationship is counterintuitive, the experience during the most recent oil price downfall provides some insights. With oil prices falling rapidly and price volatility spiking from 2014 to 2016, many Canadian oil producers also reduced their hedging program. There are a couple of important possible reasons for this. First, hedges tend to become costlier when oil price volatility is high because the volatile environment may discourage traders and speculators, who are typically on the side of the derivative contract, from participating in the market.[12] In fact, there may be a non-linear relationship between price volatility and market liquidity. Second, the expected payout based on the futures curve oil price was below (or at least not significantly above) the expected cost of producing oil for many

[11] These results remain largely unchanged when we try to use WCS as a benchmark for oil prices and volatility. Since most hedging contracts are WTI-based, the choice was made to proceed with WTI as a benchmark in the models.
[12] Unfortunately, the data on the cost of hedging for each contract were not available in most annual reports.

Canadian firms. Essentially, firms were unwilling to hedge at a price point that ensured they would incur a loss. Implicitly, this may reflect different assumptions for future oil prices by oil producers and other market participants.

While signs of the parameter estimate for firm's total asset size, *asset*, are in line with our prior expectations, we are unable to consistently confirm the statistical significance of these results. Our results do not provide any supporting evidence for the hypothesis that the underinvestment problem drives hedging decisions. To a certain extent, the lack of statistical significance may reflect a relatively smaller sample size and degrees of freedom. This is one of the drawbacks of this study.

Based on our results, we consistently find that a weaker Canadian dollar is associated with lower hedging activity. Given the correlation between oil prices and the exchange rate, the weaker Canadian dollar acts as a margin cushion for many Canadian firms when oil prices are low. Indeed, many in the industry sell their production in US dollars but report revenues and incur expenses in Canadian dollars. In a context of minimizing the likelihood of financial distress, *ceteris paribus*, a lower Canadian dollar helps, as has been evident in the most recent episode of oil price declines.

6 Conclusion

As discussed earlier, numerous studies have explored the determinants of hedging from both the theoretical and the empirical perspective. Based on the sample and type of industries studied, previous studies uncovered relationships between a firm's hedging decision and the expected cost of financial stress faced by the firm, firm characteristics and current market conditions. Our empirical analysis builds on these previous studies and focuses on the experience of Canadian oil producers from 2005 to 2015.

We show that the expected cost of financial distress—as proxied by debt ratios and credit ratings or the Altman Z score—are associated with hedging behaviour for Canadian oil producers. Among all the variables that were tested, relationships between financial distress and hedging behaviour were the only ones to be consistently statistically significant and robust across specifications. This finding is in line with our prior expectations. The boom in the Canadian oil sands over the past decade was fuelled in part by the rapid development of small and medium-sized firms. Typically, these firms are heavily leveraged, and they are the most vulnerable to oil price risks. As a result, they tend to pursue hedging strategies more aggressively, which contributes to an overall increase in hedging activities by Canadian oil producers. In contrast to previous studies and some theoretical predictions, we find mixed evidence on the influence on hedging from other factors, such as firm characteristics and changes in market conditions.

We note that our findings may be sensitive to the time periods of interest, and they may be subject to important non-linearities. Unfortunately, the sample size did not allow these considerations to be accounted for in this study. Costs of hedging is another construct that needs to be tested in future related studies. One may argue that explicitly controlling for the fees associated with options and fixed-volume contracts may be empirically associated with the decision to hedge.

Appendix 1—Hedging implemented using financial options

Instruments used by Canadian oil producers for hedging activities can be broadly separated into two categories: fixed contracts (or swaps) and financial options. A fixed contract is the most straightforward form of hedging: a firm agrees to sell to a counterparty a specific amount of oil for a specified price over a specified period. Similarly, a swap is an agreement whereby the producer pays the spot price to another party and receives a fixed price in return, essentially ensuring the producer against a decline in oil prices. In both cases, firms fully hedge their oil price risk for the volume of oil specified. The payoff or value of these hedging instruments is therefore a linear function of the expected spot price relative to the contract price upon maturity. Producers can also hedge the oil price risk through financial options: puts and collars. A put offers a producer the right, but not the obligation, to sell oil at a specified strike price. This instrument provides a hedge against a decline in oil prices below the specified strike. However, since the producer is not obligated to sell upon maturity, this instrument activates only if oil prices fall below the strike price.

Unlike fixed contracts, the value of financial options is not a linear function of the expected spot price relative to the strike price. Following the literature, we use the Black–Scholes option price model to help compute the effective hedge ratio for hedging through financial options. We compute the delta for put and call options using the Black–Scholes model (equations A-1 to A-3). The delta of a financial option represents the sensitivity in the option value with respect to a change in the price of the underlying asset.

$$delta\ (put\ option) = -e^{-rT}N(d_1) \tag{A-1}$$

$$delta\ (call\ option) = e^{-rT}N(-d_1) \tag{A-2}$$

$$d_1 = \frac{\ln\left(\frac{F_0}{X}\right)+\left(r+\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{A-3}$$

where

T: average duration to maturity. For example, if a financial contract covers 2016, the average time to maturity of the contract is six months.

F_0: oil prices at maturity based on the Western Texas Intermediate (WTI) futures curve

X: exercise price for the financial contract

σ: implied volatility in oil prices during the past year

r: risk-free interest rate (specifically, the US Federal Reserve funds rate)

Table A-1: Descriptive statistics of hedge ratios

	Observation	Mean	SD	Median	Firms with 0 hedges	
					number of firms	share
2005	31	10.15	14.15	0	17	54.8 %
2006	36	5.96	12.06	0	21	59.5 %
2007	40	10.23	14.62	1.85	20	50.0 %
2008	45	10.72	19.37	0	26	57.8 %
2009	51	9.11	14.69	0	33	64.7 %
2010	60	6.50	11.24	0	40	66.7 %
2011	64	9.68	15.68	0	39	60.9 %
2012	76	15.39	20.58	0	39	51.3 %
2013	80	20.37	24.35	12.55	36	45.0 %
2014	79	17.74	21.64	7.9	33	41.8 %
2015	55	10.01	13.95	0	38	51.4 %
Total	636	12.40	18.42	0	342	53.8 %

Appendix 2—Standard & Poor's domestic long-term issuer credit ratings

Table A-2 lists the distribution of S&P domestic long-term issuer credit ratings in the sample. Ratings have a fair level of variation with clustering at B and B- grades.

Table A-2: Mapping S&P domestic long-term issuer credit ratings and values of *cr* credit rating variable

S&P domestic long-term issuer credit rating	Value of *cr* variable	Number of observations
AAA AA+ AA AA– A+	6	10
A A–	5	18
BBB+ BBB BBB– BB+ BB BB– B+	4	31
B	3	84

B−	2	413
CCC	1	60
CC		
C		
D		

Appendix 3—Computation of Altman's Z-score

The Altman Z-score is a univariate, accounting-based index of financial distress that is calculated according to financial ratios. The score was developed by Altman in a series of papers (1968, 2013; Altman and Hotchkiss 1993). The discriminant function for Altman's Z-score is an equation that weighs five financial ratios by the estimated coefficients in Altman and Hotchkiss (1993); see equation A-4.

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 1.0X_5 \quad \text{(A-4)}$$

X_1= working capital / total assets
X_2= retained earnings / total assets
X_3= earnings before interest and taxes / total assets
X_4= market value of equity / total liabilities
X_5= sales / total assets

According to Altman and Hotchkiss (1993), Z-scores above 2.99 point to solvency and financial health. Firms with Z-scores in the "ignorance zone," the interval between 1.81 and 2.99, should be considered with caution. Finally, firms with a Z-score below 1.81 are likely to be in financial distress with a significant probability of default on debt. According to Altman (2013), the equation seems to have a good fit. Between 1968 and 1999, the model was able to be predict bankruptcy one year before the event for 80 to 90 per cent of cases with a Type II error of approximately 15 to 20 per cent.

In the energy sector, oil producers face considerable exploration and development costs. Many of these companies are likely to face financial distress during periods of volatile oil prices. A positive and significant relationship between hedging and leverage would be consistent with this narrative.

Additional regression results

Table A-3: Results from the Tobit random-effects model

Variable (t-1)	Hedge ratio			
	I	II	III	IV
Short-term debt	0.251***	0.268***		
	(0.075)	(0.075)		
Long-term debt	0.313***	0.248***		
	(0.076)	(0.078)		
Credit ratings	-1.999	-5.167**		
	(1.601)	(2.000)		
Altman's Z-score			-1.227***	-1.220***
			(0.301)	(0.306)
WTI prices		-6.279*		-6.283*
		(3.522)		(3.691)
WTI futures curve slope		-2.960*		-2.962
		(1.697)		(1.778)
WTI price volatility		-2.369**		-2.547**
		(1.092)		(1.143)
CAD/USD exchange rate		-0.676**		-0.615*
		(0.308)		(0.321)
Size of firm (assets)		2.527***		1.212
		(0.970)		(0.749)
Price-earning ratio		-0.001		-0.005
		(0.001)		(0.007)
Prob > chi2	0.00	0.00	0.00	0.00
Observations	522	522	494	494
Number of firms	90	90	88	88

Note: *, **, and *** denotes significance at the 1, 5, and 10 per cent confidence level, respectively. Marginal effects are displayed. Numbers in parentheses refer to the standard error. Intercepts and coefficients for year dummies in each column are omitted for brevity. WTI means West Texas Intermediate.

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