Corporate Hedging and Collateral Constraints: Evidence from a Difference-in-Difference Approach

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Abstract

Financially constrained firms have incentives to hedge in order to protect against declines in their financial status. Conversely, lack of collateral may prevent them from doing so. This paper brings evidence from a difference-in-difference approach to shed light on this central question in corporate hedging theory. Supporting the collateral constraints-theory of Rampini, Sufi, and Viswanathan (2014), I find a significant decrease in the hedge ratios of previously healthy firms that became financially distressed. Further supporting the theory, the evidence suggests that hedging crowded out investment in real assets.

Key words: Corporate hedging; financial distress; risk management; financial constraints; collateral constraints

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A seeming paradox of risk management is that it may become more costly and difficult to implement the more you need it. Consider first that one of the key roles ascribed to risk management is to make sure that firms are able to undertake investment projects when they otherwise would be unable to attract external financing in the capital markets (Froot, Scharfstein and Stein, 1993, henceforth FSS). A financially constrained firm would therefore seem to have a clear incentive to hedge, because further deteriorations in its financial status would make its underinvestment problem worse or even trigger a costly bankruptcy (Smith and Stulz, 1985).

Intriguingly, however, more recent theoretical models reach the opposite conclusion to FSS (1993) with regard to how financial constraints influence hedging. Mello and Parsons (1999) and Rampini, Sufi, and Viswanathan (2014, henceforth RSV) show that the firm's ability to execute hedging may decline the more financially constrained it becomes, thus predicting a *negative* relation. This theoretical prediction is brought about by lack of collateral. Specifically, both hedging and external financing require collateral, which is scarce. As a consequence, borrowing and hedging become competing objectives for the financially constrained firm. RSV (2014) show that when the marginal product of capital is high, which tends to be the case for constrained firms, using collateral to borrow for investment is optimal, thereby crowding out hedging.

The evidence to date on the hedging-financial constraints relation does not tell a consistent story. The fact that large and presumably unconstrained firms hedge more is well documented. Already Stulz (1996) in his survey of the empirical literature concluded that this is one of the clearest and most robust findings. In their empirical study of the airline industry, RSV (2014) also find that large firms have higher hedge ratios.[1] However, once size is controlled for, financial factors like leverage and cash holdings typically explain hedge ratios in ways that agree with the theory in FSS (1993). Leverage, for example, is positively related to hedge ratios (Tufano, 1996; Haushalter, 2000; Kumar and Rabinovich, 2013). Cash holdings, which offer an alternative form of risk management, are negatively related to hedging activity (Disatnik, Duchin, Schmidt, 2014; Croci, del Guidice, and Jankensgård, 2016).

To find a way out of this impasse, this paper brings evidence from a difference-in-difference (DID) approach using hand-collected data on derivative positions in the oil and gas industry (SIC 1311). I obtain 2,278 firm-quarter observations in the baseline tests. This industry is considered ideal for studies on corporate hedging thanks to economically large exposures, significant variation in hedge ratios, and data disclosure practices (Haushalter, 2000; Jin and Jorion, 2006). However, studies that incorporate exogenous variation are extremely rare in corporate risk management (Bakke, Mahmudi, Fernando, and Salas, 2016). To identify changes in hedging behavior I exploit the sudden and dramatic price decline in the last quarter of 2014. Throughout 2011 and Q3 2014 the oil price (WTI) averaged $96, never dipping below $80. In January 2015 the oil price was trading at roughly 50% of that average. In the last month of that year, the average was down to $37. By that time, the net worth of many oil and gas firms was already severely impaired, and the industry was facing very difficult refinancing conditions. The industry had, within the space of ten weeks, gone from a state of well-being to one of looming crisis.

[1] Their main empirical variable 'net worth' is the market capitalization of equity. It correlates strongly with size measured as total assets (they do not disclose this number. The Pearson correlation in my sample is 0.85). Scaling market capitalization by assets, as they also do, reduces the size-effect, but it also changes the interpretation. The new equity-to-assets variable effectively captures leverage, except that equity rather than liabilities is used to compute it.

The DID-approach allows us to test how firms respond to an exogenously caused decrease in financial constraints (net worth).[2] The theory of FSS (1993) predicts that the hedge ratios of constrained and unconstrained firms *converge* following the shock, as the weaker firms have even stronger incentives than before to protect against future underinvestment and bankruptcy. The theory of RSV (2014) instead predicts that the hedge ratios of the two groups *diverge*, as the impaired access to collateral of the constrained group takes a relatively harder toll on their ability to hedge. The DID is a more powerful test because it allows us to neutralize the strong size-influence that tends to confound empirical measures of financial constraints, including the net worth-proxies used in RSV (2014). The confounding effect occurs because large firms hedge more for reasons that are *unrelated* to their superior access to collateral or external financing, such as being more financially sophisticated; finding it easier to incur the fixed costs of a risk management program (Stulz, 1996); or because they are more affected by agency costs of risk management, leading to excessive use of derivatives (Jankensgård, 2016). This omitted-variable problem makes it very hard to disentangle the causal effect of financial constraints on corporate hedging in the absence of exogenous variation.

Initially I confirm, consistent with RSV (2014), that firms with above-median net worth hedge more. On average, their hedge ratio is about 0.20 higher than for low net worth firms. As discussed, however, because of the size-association of the net worth-measure, it is difficult to use it to make inferences about the role of financial constraints in explaining hedging behavior. Therefore I define a treatment indicator that takes the value 1 post-shock (Q1 2015 until Q2 2016), zero otherwise, as well as a low net worth indicator that takes the value 1 if

[2] In this article the terms net worth and financial constraints are used interchangeably. In the model of Rampini et al (2014) collateral (financial) constraints are defined in terms of net worth, which is the sum of current cash flow, the value of capital net of debt, plus the payoff of any contingent claims used to hedge. As noted previously, empirically they use market capitalization to proxy for net worth (alternatively deflated by total assets).

the firm has below-median net worth (prior to the shock). The DID-estimator is the interaction term between these two binary variables. The treatment indicator, though, is of interest in itself. An overall decrease is supportive of the collateral constraints theory of RSV (2014), whereas a positive treatment effect would indicate that the industry as a whole responded to the heightened risk by hedging more, consistent with FSS (1993) and Smith and Stulz (1985).

The evidence from the DID-approach shows that the hedge ratios of firms that are classified as constrained and unconstrained neither converge nor diverge converge following the shock. The p-value of the DID-estimator is 0.30 (0.21 if controls are included). A closer inspection reveals that this happens because the hedging activity of both groups was reduced. The treatment indicator is -0.04, suggesting an overall decrease in hedging post-shock. More substantial support for RSV (2014) comes from splitting the two groups according to whether or not they ended up in distress post-treatment.[3] According to RSV (2014) the cost of hedging is prohibitively expensive for distressed firms due to collateral constraints and high marginal productivity of capital.This analysis reveals that the reduction in hedging is almost entirely due to firms that became fdistressed after the shock, regardless of their pre-shock status in terms of net worth.

The most compelling evidence in support of RSV (2014) comes from an analysis of high net worth firms that transited into distress. These firms could have hedged more as they approached distress and experienced an increasing cost of external financing. Their access to hedging, and predisposition to use it, is evident pre-shock (their average hedge ratio is 0.47 in this period). Instead, despite this access they hedged gradually less, ending up with hedge

[3] To capture distress I follow Allayannis and Mozumdar (2004), who argue that negative operating cash flows signal a particularly weak financial situation. I define a firm to be distressed if it has four or more quarters with negative cash flows post-treatment (out of 6 possible).

ratios that were approximately 24% lower compared to pre-shock levels. A rather typical example of this behavior is Cimarex Energy. Cimarex had positive operating income before depreciation in all years before Q4 2014, a period in which their average hedge ratio was 17.2%, peaking at 27% in Q1 2014. Post-treatment, when their operating income was negative for six consecutive quarters, their hedge ratio was 5%. In the three first quarters of 2015 they had no outstanding hedges at all.

The theory of RSV (2014) also finds support by another key finding, namely that hedging appears to have crowded out investment in real assets. This finding holds for the sample as a whole but in particular for firms that subsequently became distressed. While RSV (2014) assume, for analytical tractability, that managers allow investment needs to override hedging, managers may actually prioritize risk-reduction over value-maximization when faced with collateral constraints. That is, despite the fact that the marginal productivity of capital is high, risk-averse managers could prefer to underinvest if investment and hedging are competing uses of scarce resources. Such a tendency can comfortably be accounted for within a simple managerial risk aversion-framework.[4] Already Tufano (1996) observed the power of managerial risk aversion-models to explain firms' hedging behavior.

To investigate crowding-out effects between hedging and investments in real assets I carry out a DID-test with a measure of investment in plant, property, and equipment as dependent variable. Before the shock there is no clear relation between the investment rate and the hedge ratio. However, the DID-test reveals a highly significant *negative* association between investment and hedging post-shock. While not decisive evidence of causality, this is consistent with an argument that hedging crowded out investment in this period. Further

[4] One mechanism that could bring this about is a requirement by the counter-part in the hedging transaction that the firm cuts back investment to preserve liquidity.

sample splits show that the crowding-out effects only occurs in firms that are classified as distressed post-treatment. The numbers are substantial: in the full-sample regression, a firm that wanted to hedge 100% of its production would on average reduce investment by 7.5%. For firms in distress the corresponding number is even higher (10-30% depending on net worth). This suggests that managers were making the opposite trade-off compared to the one assumed by RSV (2014). But this finding still supports their theory because the key mechanism of the collateral-constraints theory (lack of collateral) is the most plausible explanation.

I consider alternative explanations for the patterns in the data. The falling hedge ratios could be explained by selective hedging, which is the well-documented tendency for firms to incorporate market views in their hedging strategies (Brown, Crabb, and Haushalter, 2006; Adam and Fernando, 2006; Géczy, Minton, and Schrand, 2007; Adam, Fernando, and Salas, 2017). Stulz (1996) argue that financially unconstrained firms with an information advantage are more likely to engage in selective hedging. One interpretation is therefore that large firms (high net worth by association) generally hedge more selectively and that they reduced the amount of discretionary hedging in the unattractive low-price environment that ensued after the shock. However, the data is not consistent with the selective hedging-hypothesis. High net worth firms that remain classified as such post-treatment, and therefore are most likely to have the financial capacity to support selective hedging, do not visibly alter their hedging behavior. On the other hand, those that were unconstrained but later experienced distress did significantly reduce their hedging. If selective hedging was the driving factor the pattern would have been the opposite.

I also consider whether the drop in hedge ratios for distressed firms is explained by the fact that these firms also experienced the largest drop in investment opportunities. According to FSS (1993) firms whose investment opportunities are sensitive to the hedgeable risk factor have less need for hedging. To evaluate this possibility I separate between economic and financial distress using the distinction between operating performance and leverage in Andrade and Kaplan (1998). A reduction in investment opportunities ought to be driven by underlying economics, not financial factors like leverage and cash, which instead capture financial distress. Therefore, I split the firms that went into distress post-shock into two subsamples based on whether they had high or low leverage. This analysis reveals that the drop in hedging is only significant for firms with above-median leverage. I repeat the analysis using cash balances as splitting criterion, finding that the decrease occurs only in low-cash firms. These results strongly suggest that financial distress, not economic, was primarily responsible for the change in hedging behavior, mitigating any concern that systematic differences in investment opportunities are unduly influencing the results.

Finally I consider whether the decrease in hedging is driven by a version of the asset substitution problem developed by Jensen and Meckling (1976) and first applied to hedging by Stulz (1996). In this theory, firms prefer to increase risk exposures so as to increase shareholder value at the expense of bondholders given the limited liability of shareholders. If firms are in distress and face a high probability of experiencing negative operating income, hedging to lock in prices would virtually ensure that this outcome is obtained. Such a strategy would serve mainly the benefits of bondholders by making debt safer, as opposed to shareholders who may prefer a small probability of a positive outcome over a guaranteed loss. Unfortunately, this prediction is observationally equivalent to the theory in RSV (2014) in that more leveraged firms that enter financial distress would be expected reduce hedging more (which I am able to document). Speaking against the notion of asset substitution, however, is the fact that hedging is associated with lower investment rates post-treatment, suggesting that managers were willing to sacrifice investment for risk management. It is by no means clear that managers, who control the hedging decisions, have the same incentives as shareholders to engineer a risk profile that effectively bets the firm.

This paper concludes that the paradox of risk management is real. The more firms appear to need risk management, the less able they are to execute it. This holds important implications for managers and boards of directors, who need to anticipate the difficulty and cost of executing hedging when events have already turned against the firm. My findings indicate the need for a dynamic view on risk management that factors in this potential future difficulty.

II. Theory and empirical predictions

One of the key justifications of corporate risk management is that it can help ensure that firms are able to undertake investment projects that create value for the firm's shareholders (FSS, 1993). FSS make the observation that volatility in internally generated cash flows translates into volatility in either money raised externally or in the firm's investment program. If one makes the assumption that external financing is costly, fluctuations in operating cash flows may disrupt the firm's optimal investment program. The insight of FSS is that corporate hedging can increase firm value under such conditions by coordinating investment and financing policies. Hedging can be used in such a way that it generates cash flows in scenarios where the firm would otherwise have had to cut back on its investments due to an excessively high cost of external capital.

It follows from the theory of FSS that the incentives to hedge are stronger in firms that face a high cost wedge between internal and external financing. These are the conditions in which derivative cash flows can best fulfil its role of stabilizing and increasing investment. What is more, as the firm's financial condition deteriorates, successively better investments are scaled back. This means that the more financially constrained the firm becomes, the better and more profitable are the investments that are put at risk (in other words, the marginal productivity of capital plausibly increases in the level of financial constraints). At some point, other potentially large costs of financial distress will also loom, creating additional incentives to hedge. These involve forced asset sales at a discount to fair value (Shleifer and Vishny, 1992) and direct and indirect costs of bankruptcy (Smith and Stulz, 1985). The above analysis leads to the following hypotheses:

H1 (a): Financially constrained firms have higher hedge ratios than unconstrained firms.

H2 (a): The average hedge ratio of an industry increases following an industry-wide negative shock to net worth.

H3 (a): Financially constrained firms increase their hedge ratios relative to unconstrained firms following an industry-wide negative shock to net worth.

The collateral constraints-theory of hedging in RSV (2014) reaches very different conclusions with regard to the impact of financial constraints on hedging. Their model set-up modifies two key assumptions in FSS (1993), namely that there is no investment in real assets at the time of the hedging decision, and there are no collateral constraints on hedging. The fundamental premise in RSV (2014) is that collateral constraints link the availability of financing and risk management. Promises to pay under a hedging contract need to be collateralized, just as promised loan repayments. Hence, in their model managers choose investment, financing, and risk management policies given collateral constraints. The marginal productivity of capital is what resolves the trade-off between risk management and borrowing. Low net worth implies that the firm is not able to purchase much capital, and consequently the marginal productivity of that capital must be high. This suggests that low net worth firms will prioritize borrowing to realize investments with a high marginal productivity rather than hedge. This logic leads to the following hypotheses:

H1 (b): Financially constrained firms have lower hedge ratios than unconstrained firms.

H2 (b): The average hedge ratio of an industry decreases following an industry-wide negative shock to net worth.

H3 (b): Financially constrained firms decrease their hedge ratios relative to unconstrained firms following an industry-wide negative shock to net worth

III. Empirical framework

The most basic test of the effect of financial constraints on corporate hedging takes the following form:

$$h_{i,t} = a + \omega T_i + \delta z_{i,t} + \varepsilon_{i,t} \quad (1)$$

In Eq.1 $h_{i,t}$ is the hedge ratio of firm i at time t. T_i is a binary variable that equals one if firm i is financially constrained, and z_{it} is a vector of control variables. As discussed in the introduction, however, Eq. 1 is likely to suffer from omitted variable bias, making it hard to disentangle the causal effect of financial constraints on corporate hedging. The problem is largely caused by the well documented size-effect in corporate hedging, which confounds inferences. Several of the reasons advanced for explaining why large firms hedge more are unrelated to their superior access to collateral or external financing as such. For example, they are usually considered more financially sophisticated, and find it easier to incur the fixed costs of a risk management program (Stulz, 1996); or being afflicted by agency costs of risk management, leading to excessive use of derivatives (Jankensgård, 2016). This renders Eq. 1 powerless to adequately test hypotheses 1 (a) and 1 (b).

Size is a highly endogenous proxy for financial constraints even in the absence of such hedging-specific differences. Kadapakkam, Kumar and Riddick (1998) and Andrén and Jankensgård (2016) show that investment-cash flow sensitivities, which have been interpreted as measures of financial constraints, are higher, not lower, for larger firms. Andrén and Jankensgård (2016) argue that this happens because large firms have other characteristics that simultaneously influence the demand for and cost of external financing, such as having lower investment rates and higher leverage.

Matters improve if an exogenous shock to net worth is incorporated into the empirical design. Then identification is made easier because we can make unambiguous predictions with regard to the change in hedging behavior that results from the shock. To implement this test we add an event dummy d_t that equals one after the event (in our case, the shock to net worth in Q4 2014) and zero before. The event dummy d_t indicates whether the average hedge ratio of the industry as a whole went up post-shock, thereby allowing us to test hypotheses 2 (a) and 2 (b).

$$h_{i,t} = a + d_t + \delta z_{i,t} + \varepsilon_{i,t} \tag{2}$$

Eq. 2 can give potentially important clues as to how firms' hedging activity is affected by a major change in financial constraints. We may be able to formulate an even more stringent test of the broader hypothesis, however, if we combine the logic of Eq. 1 and 2 to obtain a Difference-in-Difference (DID) specification. The DID estimate is given by the coefficient θ on the interaction term (predicted positive by FSS, 1993, and negative by RSV, 2014). It indicates the effect the shock to net worth had on the hedging behavior of financially constrained firms *relative* to its impact on unconstrained firms. This allows us to test hypotheses 3 (a) and 3 (b) using Eq. 3.

$$h_{i,t} = a + d_t + \omega T_i + \theta d_t T_i + \delta z_{i,t} + \varepsilon_{i,t} \tag{3}$$

An important circumstance regarding the implementation of Eq. 3 for the purposes of this study is that both groups are in fact treated by the shock (the price-induced collapse in net worth), whereas in a classic "natural experiment" the exogenous shock affects only the treated group, which is identical to the control group in as many respects as possible. In stylized terms, for the test to be effective, we would expect that financially constrained firms transit from mild to severe financial constraints post-shock, whereas the unconstrained group either remains unconstrained or become financially constrained. The power of the test in Eq. 3 will be undermined to the extent that a lot of previously unconstrained firms are sent into severe financial constraints by the shock, or to the extent that a lot of constrained firms are largely unaffected by it. I will analyze such issues detail in section V.

Another potentially problematic aspect is that Eq. 3 does not solve the endogeneity issue because obviously hedging also affects firm value. This would be especially evident in circumstances like those after the shock in Q4 2014 when firms with hedges-in-place were benefitting from the cash inflows. This may not be very problematic, however, if one considers that net worth is supposed to be the sole determinant of “new” hedging, which is what my analysis concerns. Given this, if “old” hedging to some extent influences net worth is a moot point: it is just the level of net worth per se that matters, regardless of its sources. The core of the question is whether financial constraints (measured as low net worth) prevent firms from initiating new hedges, which, if true, would manifest itself as a drop in hedging activity.

IV. Sample, variables, and descriptive statistics

A. Sample

The sample used in this study consists of publicly traded oil and gas producers in the US (SIC code 1311) between Q1 2013 and Q2 2016. The advantages of using the oil and gas industry for studies of corporate hedging are well known. It is one of very few to disclose sufficiently detailed information about derivative positions. Jin and Jorion (2006) argue that it is a homogenous industry, yet it exhibits significant variation in hedge ratios. Furthermore, according to Bakke et al (2016) the industry’s cash flow volatility that is high enough to make risk management economically important.

The oil and gas industry is obviously different from airlines, the industry used in RSV (2014), in that it hedges primarily its outputs, as opposed to the input costs (fuel). According to De Angelis and Ravid (2017), a firm could hedge input and output risk differently depending on its market power. However, RSV are explicit about the fact that there exists no conceptual difference between hedging inputs or outputs in their model. Collateral requirements are ubiquitous in oil and gas hedging. However, they appear to be exclusively framed in terms of having available enough cash or unused credit lines, as in Mello and Parsons (1999). RSV (2014) discuss examples where airlines have pledged aircrafts to secure hedging transactions. Lending with reserves as collateral does occur in the oil and gas industry, particularly when economic conditions got worse after the shock in Q4 2014, but I have not been able to find any equivalent examples of reserves-based collateral to support hedging.

Firms are eligible for inclusion if they are headquartered in the US; publicly listed; and have at least $1mn in total assets in all years. I furthermore require that 10-Qs (quarterly reports) be available from the online EDGAR database, and that firms report their derivative positions in sufficient detail to quantify different hedging strategies.[5] The latter criterion essentially means that firms must report their hedging position in tabular form. Fortunately, most firms use this form of disclosure. Firms that report a value-at-risk or a sensitivity measure, which are also allowed under U.S. accounting rules, are deleted because the information is insufficient to determine the extent and type of hedging.

All financial statement data and industry specific operating data are obtained from Compustat. This renders a total of 2,424 firm-quarters, corresponding to 221 unique firms. Hedging or production data was unavailable or impossible to code for 137 of these firm-quarters, which brings the total number of observations to 2,287 in the main model specification. In section V additional filters are imposed on the data for robustness checks.

[5] Hedging positions are identified by carefully reading the 10-Ks, as well as through a keyword search. Examples of search words are: “item 7a,” “hedg,” “derivative,” “market risk,” “swap,” “collar,” “forward,” “put option,” and “risk management.”

B. Hedge ratio

The main variable used in this study is *Hedge Ratio*. Hedge Ratio is computed as the sum of linear hedging contracts and put option contracts bought with a maturity of less than 12 months, scaled by expected production within the next 12 months (barrels of oil equivalents). Linear contracts consist of forwards, futures, and price swaps, that is, derivative instruments in which the payoff is a linear function of the underlying commodity. Natural gas is converted into barrels of oil equivalents using the standard assumption that 6 Mcf of gas has the same energy content as 1 bbl of oil. Expected production is assumed to be equal to actual production (i.e. perfect foresight).

C. Net worth

In the model of RSV (2014) collateral (financial) constraints are determined by net worth. I follow their definition and define *Net Worth* as the market value of equity (in $ million). I then create a binary variable that takes the value 1for firms classified as having low net worth, 0 otherwise. It is important how this indicator variable is constructed. To use the overall sample median would be problematic, because the fraction of firms that are classified as below median would jump when the treatment occurs in Q4 2014. Even if firms are classified relative the median in each successive year problems remain because this approach allows firms to transit between groups, which gives rise to largely mechanical effects that does not reflect changes in actual hedging behavior. Therefore, the groups are fixed pre-treatment. Specifically, *Low Net Worth* takes the value 1 if the firm has below-median net worth in at least 4 of the 7 quarters before the shock. Using this definition produces groups that are roughly balanced in numbers (45% are classified as constrained and 55% as unconstrained). Alternatively I define this dummy variable in terms of the value of Net Worth just before the shock (Q3 2014). Using this definition renders similar results.

D. Other variables

Assets is the total book value of assets (in $ million). *Neg Cash Flow* is a binary variable that takes the value 1 if Operating income before depreciation is negative, 0 otherwise. *Leverage* is total debt scaled by total assets. *Cash* is defined as cash and cash equivalents scaled by assets. *Investment* is computed as the sum of the change in PPE and depreciation and amortization, scaled by beginning-of-year total assets. Leverage, Cash and Investment are winsorized at the 1 and 99th percentiles. The treatment indicator is *Post*, which takes the value 1 in Q1 2015 through Q2 2016, 0 otherwise.

E. Descriptive statistics

Table I reports the descriptive statistics for the variables used in this study. The fraction of firms that use derivatives is 54%. This is a comparable number to the fraction of hedgers reported in Haushalter (2000) and Jin and Jorion (2006) for the oil and gas industry (57% and 65%, respectively). Conditional on hedging, the average hedge ratio is 49.8% (27.1% for the whole sample).

[INSERT TABLE I ABOUT HERE]

Figures I and II illustrate the setting of the DID-regressions in section V. After fluctuating for a prolonged period around $90-100, the oil price roughly halved within the space of one quarter (Q4 2014). The abrupt fall in the oil price entailed an equally abrupt drop in the net worth of the industry as a whole. This can be seen in Figure II, which depicts the median net worth of the sample between Q1 2013 and Q2 2016. By Q1 2015 the median net worth had halved compared to the pre-shock high, and one year later (Q1 2016) it had halved again. If net worth and collateral constraints have a decisive role on corporate hedging, these ought to be the circumstances in which this influence manifests itself. Figure III shows the fraction of firms that reported negative operating income (EBIT). As can be seen, this fraction increased dramatically following the shock. In 2015 it is consistently above 50% and peaks just below 70% in the 4th quarter. This clearly illustrates the severity of the shock for the firms in the oil and gas industry.

[INSERT FIGURE I ABOUT HERE]

[INSERT FIGURE II ABOUT HERE]

[INSERT FIGURE III ABOUT HERE]

V. Results

A. Difference-in-Difference results (financial constraints)

I begin by checking the parallel trend assumption for the two subsamples in which Low Net Worth takes the value one and zero respectively. This analysis (unreported) shows that the assumption is not violated. The difference in the pre-shock quarters (Q1 2013 through Q3 2014) hovers around 0.2 and 0.25 with no detectable trend.

Table II reports the results from four different regressions. Model 1 contains only the indicator variable Low Net Worth. According to the coefficient, on average low net worth firms hedge less by 0.20 compared to their high net worth peers. However, due to its strong association with firm size, inferences are hard to make with regard to the collateral constraints-corporate hedging relation.[6] Model 2 adds another indicator variable, Post, which

[6] Net worth and total assets have a correlation of 0.85 in this sample.

takes the value 1 in the quarters following the shock, 0 otherwise. It indicates a statistically significant decrease in hedging following the shock of -0.04.[7]

Model 3 is the DID-specification. It interacts Low Net Worth with Post to see if the hedge ratios of financially constrained firms converge or diverge following the shock. The DID-estimator in Model III comes out insignificant. Model 4 repeats the DID, except that it adds three major control variables from the corporate hedging literature: total assets, leverage, and cash. These control variables all have the expected sign and are significant at the 1%-level, and including them noticeably improves the explanatory power of the model. The DID-estimator continues to be statistically insignificant, however.

[INSERT TABLE II ABOUT HERE]

The DID-specification in Table II indicates that the hedge ratios of financially constrained and unconstrained firms neither converged nor diverged following the negative shock to net worth. This would appear to suggest that neither theory is descriptive. Such a conclusion would be premature, however, since the overall decrease in hedging is supportive of RSV (2014). The decrease is visible in both constrained and unconstrained firms. Figure IV illustrates the mean hedge ratios of these two categories of firms between Q1 2013 and Q2 2016.

[INSERT FIGURE IV ABOUT HERE]

[7] Changes in production volumes are not driving this effect. Production did decrease somewhat towards the end of the sample period as uneconomic production was closed or scaled down, but a similar effect is obtained when the period is restricted to 3 quarters before and after the shock, when production volumes were essentially maintained.

As discussed in section II, in order to study changes in hedging behavior the sample is balanced in that firms are required to have at least three quarters both before and after treatment to be included in the sample. In addition, the groups are fixed pre-shock. One might argue that a proper test of whether net worth drives hedging should allow for transit between the groups. If one takes this view, whether a firm was classified as constrained in the past or not should not matter; its current hedging activities would only be determined by its present net worth. In unreported regressions I re-estimate Table II except that transit is allowed so that a firm is classified relative the median net worth in each quarter. In this case, the DID-estimator is positive and significant. However, it turns out that the result is mechanical in the sense that high-net worth firms that were established hedgers were re-classified into the low-net worth group following the shock. Therefore, the DID-estimator in this set-up does not necessarily indicate a within-firm change in hedging behavior. But it presents us with an interesting observation, namely that that some high net worth firms appear to have been heavily impacted by the treatment. As we shall see in the next section, a fair share of them even ended up in distress, which has important implications for our analysis.

B. The impact of distress on hedging behavior

The model of RSV (2014) explicitly predicts that severely constrained, i.e. distressed, firms do not hedge at all because of a combination of collateral constraints and high marginal productivity of capital. This suggests that several clues can be had by studying distressed firms more closely. My empirical strategy to explore this used revolves around the idea that perhaps the most valid test of the theory is whether hedging decreased or not in firms that were financially unconstrained (high net worth) but ended up in distress after the shock. This transition, I argue, represents ideal conditions for testing the predictions of RSV (2014): these firms had access to hedging, demonstrably were willing to use it, but subsequently experienced a sharply increased cost of external financing to the point of becoming distressed. FSS (1993) predict that such firms would increase hedging in response to a higher cost of financing, whereas RSV (2014) predict that they decrease it as collateral became increasingly scarce.

Following Allayannis and Mozumdar (2004) I use negative operating cash flow (here defined as negative operating income before depreciation) as a proxy for distress. I define a firm as distressed if it had more than 4 quarters (out of 6 possible) post-treatment. According to Allayannis and Mozumdar, negative cash flow is a useful way to characterize firms that are in a distressed situation. As shown earlier in Figure III, the fraction of firm-years with negative cash flows increased dramatically following the shock in Q4 2014, underscoring the heavy toll the price drop was taking on the industry as a whole.

Table III reports the change in hedge ratios for four different groups. The initial sort is on high or low net worth. These measurements are taken pre-shock, as before. The new feature is that there is a second sort, which depends on whether the firm subsequently ended up in distress. That is, high net worth firms are divided into two sub-groups according to whether they became distressed post-shock or not. The same is done for low net worth firms.

[INSERT TABLE III ABOUT HERE]

Table III shows that it is the subsample consisting of high net worth firms that became distressed that sees the largest decrease in hedging (-0.115). For this subsample, the model explains patterns in hedging well in that size, leverage, and cash are significant with the expected signs. For high net worth firms that did not became distressed the model lacks explanatory power. The fact that financial status is unrelated to hedging may suggest that in these firms hedging is perhaps driven by other motives, such as selective hedging.

The results in Table III clearly support the theory in RSV (2014). The firms that exhibit the largest decrease in hedging are precisely those that could have hedged more if the theory in FSS (1993) had been descriptive of the patterns in the data. They were relatively large and healthy firms who were established hedgers before treatment. As their financial health deteriorated, there ought to have been ample opportunity to intensify hedging in order to deal with the increasing risk. Instead, according to Table III, they successively scaled it back as financial resources got scarcer.

C. Economic versus financial distress

An alternative explanation for the finding that distressed firms reduced hedging the most is that they simultaneously experienced the largest drop in investment opportunities. The predictions of the theories of FSS (1993) and RSV (2014) are derived under assumptions about unchanged investment opportunities. When the oil price fell, however, much fewer projects had attractive economics compared to before the shock, and this impact could be systematically different for firms that had the largest decrease in hedging. To evaluate this potential concern, I distinguish between economic and financial distress following Andrade and Kaplan (1998). Whereas negative operating cash flows signal primarily poor economics and profitability, i.e. economic distress, financial distress implies high leverage (and/or low cash balances), which amplifies the firm's difficulties to withstand periods of weak cash flow generation.

Table IV reports the findings from regressions in which the firms that went into distress are divided in to subsamples depending on their status in terms of leverage (Models 1 and 2) and cash balances (Models 3 and 4). The take-away from Table IV is that it is financial distress that is decisive in producing the decrease in hedging. The reduction in the hedge ratio is only visible in the above-median leverage group and the below-median cash group, i.e. the ones with the weakest balance sheets. It took not only negative operating income, but also a weak balance sheet, for the effect to take place. This suggests that the pattern is not driven by underlying economics of investment opportunities but rather by collateral constraints (i.e., the cost wedge on external financing).

[INSERT TABLE IV ABOUT HERE]

One can also view the results in Table IV in light of the model in Mello and Parson (1999). These authors frame collateral constraints on hedging in terms of cash and debt capacity instead of net worth. The findings I report are consistent with the idea that scarce collateral in the form of low cash and low spare debt capacity prevented access to hedging.

D. Did hedging firms underinvest?

In this section I investigate one of the key premises in the RSV model (2014), namely that the managers in financially constrained firms use the existing (and scarce) collateral to fund investment rather than hedge. One possibility is that managers were not, as presumed, impassionate value-maximizers. Value-maximization may not be a particularly accurate model of managerial behavior under conditions of severe financial constraints, in which case they may not allow debt-financed investment to override the hedging decision. It is well-known that managerial risk aversion may lead to higher-than-optimal hedge ratios (Smith and

Stulz, 1985), and managerial incentives-models have proven relevant to explain hedging in practice (Tufano, 1996; Bakke et al, 2016).

To investigate this idea I use investment as dependent variable. Results are reported in Table V. Model 1 is the basic DID-specification. Initially the association is positive, suggesting that firms with a higher investment rate hedge less (consistent with the logic of FSS, 1993). Post-treatment there is a significant drop in investment. The DID-estimator is negative and more than twice the size of the initial coefficient, suggesting that, in contrast to pre-treatment, hedging is now associated with less investment. Model 2 includes firm fixed effects.

[INSERT TABLE V ABOUT HERE]

The results in Table V lend support to the idea that there was a crowding-out effect between hedging and investment. To the extent that collateral constraints implied a choice between hedging and investment, many managers appear to have opted for hedging. In the prevailing crisis mood, it is perhaps not surprising that managers sought to implement hedging positions to ensure survival, even if this came at the expense of underinvestment.

Table VI breaks the sample down into groups depending on whether they were classified as high or low net worth firm prior to the shock, and whether they became economically distressed post-treatment. The results show that the crowding out effect post-shock only occurred in the most distressed subsample. This is consistent with the logic of the model in RSV (2014): healthier firms were better able to maintain their hedge ratios without sacrificing investments in real assets.

Figure V shows the development of leverage between Q1 2013 and Q2 2016 for firms classified as high net worth firms prior to treatment. These firms are divided into two subgroups: those that ended up in distress post-shock and those that did not. It is evident that the firms that became distressed were more actively using debt markets to stay afloat. This borrowing activity creates the preconditions for the crowding effects reported in Tables V and VI because they were using what collateral they may have had to support it, effectively maxing out their debt capacity. Maintaining hedging under such conditions would have used up further collateral, thus enacting the trade-off between hedging and real investments.

[INSERT FIGURE V ABOUT HERE]

E. Other explanations

The overall decrease in hedging activity, and that of financially distressed firms in particular, may be possible to account for with reference to other theories of firm behavior. For example, one may search for explanations in the literature on selective hedging, which is defined as varying the size and timing of hedging positions based on market views (Stulz, 1996; Adam, Fernando, and Salas, 2015). This literature has documented significant 'excess volatility' in hedge ratios, that is, fluctuations in hedging that cannot be explained by changes in fundamental determinants of hedging (Brown, Crabb, and Haushalter, 2006; Adam and Fernando, 2006; Géczy, Minton, and Schrand, 2007; Adam et al, 2015).

One possibility is therefore that the decrease in hedging simply reflects that hedging became less attractive in the low-price environment. While "prize-optimization" may have been going on to some extent, this line of argumentation is contradicted by the observation that it was precisely the healthy firms that became financially distressed that decreased hedging the most, whereas there was no noticeable decrease in those that remained healthy. According to Stulz

(1996) the firms most likely to engage in selective hedging are those that have an information advantage and enough financial muscles to support selective hedging. If high net worth (size) is taken as a proxy for information advantage (through their higher financial sophistication and resources) then selective hedging would predict a larger decrease in those firms that were in better shape post-shock because these firms had the comparative advantage both in terms of information and financial condition. We observe the opposite.

Another theoretical insight that could potentially explain the observed pattern is asset substitution, first analyzed by Jensen and Meckling (1976). In this setting, the managers of highly leveraged and financially distressed firms who act in the interest of shareholders have incentives to *increase* risk exposures, despite the high overall risk. From the viewpoint of shareholders their limited liability caps downside risk, so that for them it is optimal to accept a higher risk of bankruptcy in exchange for an increase in the probability of ending up with a positive payoff. From this it follows that perhaps the managers of firms that became financially distressed chose to hedge less out of a desire to maximize the upside potential for shareholders, possibly at the expense of debt holders. This proposition is somewhat difficult to test. The asset-substitution theory is observationally equivalent to the RSV (2014) theory in that it predicts that financially distressed firms hedge less. While this argument cannot be ruled out, it ignores managerial incentives to maintain the firm as a going concern. Also, the observation that investments were sharply curtailed in these firms contradicts the notion of asset substitution. Value-maximizing behavior would have implied that investments were upheld to preserve upside potential for shareholders, thus crowding out hedging rather than the other way around.

VI. Conclusions

One of the most important aspects of corporate hedging theory concerns the hedging behavior of financially constrained firms. While they have well-known incentives to use risk management, such as avoiding underinvestment due to a high cost of external financing (Froot et al, 1993), a recent theoretical model by Rampini et al (2014) has brought attention to potential limitations in executing hedging due to collateral constraints. In this paper I have brought evidence from a Difference-in-Difference (DID) approach to investigate which of these theories best explain the response of oil and gas firms to the exogenous shock to net worth caused by the dramatic fall in the oil price in Q4 2014.

The evidence from the DID-approach provides strong support for the collateral constraints-theory of hedging in Rampini et al (2014). First, there is a decline in overall hedging activity following treatment. Second, this decrease is largest in high net worth firms that subsequently became distressed. Third, the decrease is also more noticeable in distressed firms with high levels of leverage and low levels of cash. Fourth, the evidence also suggests hedging crowded out investments in real assets, which would happen if collateral is scarce and risk-averse managers prefer managing risk over maintaining investment rates. Collateral constraints, then, appear to have been binding enough to hold back an increased demand for hedging in the firms that, from all appearances, would have needed it the most.

These findings strongly suggest that the paradox of risk management is real. Risk management gets increasingly costly and inaccessible the more firms need it. When the cost of external financing is already very high, and conventional theories would indicate that hedging is called for to reduce expected costs of financial distress, the cost of executing hedging could be too high already. Managers of such firms may have to contemplate using up scarce liquidity or collateral and thus exacerbate underinvestment, or refrain from hedging and accept risk exposures at a time when they can scarcely bear it. When designing their current risk management strategy, managers and directors of the board should heed these findings and anticipate these future potential difficulties in implementing hedging.

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Tables and Figures

Table I

Descriptive statistics

	Nr obs	Mean	Median	Std. Dev.
Hedge ratio	2,315	0.270	0.100	0.320
Net Worth ($M)	2,424	3,720	300	10,061
Neg Cash Flow	2,424	0.412	0.000	0.492
Assets ($M)	2,424	5,026	734	12,903
Leverage	2,392	0.414	0.336	0.438
Cash	2,424	0.089	0.025	0.156
Investment	2,372	0.020	0.017	0.126

The sample consists of US oil and gas firms (SIC code 1311) between Q1 2013 and Q2 2016. Hedge Ratio is the sum of linear hedging contracts plus put options bought over the next for quarters scaled by expected production over the next four quarters. Net Worth is the market capitalization of equity (in USD million). Neg Cash Flow is a binary variable that takes the value 1 if operating income before depreciation is negative, 0 otherwise. Assets is the book value of total assets (in USD million). Leverage is (Long term debt + Short term debt)/Assets. Cash is (Cash + Short term investments)/Assets. Investment is the sum of the change in property, plant, and equipment plus depreciation and amortization, scaled by beginning-of-year total assets.

Figure I

Oil price Q1 2013- Q2 2016 (WTI, Cushing, Oklahoma)

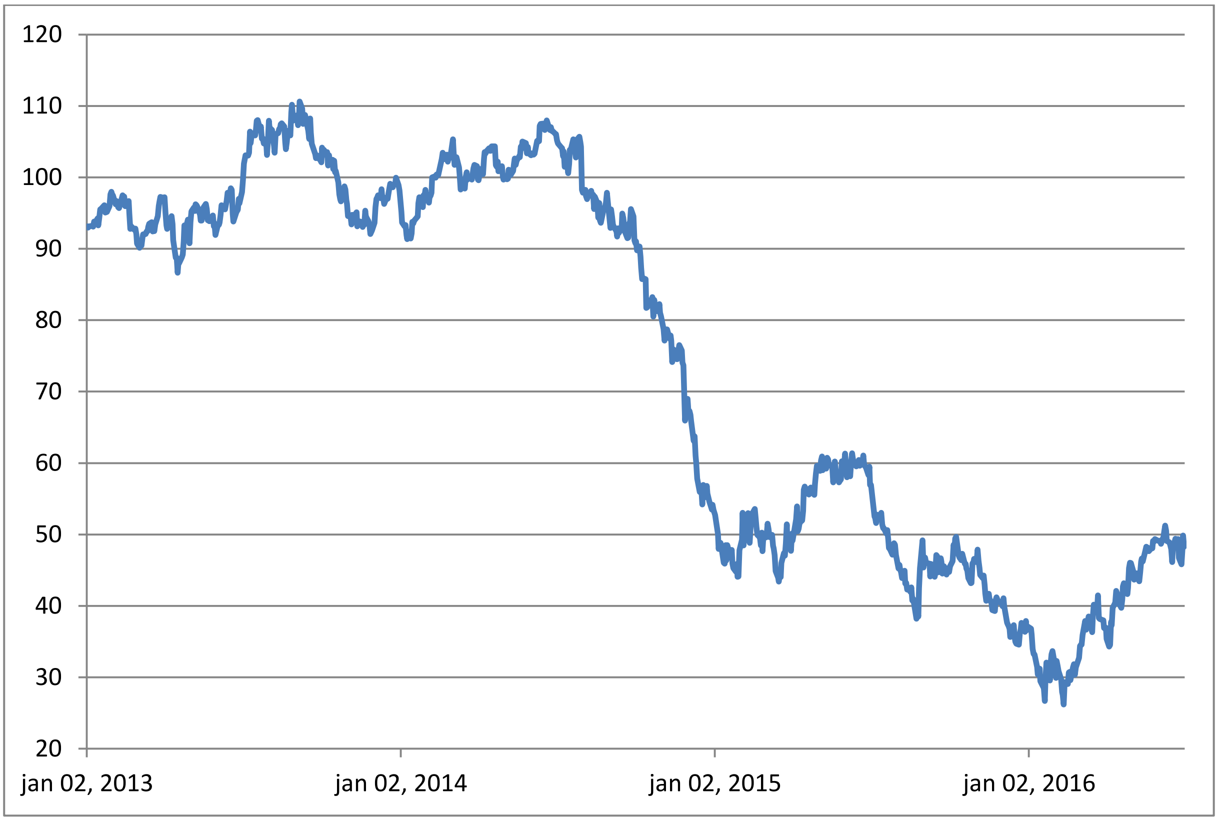


Figure II

Median of Net Worth Q1 2013- Q2 2016

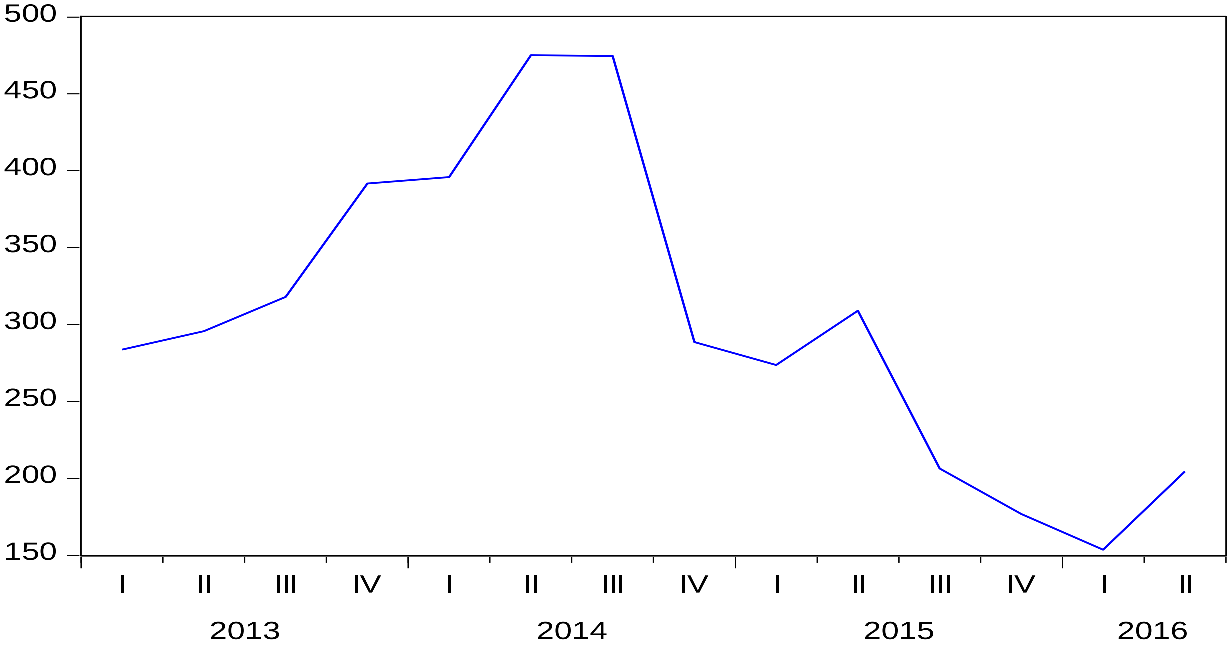


Figure III

Fraction of firms with negative operating income before depreciation Q1 2013- Q2 2016.

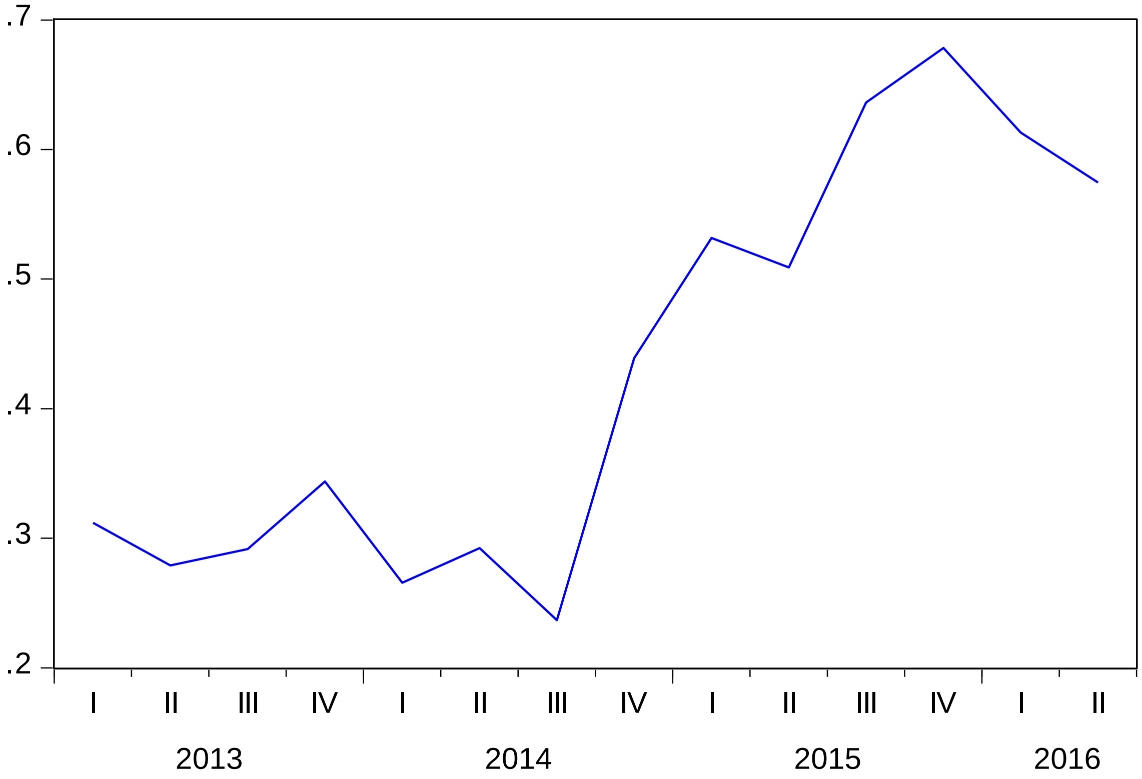


Table II

Difference-in-Difference estimation of hedge ratio (financial constraints)

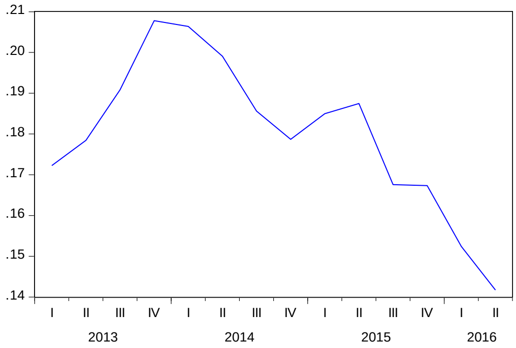
	(1)	(2)	(3)	(4)
Constant	0.383***	0.402***	0.408***	0.000
	(11.3)	(11.6)	(11.5)	(0.12)
Low Net Worth	-0.201***	-0.203***	-0.216***	-0.02
	(-4.43)	(-4.47)	(-4.44)	(-0.51)
Post		-0.042***	-0.056**	-0.07***
		(-2.77)	(-2.54)	(-3.17)
Low Net Worth * Post			0.030	0.030
			(1.01)	(1.24)
Log(Assets)				0.04***
				(4.80)
Leverage				0.110***
				(2.80)
Cash				-0.280***
				(-2.90)
Nr observations	2,287	2,287	2,287	2,255
Adj. R^2	0.098	0.102	0.102	0.236

OLS estimations of hedge ratios for US oil and gas firms between Q1 2013 and Q2 2016. Standard errors clustered at the firm level are used in all estimations. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Figure IV

Mean of hedge ratio conditional on Net Worth

Panel A: Net Worth < Median



Panel B: Net Worth > Median

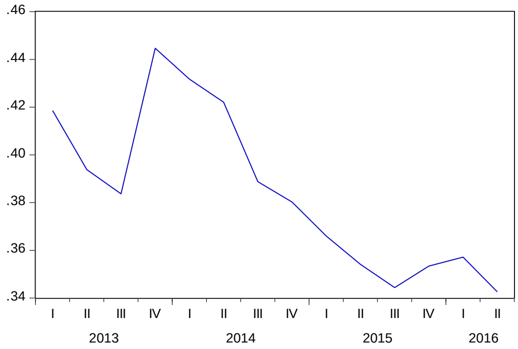


Table III

Hedge ratios conditional on (initial) net worth and (subsequent) economic distress

	High net worth => economic distress	High net worth => no economic distress	Low net worth => economic distress	Low net worth => no economic distress
Constant	-0.172*	0.329*	-0.108*	-0.21***
	(-1.73)	(1.79)	(-1.79)	(-3.76)
Post	-0.115***	-0.052	-0.013	-0.03
	(-3.43)	(-1.55)	(-0.58)	(-1.09)
Log(Assets)	0.080***	-0.002	0.065***	0.080***
	(5.96)	(-0.14)	(4.49)	(7.27)
Leverage	0.209**	0.266	0.050**	0.130*
	(2.35)	(1.19)	(2.19)	(1.88)
Cash	-0.963***	-0.511	-0.122	-0.37**
	(-2.99)	(-0.92)	(-1.41)	(-2.29)
Nr observations	418	568	449	350
Adj. R^2	0.401	0.042	0.042	0.334

OLS estimations of hedge ratios for US oil and gas firms between Q1 2013 and Q2 2016. Standard errors clustered at the firm level are used in all estimations. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table IV

Hedge ratios sorted on economic distress, cash, and leverage

	Economic distress & high leverage	Economic distress & low leverage	Economic distress & high cash	Economic distress & low cash
Constant	-0.019	-0.159***	-0.041	-0.250***
	(-0.17)	(-2.71)	(-0.60)	(-4.635)
Post	-0.111***	-0.010	-0.016	-0.080***
	(-3.12)	(-0.42)	(-0.58)	(-3.331)
Log(Assets)	0.077***	0.041***	0.051***	0.091***
	(5.90)	(4.15)	(4.64)	(9.913)
Leverage	0.020	0.722***	0.055*	0.141***
	(0.54)	(3.87)	(1.68)	(3.230)
Cash	-0.485*	0.028	-0.208*	1.892
	(-1.81)	(0.31)	(-1.72)	(0.672)
Nr observations	455	471	471	455
Adj. R^2	0.444	0.431	0.355	0.504

OLS estimations of hedge ratios for US oil and gas firms between Q1 2013 and Q2 2016. High and low leverage means above and below the sample median, respectively. High and low cash means above and below the sample median, respectively. Standard errors clustered at the firm level are used in all estimations. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table V

OLS estimations of investment between Q1 2013 and Q2 2016

	No firm fixed effects	Firm fixed effects
Constant	0.021*	0.003
	(1.95)	(0.04)
Hedge Ratio	0.022	0.028
	(1.44)	(0.93)
Post	-0.071***	-0.062***
	(-7.65)	(-5.92)
Hedge Ratio*Post	-0.051**	-0.079***
	(-2.11)	(-2.90)
Log(Net Worth(-1))	0.004***	0.007
	(3.27)	(0.78)
Leverage (-1)	-0.006	-0.019
	(-0.56)	(-0.56)
Cash (-1)	0.027	0.115*
	(1.44)	(1.69)
Nr observations	1,811	1,811
Adj. R2	0.142	0.212

The dependent variable is investment in plant, property and equipment deflated by beginning-of-year total assets. Standard errors clustered at the firm level are used in all estimations. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table VI

OLS estimations of investment conditional on net worth and financial distress

	High net worth => financial distress	High net worth => no financial distress	Low net worth => financial distress	Low net worth => no financial distress
Constant	0.246***	-0.096	-0.014	-0.140**
	(2.69)	(-0.71)	(-0.31)	(-2.05)
Hedge Ratio	0.038	0.005	0.141**	-0.053
	(0.84)	(0.18)	(2.01)	(-0.86)
Post	-0.090***	-0.042***	-0.057***	-0.042***
	(-3.92)	(-3.05)	(-3.27)	(-2.63)
Hedge Ratio*Post	-0.090**	-0.017	-0.321***	0.021
	(-2.18)	(-0.51)	(-6.25)	(0.29)
Log(Net Worth(-1))	-0.020**	0.016	0.005	0.041***
	(-2.04)	(1.21)	(0.61)	(2.64)
Leverage (-1)	-0.139***	0.017	0.023	-0.00
	(-3.32)	(0.35)	(0.48)	(-0.06)
Cash (-1)	0.195	0.246	0.038	0.233*
	(1.59)	(1.46)	(0.51)	(1.79)
Firm fixed effects	Yes	Yes	Yes	Yes
Nr observations	418	568	449	350
Adj. R^2	0.398	0.156	0.216	0.205

The dependent variable is investment in plant, property and equipment. The sample period is Q1 2013 to Q2 2016. Standard errors clustered at the firm level are used in all estimations. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Figure V

Leverage

This figure shows leverage between 2013 Q1 to 2016 Q2 for firms conditional on being classified as high net worth firms prior to the oil price collapse in Q4 2016. These firms are classified into two groups depending on whether they subsequently became financially distressed.