Time to Get Mature: Exploring How Firms Choose Hedging Maturity

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Abstract

Hedging maturity, *i.e.*, how far out in time hedging activities stretch, is an important yet under-theorized aspect of corporate risk management. In this article, we analyse firms' hedging maturity decision and carry out a comprehensive empirical analysis. We develop three hypotheses to explain hedging maturity. The collateral hypothesis states that longer maturities are predicated on the availability of financial resources. The flexibility hypothesis holds that the ability to change operations or investment strategies at low cost is conducive to shorter maturities. The matching hypothesis argues that firms match their hedging maturity with the maturity of their debt and investment portfolios. Using hand-collected data on derivative positions in the oil and gas industry, we find evidence consistent with all three hypotheses.

Keywords: *hedging maturity, collateral, investment maturity, debt maturity, flexibility*

JEL Codes: G32, G31, L71

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1. Introduction

The literature on corporate hedging has looked extensively into the issue of which firms use derivatives and the extent to which they do so (‘the why hedge-question’). (Smith and Stulz, 1985; Tufano, 1996; Haushalter, 2000; Carter et al., 2006; Jankensgård and Moursli, 2020). Researchers have also analysed different techniques for modifying a risk profile (‘the how hedge-question’), construed primarily as a choice between linear and option-based hedging techniques (Adam, 2009; Croci, del Guidice, and Jankensgård, 2017).

In this article, we focus on a so far almost entirely neglected aspect of hedging behaviour, namely the maturity of firms’ derivative portfolios. Maturity refers to how far out in time the derivative contracts go. Does the firm manage its risk with a one year or a five-year horizon? This is a highly consequential yet poorly understood decision. As of today, we know little about this aspect of corporate hedging. Practitioners looking to the academic literature for guidance would find scarcely anything in the way of theories, principles, or empirical findings that could inform their thinking. We argue, however, that hedging maturity has strong implication for liquidity management and funding availability, which are crucial factors in the successful execution of corporate strategy (Froot, Scharfstein and Stein, 1993).

We develop three hypotheses to explain hedging maturity. The collateral hypothesis argues that access to longer-dated hedging contracts depends on the availability of financial resources. The argument is that, in over the counter (OTC) markets, the counterparty in a hedging transaction will worry about credit risk, which increases with the maturity of the contract (Rampini, Sufi, and Viswanathan, 2014). Additionally, firms must be able to cope with margin calls on unrealized losses, which can be substantial for longer-dated contracts (Mello and Parson, 2000). The flexibility hypothesis instead holds that the demand for longer maturities is smaller in firms that can adjust their operating or investment policies at low cost. Accordingly, hedging with longer maturities makes more sense for firms that find it hard or otherwise undesirable to exit its current policies. Finally, the matching hypothesis holds that firms decide on hedging maturity based on the maturity of their debt and investment portfolios. That is, hedging maturity is chosen to match the firm's debt or capex payment schedules to the extent that protecting these expenditures is an important objective of hedging.

We test the hypotheses using hand collected data on quarterly derivative positions in the oil and gas industry between 2013 and 2016. Based on 1230 firm-quarter observations, the average hedging maturity is 0.94 years, or approximately 11 months. 46% of derivative users have at least one derivative contract with a maturity of three years or more, indicating a widespread use of longer maturities. Importantly, we show that hedging maturity is positively correlated with the hedge ratio, defined as the hedged volume, in barrels of oil equivalent, divided by produced volume over a one-year time horizon. That is, if a firm hedges a large part of its exposure (a high hedge ratio), it is also more likely to hedge with a longer maturity. What this finding means is that hedge ratios, which are commonly used in the empirical literature as measures of hedging intensity, are biased downwards. There is clearly a sense in which hedging 70% of the expected production over two years is 'more' risk management than just hedging the same amount for the next year.

The evidence strongly suggests that the hypotheses are descriptive of how firms determine hedging maturity. Hedging maturity is positively related to the two main proxies for collateral, cash and asset tangibility. In our baseline regressions, a one standard deviation increase in these two variables is associated with an increase in hedging maturity of 34 days (20% of its standard deviation or 12% of the median hedging maturity). We also find, consistent with the matching hypothesis, a significant and positive relation between both investment and debt maturities and hedging maturity. A one standard deviation increase in debt maturity is associated with an 11-day increase in hedging maturity, whereas the analogous figure for investment maturity is a 14-day increase. Moreover, hedging maturity decreases with exposure to shale gas activities. This is an inherently flexible business that can be discontinued and restarted within a much shorter time span compared to traditional oil fields, thus providing fewer incentives to hedge with long maturities. A one standard deviation increase in the firm's shale gas activities is associated with a 12-day decrease in hedging maturity.

We also investigate the determinants of hedging maturity considering whether the firm uses options or contracts with a linear payoff (e.g., forwards or futures). The baseline results hold up for linear instruments, but the hypotheses do not explain hedging maturity for option-based strategies to the same extent. This finding is consistent with the collateral hypothesis since linear instruments are those that present the biggest concern about counterparty credit risk. To see why, consider that paying for put options upfront involves no credit risk for the counterparty, whereas unrealized losses on forward contracts do present such an issue, more so than in the case of option-based strategies in which the put options are financed by selling call options.[1] Another line of explanation is that linear instruments are more reliably used for risk management purposes, creating a better fit with the theory, whereas option-based strategies more frequently contain a speculative element (Jankensgård, 2019).

Do the relationships we observe in the data provide evidence of causality? For the collateral hypothesis, we are able to incorporate an exogenous shock in the form of the collapse in the oil price that occurred in late 2014. This collapse, which was unexpected by forward markets and industry analysts, entailed a halving of the oil price within the space

[1] When the put options bought are financed by selling call options in a so-called 'collar strategy', the sold calls do bring attention to credit risk and collateral. However, they do so to a lesser extent than linear instruments because the strike price on the calls will be a different and higher number than the prevailing forward price, which limits the size of the potential losses.

of ten weeks (Dudley et al, 2022). It had the obvious effect of making collateral scarcer and more valuable, because the providers of both debt and derivatives became more concerned about counterparty credit risk, and therefore more likely to require higher collateral than before the shock. According to Rampini et al. (2014), borrowing to fund investment in real assets and hedging are competing uses of scarce collateral, a trade-off that came to a head during this industry crisis. In keeping with this interpretation, the marginal impact of an additional unit of collateral (both cash and asset tangibility) increased post-shock. That is, the effect of collateral on hedging maturity is stronger after the oil price collapse. Without claiming that this empirical approach represents a solid identification strategy, we believe it partially mitigates endogeneity concerns. For the matching hypothesis, causality is a moot point to the extent that the debt and hedging decisions tend to occur simultaneously. Only if the firm sets its policies in a clear sequence in which the debt maturity choice precedes the hedging maturity decision does it make sense to speak of causality. There is not much in the theory, however, to make a strong case for a sequential process. Quite the opposite: banks are known to sometimes lend money only conditional on firms' hedging. According to Bessembinder (1991), one of the ways hedging creates value is indeed by lowering the interest rate required by the lender, and there is a great deal of empirical evidence in this regard (e.g., Campello et al., 2011; Chen and King, 2014). Finally, for the flexibility hypothesis, in contrast, it seems reasonable to argue that this feature is exogenously given by the firm's production technology and not decided on in light of the availability of hedging instruments with certain maturities.

This paper contributes to the literature on corporate risk management by developing hypotheses and providing empirical evidence on a hitherto neglected aspect of the hedging decision. The evidence on hedging maturity is indeed very sparse. It is briefly mentioned in Adam and Fernando (2006), who investigate if the risk premium inherent in forward contracts depends on the hedging horizon. Mello and Parsons (1995) draw some lessons from maturity mismatching in hedging strategies using the case of Metallgesellschaft. The remainder of this paper is as follows. Section 2 discusses the theoretical fundamentals for our hypotheses. Section 3 describes the data and presents our empirical methodology. Section 4 presents our estimations and inferences, and section 5 summarizes our conclusions and final remarks.

2. Hypotheses development

The hedging maturity decision is an integral aspect of a firm's hedging strategy. Basically, given a decision to hedge, it needs to decide on three things. First, how much of the exposure should be covered. Second, which kind of hedging instrument to use. Third, how far out in time the hedging contracts should go. Importantly, the maturity of the derivative contracts partly decides overall hedging intensity. A longer hedging maturity means "more hedging", just like a higher hedge ratio does. As noted earlier, hedging 70% for two years adds up to a heavier usage of derivatives than the same amount of hedging for only one year. However, hedging maturity can also be construed as part of the "how hedge" question. Just like the choice of hedging instrument is an implementation issue once the firm has decided to hedge a certain exposure, so is the choice of hedging maturity.

It is well understood from theoretical work that corporate hedging makes sense when the firm has valuable investment opportunities and external funding is costly (Froot, et al., 1993). Hedging creates value to the extent it reduces the expected costs of various forms of financial distress, pointing to a higher marginal value of hedging in financially weak firms that are closer to distress (Smith and Stulz, 1985). How firms choose between derivatives with a linear payoff and option-based strategies has also been shown to be a function of the firm's financial health (Adam 2002; Adam, 2009; Dudley et al 2022). Options allow firms to coordinate the supply and demand for liquidity across scenarios more efficiently when exposures are non-linear, such as under conditions of financial distress.

Given these arguments, an association between hedging maturity and financial status is to be expected. However, it may not be as straightforward as expecting financially distressed firms to hedge more by extending the maturities of their derivative contracts. In fact, there are reasons to expect the opposite relation due to supply-side concerns. The key is to recognize that hedging needs to be either financed by cash or supported by collateral to mitigate the counterparty's concern about credit risk (Dudley et al, 2022). Both these internal resources are scarce in financially weak firms. Theoretical work has in fact established a convincing *negative* link between financial weakness and hedging intensity. Weaker firms lack the financial resources that would placate concerns about being able to cover losses on the contract, and they are therefore more likely to be denied access to hedging (Mello and Parsons, 2000). Lacking in internal resources could also spell difficulties in coping with margin calls that may occur during the contract's lifetime as unrealized losses accumulate, potentially to the point of causing acute liquidity stress. Credit risk, which is to say the risk of a default on the terms in a financial contract, generally increases with maturity. In line with these arguments, the model of Rampini et (2014) predicts an absence of hedging with longer-dated contracts for collateral-constrained firms. We should therefore expect that the need to support hedging with collateral gets increasingly pressing the further out in time the contract goes.

H1 *Firms supported by more collateral hedge with longer maturities*

The collateral logic need not rule out that some firms extend their hedging maturities in response to a perceived potential for future financial distress. This would tend to happen if the firm's debt instalments and investment needs are skewed towards longer time horizons. That is, if a firm anticipates heavy expenditures beyond a one-year horizon, it could make sense to match those outflows with a hedging programme of similar maturity. This argument is essentially the same as in the model of Froot et al (1993) in which hedging serves to co-ordinate the supply and demand of liquidity, except that we extend the time horizon and allow for differing profiles with respect to the maturity of the firm's cash commitments. All of which leads us to expect longer hedging maturities in firms that have comparatively more cash outflows related to debt and investment occurring further out in time (in other words, those that have longer debt and investment maturities).

H2 *Hedging maturity is positively related to the maturity of cash outflows*

Another consideration that could play into the hedging maturity decision is the degree of flexibility that the firm has to adjust its operating and investment policies at low cost. Having the flexibility to exit a position that has become unattractive is a very general risk management device (Christie et al, 2022). Risk is reduced to the extent company can scale its volume of business activities up or down in response to fluctuations in demand without incurring any substantial adjustment costs, in which case it is said to have a low operating leverage (Mandelker and Rhee, 1984.) Just as with debt obligations, not meeting contractual obligations related to operations amounts to a form of default with potential legal and reputational consequences.

The flexibility to adjust a firm's investment spending is also important to consider. Froot et al (1993) argue that certain investment opportunities become less attractive when the hedgeable risk factor moves in an unfavourable direction. In these cases, firms have a natural hedge in that the demand and supply of liquidity align dynamically, which reduces the need for hedging. These arguments carry over to hedging maturities, as firms endowed with higher degrees of flexibility in terms of adjusting investment spending should find it less attractive to enter derivative contracts with longer maturities. Such firms already have the means to adapt to changing circumstances, which reduces the marginal value of longer-dated hedging contracts that assume a fixed volume of activity.

H3 *Hedging maturity is negatively related to flexibility*

3. Data and Methodology

3.1 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 is high enough to make risk management economically important.

Firms are eligible for inclusion if they are headquartered in the US; publicly listed; and have at least $ 1million in total assets in all quarters. We 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.[2] 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. We restrict the sample to the hedging firm-quarters, because a firm's decision of its hedging maturity is naturally contingent on having decided to hedge its price exposure in the first place.

All financial statement data and industry specific operating data are obtained from Compustat. Our final sample is comprised of an unbalanced panel of 122 unique firms, corresponding to a total of 1,230 firm-quarter observations.

3.2 Empirical methodology

The tests in this paper take the following general form:

$$HM_{i,t} = \alpha + \beta_1 Cash_{i,t} + \beta_2 Tangible\ Assets_{i,t} + \beta_3 Debt\ Maturity_{i,t} + \beta_4 Invest\ Maturity_{i,t} + \beta_5 Invest\ Flexibility_{i,t} + \beta_6 Oper\ Flexibility_{i,t} + \Gamma' Controls_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \qquad (1)$$

In Equation (1), the subscripts *i* and *t* refer to the firm *i* and the quarter *t*, respectively. *HM* is a measure of the hedging maturity of the firm *i* at time *t*. *Cash* and *Tangible Assets* are proxies for the availability of different forms of collateral. *Debt_Maturity* and *Invest_Maturity* are measures of the time profile of the firm's debt and investment spending, respectively. *Invest_Flexibility* and *Oper_Flexibility* are proxies for the flexibility inherent in the firm's investment and operating policies, respectively. *Controls*

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

is a set of control variables from the literature on corporate hedging (debt ratio, investment rate, and firm size). Importantly, we include the hedge ratio in the set of controls, as the test should analyze hedging maturity for any given volume of hedging. As our descriptive statistics will show, the hedge ratio is strongly correlated with hedging maturity. This correlation implies a confounding effect if the hedge ratio is absent from the empirical model. We provide the precise operational definition for all the variables in our next subsection. All the models are estimated with firm fixed effects (μ_i). The use of firm fixed effects alleviates concerns about time-invariant unobserved firm features that drive hedging maturity, such as corporate governance and the quality of risk managers and other time-invariant features. Season quarter fixed effects (δ_t) consider any seasonality that might be present in hedging maturity patterns. Finally, $\varepsilon_{i,t}$ is the error term. The standard errors are robust to heteroskedasticity and clustered at the firm level.

As mentioned earlier, a valid concern about our baseline model described in equation (1) is that the coefficients do not necessarily provide causal relationship effects. While we mitigate most of the omitted variable problems by using firm fixed effects, one could still (correctly) be concerned about simultaneity bias, as it is likely that hedging maturity decisions might affect some of our right hand side variables. We address these concerns in section 4.5 later in the paper.

3.3 Variable construction

Hedging maturity. We calculate the *Hedging maturity* as the weighted average of the firm's reported hedging horizons. We first create weights by dividing the volume hedged with each maturity by the sum of all outstanding contracts. The hedging horizon is then multiplied with the corresponding weight. The years are calendar years expressed in increments of one. For example, in an annual report concerning the fourth quarter of 2014, any contracts maturing during the next 12 months (January through December 2015) would be summed up. Since we cannot perfectly identify the maturity of the contracts, we use the midpoint of each of the maturity ranges reported in the 10-Q. Therefore, we consider the contracts that mature during the next 12 months as a half-year hedging maturity. Contracts maturing between 12 and 24 months out from the balance sheet date are attributed a hedging maturity of 1.5 years, and so on. This way of coding follows from the way derivative contracts are reported in quarterly reports (10-Qs). While some firms do report the exact date that their outstanding contracts mature, most will lump several contracts into aggregates that correspond to a certain time interval in the future, usually based on calendar year.

To exemplify the calculation, consider a firm that reports that it has hedged 2000, 1500, and 1000 barrels of oil equivalent (boe) for the coming year and the two following years, respectively. The total hedged volume would sum to 4500 boe for this firm. Its average hedging maturity would be calculated as 2000/4500 * 0.5 + 1500/4500 * 1.5 + 1000/4500 * 2.5 = 1.27. It is important to distinguish between the average maturity, calculated as above, and the actual maturities of the firm's contracts (0.5, 1.5 and 2.5 in the example). The weighted average collapses all the actual maturities into a summary measure that captures the firm's overall tendency to use longer or shorter hedging maturities.

In the calculations of hedging maturity, we only consider positions that hedge risk exposures, which for the producers in our sample imply forward contracts and bought put options. Consequently, we do not consider options that have been sold to finance these hedging positions since they do not constitute hedging of risk per se (see Dudley et al, 2022, for a detailed analysis of different ways of financing a hedging position). For the same reason, we exclude bought call options since they are likely to be speculative positions rather than hedging).

Linear maturity and *Option maturity*. We repeat some of our tests using measures that describe the average maturity conditional on the type of hedging instrument. Linear hedging instruments are those for which the payoff at maturity is a linear function of the product price being hedged, *i.e.,* forwards, futures, and swaps. Options, in contrast, are characterized by the ultimate payoff being a non-linear function of the underlying product price. For *Linear maturity*, we repeat the same calculation of average maturity, but considering only linear hedging contracts. We calculate *Option maturity* analogously, based only on the option contracts. As done with *Hedging maturity*, we do not consider sold put options or bought calls when calculating the average maturities.

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 (in boe). Natural gas is converted into barrels of oil equivalents using the standard assumption that 6 million cubic feet (Mcf) of gas have the same energy content as 1 barrel (bbl) of oil. Expected production is assumed to be equal to actual production.

Test variables

To test the collateral hypothesis, we use *Cash* and *Asset tangibility*. Cash represents liquid assets that can be used to absorb margin calls related to unrealized losses on derivative contracts (Mello and Parson, 2000) or to cover cash obligations the firm otherwise would have defaulted on. *Cash* is defined as cash and cash equivalents scaled by total assets. Asset tangibility refers to the amount of fixed collateral that can be pledged as collateral in financial contracts. *Asset tangibility* is defined as Plant, Property, and Equipment scaled by total assets.

To test the maturity hypothesis, we create *Debt maturity* and *Investment maturity*. *Debt maturity* is a measure of the time profile of the firm's interest-bearing liabilities and is defined as long-term interest-bearing liabilities scaled by total interest-bearing liabilities.

A higher value thus means that a larger fraction of the firm's liabilities is due later than 12 months from the balance sheet date. Investment maturity is a measure of the time profile of the firm's capital expenditure. *Investment maturity* is equal to Tobin's Q, defined as assets minus book value of equity plus the market value of equity, divided by the book value of assets. A higher value thus means that the firm expects to spend a larger fraction of its capital expenditure further out in time compared to the amount it expects to spend in the near term. Capital expenditure (see below) is one of the control variables, so *Investment maturity* can be argued to capture the weight on future investment spending relative to current spending.

To test the flexibility hypothesis, we create Operating flexibility and Investment Flexibility measures. *Operating flexibility* is the log of the number of times the word 'shale' appears in the firm's quarterly report (10Q). Drilling for shale gas (or shale oil) is an inherently more flexible business activity as it can be discontinued or scaled up on short notice if circumstances change in a material way. Investment flexibility is a measure of the flexibility that exists in the firm's investment program to modify the level of spending at low cost. *Investment flexibility* is defined as the exploration expenses[3] scaled by capital expenditure. Traditional capital expenditure, in contrast, frequently involves a consortium of operators who commit to multi-year and legally binding development projects.

Other variables. We define *Size* as the natural logarithm of the total book value of assets (in $ million). *Capex* is capital expenditures scaled by total assets, while *Total debt ratio* is the ratio of total debt to total assets. *Distance-to-Default* is calculated based on Merton's

[3] The term "exploration" generally refers to the investments aimed at the discovery of new oil and gas deposits, ranging from geological studies of possible carbon deposits to the drilling of exploratory wells, and some of these investments may occur even before obtaining a concession to produce oil in a certain area. Development investments take place after successfully completing the appraisal period, and generally after obtaining a concession from a regulator to a consortium of operators. Regulators normally require that the consortium firmly commits to a development investment schedule. If the firm decides not to pursue the investment schedule (either because it is unable or unwilling to do it), this may result in sanctions from the regulator and reputation damage with the consortium partners. Therefore, this commitment implies little investment flexibility.

distance to default measure, defined as in Badoer et al. (2020). The indicator variable *Post* is meant to capture the period that takes place after the negative shock in oil price and takes the value 1 in Q4 2014 through Q2 2016, and 0 otherwise.

4. Results

4.1 Descriptive statistics

In Table 1 we report the frequencies of the longest hedging horizons associated with each observation. For example, a hedging horizon within the 4th year for a given firm-quarter observation means that the longest contract held by the firm matures within the 4th year.

In 206 of our firm-quarter observations, firms only have derivatives maturing in the year following the balance sheet date, meaning that their hedging horizon is within the 1st year. The most common horizon in the data is the 2nd year, with 454 (almost 37%) of the observations. For horizons longer than that, the number of observations drops by roughly 50% for each additional year. Hedging horizons longer than the 5th year are exceedingly rare and used in only 3.33% of hedging firm-quarters. The longest observed horizon is the 8th year, so the horizons range from the 1st to the 8th year.[4] However, a respectable minority (10.57%) of firms use a horizon within the 5th year or longer. In the last column of Table 1, we compute the weight, in terms of notional value, of the derivatives according to their maturities and average these weights across the observations. While the 2nd year hedging horizon is the most common, the hedged amounts are much larger within the 1st year horizon, as indicated by their respective weights in the average maturity calculation (68.97% vs 22.44%). Derivatives with horizons within the 4th year or longer account for less than 3% of the overall hedge of firms.

[4] The 8-year hedging horizon is observed for Quicksilver Resources in 2013, who reports a contract maturing in 2021. However, the amounts are generally tiny for hedging horizons beyond 5 years. In the case of Quicksilver, the 2021-contract represented less than 1% of the total hedged volume.

[Insert Table 1 about here]

Table 2 reports some descriptive statistics for the average hedging maturity. The figures shown in Panel A indicate that, as noted before, the average hedging maturities are compressed relative to the range of hedging horizons actually observed. This is due to the large weight of short-horizon derivatives. About half of our observations have an average hedging maturity in the 0.5 to 1.0 year range, which reflects the large weight of derivatives maturing in the first year (considered as having 0.5 year maturity in our computation) and the second year (considered as 1.5 years). Still, more than 10% of our observations (133) have an average maturity that is larger than 1.5 years, suggesting substantial variation in the data.

Panel B of Table 2 maps out the mean of *Hedging maturity* for different threshold levels of the hedge ratio. Importantly, firms with high hedge ratios (in the upper tercile) tend to have longer average hedging maturities (1.189 years vs 0.737 for the 1st tercile). This relation is underscored by Figure 1, which plots the relationship between hedging maturity and the hedge ratio. It indicates a robust positive relation between these two variables. The nature of this relation implies that the hedge ratio, which is a widely used proxy for hedging intensity in empirical studies, is generally biased downward as a measure of overall hedging. Put differently, any observed difference between the hedge ratios of two firms will likely understate the true extent to which these firms differ in terms of their overall hedging intensity. To address this bias, future tests of the theories of hedging are best carried out using some composite measure that incorporates both the hedge ratio and hedging maturity aspects.

[Insert Table 2 about here]

[Insert Figure 1 about here]

Figure 2 shows the average hedging maturity along our sample period (between the 1st quarter 2013 and the 2nd quarter of 2016). There is a noticeable decrease following the drop in the oil price that occurred in the last quarter of 2014. This could reflect changes in both supply and demand conditions. The supply of longer dated hedging contracts would decrease to the extent that there was a heightened concern about future credit risk driven by the worsening outlook. Indeed, this evidence is consistent with Almeida et al. (2020), as they show that firms switch from derivatives to purchase obligations during financial distress (Almeida et al., 2017). An alternative explanation is that firms were less inclined to hedge and lock in prices that they considered to be unattractive. We must also consider the possibility that some longer-dated contracts, being in-the-money following the sharp decrease in the oil price, may have been prematurely liquidated by firms that sought to resolve their financial distress.

[Insert Figure 2 about here]

Table 3 reports summary statistics per hedging instrument type and for the combined hedging maturity variable. The mean of *Hedging Maturity* is 0.937, again reflecting the large weight of derivatives with horizons within the first and second years (considered as having maturity of 0.5 and 1.5 years, respectively). Comparing the maturities on linear and option contracts (0.929 *vs* 0.861 years, respectively) we find that they are generally lower for the latter category. We will come back to possible interpretations of this finding in section 4.3.

[Insert Table 3 about here]

Table 4 reports the descriptive statistics for the other variables used in this study. The size distribution and values for the financial variables are similar to those reported in other studies that have used oil and gas companies (see, for example, Bajo et al. 2022). *Operating flexibility* has a median value of 0, indicating that most firms did not engage in shale activities during the investigated period.

[Insert Table 4 about here]

4.2 Baseline results

Table 5 presents the results of our baseline regressions. In all the models, the dependent variable is *Hedging maturity*. Models 1-3 test the hypotheses one at a time, whereas Model 4 contains all three simultaneously, and is our preferred specification.

The results in Table 5 are in line with the predictions of the collateral hypotheses. Both Model 1 and 4 indicate statistical significance for both variables related to collateral, *i.e.*, cash and asset tangibility. The sign is positive in both cases, consistent with the idea that these resources support longer maturities by mitigating credit risk. Taking the coefficients reported in column 4, a 10 percentage points (pp) increase in *Cash* is associated with a 0.055 year (20 days) increase in hedging maturity, whereas a 10 pp increase in

Tangible Assets is associated with a 0.057 year (21 days) increase in hedging maturity, on average.

The findings in Table 5 are also consistent with the matching maturity hypotheses. The specifications reported in columns 2 and 4 of Table 5 indicate clear support for an association between debt maturity and hedging maturity. A one standard deviation change in *Debt Maturity* is associated with a change of 11 days in hedging maturity on average, using the estimate from column 4. We also find that a longer investment maturity leads to hedging with longer maturities, as a one standard deviation change in *Investment Maturity* is associated with a 14-day change in *Hedging Maturity* in the same direction.

Furthermore, we find that *Operational Flexibility* is negatively associated with hedging maturity as expected, although the coefficient is statistically significant only at the 10% level. Finally, we do not find any evidence that *Investment Flexibility* is related to hedging maturity.

As for the control variables, we note that a higher hedge ratio predicts a longer hedging maturity also in the multivariate setting. Firm size does not determine hedging maturity, whereas the debt ratio is negatively related to hedging maturity according to the estimates shown in Table 5. The latter finding indirectly supports the collateral hypothesis, as it can be argued that the debt ratio captures the extent to which collateral has already been pledged to obtain loans and other forms of debt and is thus "used up" (Rampini and Viswanathan, 2013).

[Insert Table 5 about here]

4.3 Hedging maturity per instrument type

In this section we examine whether the determinants of hedging maturity change depending on hedging instrument type. As previously noted, maturities of option-based contracts are on average shorter than the corresponding ones of linear hedging instruments.

We report the results of this investigation in Table 6, Panels A and B. Table 6, Panel A, contains the models in which *Linear Maturity* (i.e., the average hedging maturity of linear contracts) is the dependent variable. Again, we find support across the board for the collateral hypothesis. Importantly, the magnitudes of the coefficients for both *Cash* and *Tangible Assets* are larger, and their statistical significance is stronger than those reported in Table 5. According to the estimates in column 4 of Panel A, a 10 pp increase in *Cash* and *Tangible Assets* is associated to a 29-day and 32-day increase in *Linear Maturity*, respectively. There is also a strong and positive relation of hedging maturity with both *Debt Maturity* and *Investment Maturity*, as was the case when overall hedging maturity was the dependent variable. Finally, we do not find evidence in favour of the flexibility hypotheses in these regressions: while the coefficient of *Operational Flexibility* is negative as expected, it is not statistically significant at the usual levels, and *Investment Flexibility* is not statistically significant either.

The results when *Option maturity* is the dependent (reported in Table 6 – Panel B) are generally weaker. The association with *Debt Maturity* remains significant, again with the expected sign, but the magnitude of the coefficient is approximately half of the analogous coefficient for linear instruments. In contrast to the linear maturity results, *Operational Flexibility* is now statistically significant. As predicted by the flexibility hypothesis, the relationship is negative, as the ability to alter the volume of business according to circumstances at low cost would necessitate less long-term hedging of price exposures that may be very uncertain.

The collateral hypothesis, however, finds very little support in explaining option maturity, as can be seen in Table 6, Panel B. One possible explanation is that longer-dated option-based hedging strategies require less collateral. The most common situation is that put options are financed by selling call options (Dudley et al., 2022), and the strike price on the options sold tend to be higher than the forward rate that prevailed at inception. That is, hedging strategies consisting of bought puts and sold calls in combination come with strike prices that are at some distance from the forward rate. Because of this, option-based strategies hold less potential for large losses and thus represent lower credit risk, which in turn should translate into less importance of collateral.

Another possibility is that linear instruments are more likely to be used for hedging purposes rather than taking an active view on markets for the sake of earning superior profits, or so-called selective hedging (Géczy et al., 2007; Adam et al., 2017; Jankensgård, 2019). According to Dudley et al. (2022), users of the collar strategy are, on average, in better financial condition, which affords them the means to engage in selective hedging without running too high a risk of default. Any such tendency towards selective hedging in these firms could explain the overall weaker ability of the theories used in the present study, and the collateral hypothesis in particular, to predict hedging maturity.

[Insert Table 6 about here]

4.4 Debt maturity and distance-to-default

As previously discussed, there is a tension between the desirability of hedging and firms' ability to execute it as they approach financial distress. A lack of internal resources may prevent firms from accessing hedging and from extending the maturity on whatever hedging contracts they are able to negotiate. The debt maturity hypothesis, however, assumes that firms can freely select the time profile of their hedging portfolio. Considered together, these arguments suggest that we should expect the debt maturity to be more strongly related to hedging maturity for firms that are financially unconstrained. Only then are longer maturities on the table, so to speak, and firms have enough leeway to decide on their maturity profile. Weaker firms, in contrast, are more likely to use their scarce collateral to secure loans for investment in real assets that yield higher returns than financial hedging (Rampini and Viswanathan, 2010). They can therefore be expected to find it more difficult to match their longer-dated loans with hedging contracts of corresponding maturity.

Table 7 bears out the intuition that the matching of debt and hedging maturities should be stronger for financially healthier firms. For this analysis we use *Distance-to-Default* as our measure of a firm's financial condition, where a higher value signals lower default risk and thus a better financial health. In the first regression reported in table 7, we add the interactions of *Debt Maturity* and *Investment Maturity* with the continuous *Distance-to-Default* measure (defined as in Badoer et al., 2020). Consistent with our rationale above, *Hedging Maturity* increases with *Debt Maturity*, and this relationship is stronger for healthier firms, given the positive and significant coefficient for the first interaction term. In the second regression of Table 7, we replace the continuous *Distance-to-Default* measure with a dummy indicating below versus above median, and our inference is maintained. We do not find any evidence that *Distance-to-Default* modulates the relationship between *Hedging Maturity* and *Investment Maturity*, as the coefficients of interaction terms of *Investment Maturity* are statistically insignificant both in columns 1 and 2 of Table 7.

[Insert Table 7 about here]

4.5 The collateral hypothesis and the oil price shock

A valid concern about our baseline results in Table 5 is that the coefficients do not necessarily capture causal relationship effects. Hedging maturity could be endogenously determined, in the sense that hedging maturity is simultaneously determined with some of the independent variables of equation (1) (*i.e.*, the coefficients would suffer from simultaneity bias). In this section, we analyse the causality issue from the perspective of each of our main hypotheses, and address endogeneity for the collateral hypothesis by using an exogenous shock to collateral.

For debt maturity, causality would imply that the decision is sequential and that firms first decide on the structure of their debt and then search out hedging contracts with matching maturities. However, there is plenty to suggest that firms choose the structure of their debt and hedging simultaneously or in the context of each other. In the model of Bessembinder (1991), one of the benefits of credibly committing to hedging is precisely that it allows for better contract terms with creditors. Moreover, creditors are also known to occasionally demand hedging to be put in place before granting a loan. Causality under these circumstances is therefore somewhat of a moot point.[5] It is rather a question of using data to examine whether firms seem to *behave* according to this model. In other words, of documenting whether these mechanisms are strong enough to generate the predicted patterns in the data.

A similar argument can be made for investment maturity, considering that the nature of investment opportunities is what ultimately tends to shape the firm's financial policies (Smith and Watts, 1992). The model in Bessembinder (1991) generates a

[5] In other words, a proper test of causality of the matching hypothesis would require a very unique shock that would exogenously change debt maturity without directly affecting hedging maturity.

mechanism for simultaneity since hedging also improves equity investor's incentive to carry out the project. Along these lines, longer-dated (multi-period) investment projects would be expected to be accompanied by hedging contracts with longer maturities. Again, the emphasis is less on causality and more on investigating what the data has to say about firm behaviour.

For the flexibility hypothesis, a more convincing case can be made for causality. Operating and investment flexibility can be viewed as given by the firm's production technology, which is to say they are features of the technology the firm operates on and the very nature of its business. It would be a stretch to imagine that firms choose their production technology only conditional on, or even considering, the availability of longer-dated hedging contracts. This means that reverse causality (i.e.., *Hedging Maturity* causing *Flexibility* instead of the other way around) is very unlikely.

For the collateral hypothesis, however, an opportunity opens up that allows us to establish a modicum of causality. The opportunity is given by the oil price collapse that occurred in late 2014 when the oil price essentially halved over a time span of only 10 weeks. Our sample period spans the sudden, dramatic, and unexpected decline in the oil price in the last quarter of 2014. This represents an exogenous shock to default risk, which ushered in a state of profound distress in the industry. After fluctuating for a prolonged period at an elevated price level and low levels of implied and realized volatility, the oil price roughly halved within the space of one quarter. 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 2015, the average price was down to $37. While a modest decline appeared prior to Q4 2014, the price decrease accelerated in early October and, in particular, following the OPEC announcement on November 27, 2014, when the organization changed its policy objective from price targeting (abandoning its desired price range) to market-share stabilization. According to

Dudley et al. (2022) the accelerated fall that got underway in October was unforeseen by industry analysts and forward markets. For example, a poll of 30 analysts by Reuters, dated October 1st, predicted a Brent crude price of $103 for 2015. Even as late as October 26, 2014, Goldman Sachs revised their price forecast for Q1 2015 from $100 to $85. In the same week, CIBC World Markets maintained their predicted 2015 Brent average price of $100. Further underscoring the degree to which the collapse was unpredicted by markets, an analysis of net trading patterns in oil futures contracts on NYMEX indicates speculative trading on *increasing* oil prices (Dudley et al., 2022).

The shock implied a deterioration of the financial condition of the entire industry. The ensuing uncertainty, and general scarcity of internal resources, should reinforce the need for solid collateral in the context of achieving hedging with longer maturities. We would therefore expect the role of collateral in determining hedging maturity outcomes to intensify post-shock. To this end, the estimations in Table 8 add the post-shock indicator variable (*Post*, which takes value 1 from Q4 2014 onwards), and its interactions with both variables representing collateral. Columns 1, 2 and 3 of Table 8 show the estimation results for the overall *Hedging Maturity*, *Linear Maturity* and *Option Maturity* as dependent variables respectively.

Confirming the visual impression of a decline in average hedging maturities in Figure 2, the sign of *Post* on Table 8 is negative and statistically significant in the first two estimations. While this is consistent with the view that collateral became sparser, thus triggering an overall decrease in hedging maturities, other explanations cannot be ruled out. For example, in the new environment, locking in the now-lower prices through longer-dated contracts would have appeared unattractive to managers who counted on the collapse to be temporary.

More interesting for our purposes is the fact that the interactions *Cash* × *Post* and *Tangible Assets* × *Post* in Model 1 between the post-shock variable and the collateral-variables are significant and have the expected sign (positive). According to these results, the importance of cash and intangible assets in supporting longer hedging maturities does increase after the price collapse. While this does not establish definitive evidence of causality, the results are suggestive of a deciding influence on hedging maturities from the availability of collateral.

Table 8 also contains the results from the corresponding analysis when Linear Maturity and Option maturity are the dependent variables (Models 2 and 3). Again, we find a close correspondence between the results for *Hedging maturity* and *Linear maturity*, for which our conjecture holds. The effect of additional collateral on maturity is amplified in both cases. The inability of the theories to predict *Option maturity* could be put down to the stronger speculative element in option-based strategies discussed earlier, but this explanation needs further scrutiny.

[Insert Table 8 about here]

4.6 Further robustness tests

In this section we continue to explore the robustness of our results. We start by re-estimating our baseline regressions previously reported in Table 5, but replacing season-quarter fixed effects with year-quarter fixed effects, as one might be concerned that macroeconomic variations could be driving the results. The coefficients of interest, reported in Table 9, are only slightly changed in comparison to the baseline results, and our main inferences are maintained.

[Insert Table 9 about here]

[Insert Table 10 about here]

In the estimations of Table 10 we change the proxies used for *Investment maturity* and *Operational flexibility* in the regressions reported in columns 1 and 2, respectively. The first is replaced with a measure of the undeveloped oil reserves in relation to developed reserves on the view that firms with a greater share of undeveloped reserves face comparatively higher investment expenditures in the future.[6] In the second, we replace the mentions to the word "shale" with the mention to the word "fracturing" or "fracking", as the fracturing technology also allows greater production flexibility. Finally, the estimation reported in column 3 of table 10 replaces the dependent variable *Hedging maturity* with a dummy variable *Maturity_over5* that is equal to one if the longest hedging horizon of the firm is equal or more than 5 years, and 0 otherwise. Although the statistical significance of the coefficients is smaller in some cases, overall, the main inferences drawn from our baseline results are maintained.

5. Conclusions

In this study we theorize the maturity of firms' hedging portfolios and examine its determinants empirically. Hedging maturity is the third main characteristic of a hedging strategy, alongside the fraction hedged and the type of instrument used. Yet, hedging maturity has not been comprehensively investigated in the literature so far.

We develop three hypotheses to guide our empirical tests. The collateral hypothesis states that longer-dated hedging contracts are conditional on the availability of enough internal resources that can be pledged as collateral to mitigate concerns about credit risk. The matching hypothesis holds that firms choose hedging maturity so as to match hedging payoffs with the time horizon of its debt and capital expenditures. Lastly, the flexibility

[6] Undeveloped reserves require long term investments like the drilling of new wells and the investment in new oil rigs, which take longer than investments in developed reserves.

hypothesis holds that the ability to change operating and investment policies at low cost makes it less attractive to hedge with longer maturities that assume the volume of business to be fixed.

Using detailed and hand-collected data on derivative portfolios we find support for all three hypotheses. The maturity of the firm's debt portfolio reliably predicts hedging maturity, as does exposure to shale, a business that is inherently more flexible and short-term by nature than traditional oil field development. The most robust support, however, is for the collateral hypothesis. Both cash and intangible assets are positively related to the length of the hedging horizon as predicted by the hypothesis. What is more, the importance of these variables only intensified when the industry entered a period of financial distress and general scarcity of collateral following the collapse of the oil price in late 2014. We also document a strong and economically important positive relation between the hedge ratio and hedging maturity.

We conclude that hedging maturity behaves in predictable ways according to economic theories. The collateral, maturity, and flexibility hypotheses are all supported by the data. Another important conclusion to follow from our analysis is that the hedge ratio, given its strong positive correlation with hedging maturity, has a downward bias as an indicator of overall hedging intensity. This suggests that empirical measures of hedging should consider hedging maturity alongside the proportion of the risk factor being hedged. It would be interesting to see future studies that combine both aspects into a comprehensive measure of overall hedging activity. Future theoretical work could also elaborate more on the precise determinants of the optimal hedging maturity.

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Figure 1– Hedging maturity and Hedge ratio

This graph shows the relationships between *Hedging maturity* (horizontal axis) and *Hedge ratio* (vertical axis) in the sample period (2013Q1-2016Q2). For each firm-quarter, we compute *Hedging maturity* as the weighted average of the firm's hedging horizons, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q. *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).

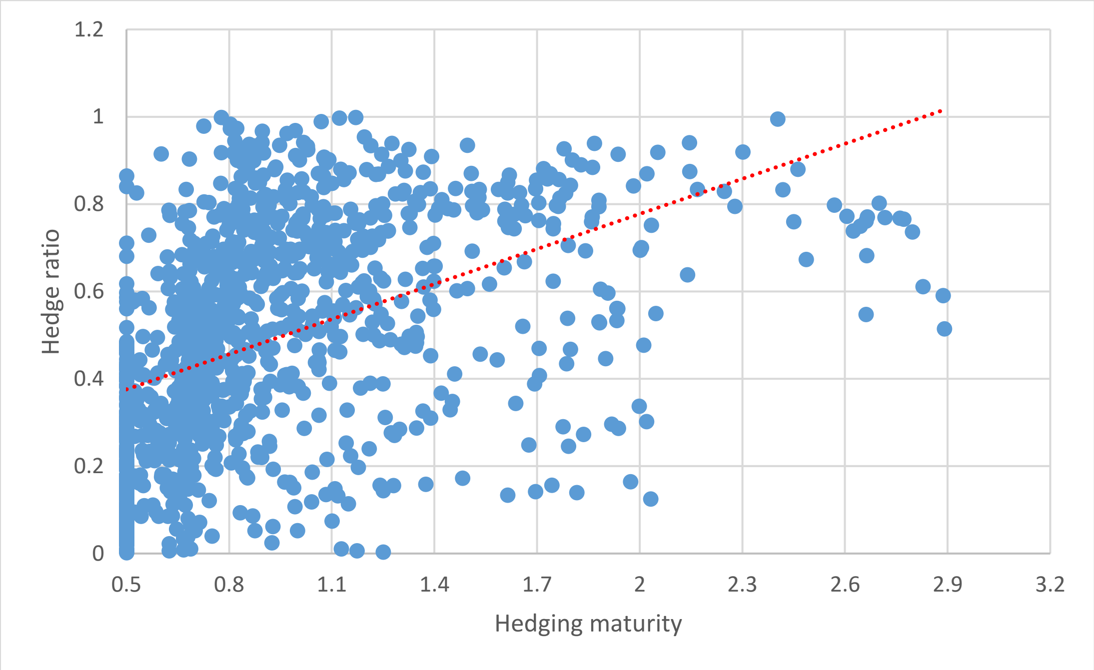

Figure 2 - Hedging maturity over time

This graph shows the average and the median *Hedging maturity* over time (sample period: 2013Q1-2016Q2). *Hedging maturity* is calculated as the weighted average of the firm's hedging horizons, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q.

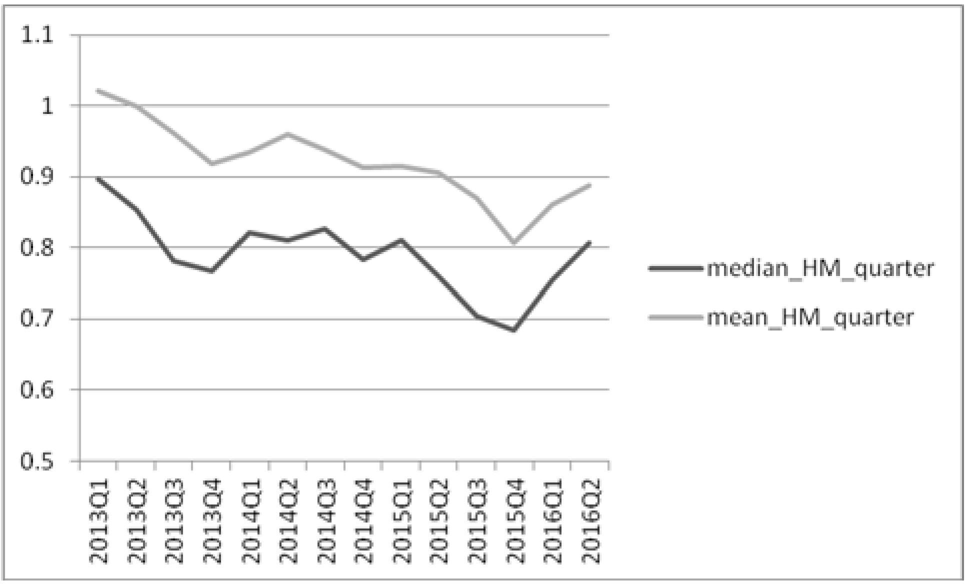

Table 1 – Hedging horizons

This table provides an overview of the hedging horizons associated to our sample firms. The first column denotes the horizon of the firm's derivative position (up to the Nth year) as reported in the 10-Q. *Longest hedge horizon (N. obs)* is the number of firm-quarter observations for which the longest maturity of the derivative position is the nth year. *At least M_ years of hedge horizon* (*N. obs)* reports the number of firm-quarter observations where the maturity of the derivative position is at least up to the nth year. *At least M_ years of hedge horizon* (% *Obs)* reports the frequency of firm-quarter observations where the maturity of the derivative position is at least up to the nth year. *% Average maturity weight* reports the weight of the derivative position in terms of notional value according to their maturities.

	Longest hedge horizon (N. obs)	**At least M_ years of hedge horizon (N. Obs)**	**At least M_ years of hedge horizon (% Obs)**	**Average maturity weight (%)**
1st year	206	1230	100	68.97
2nd year	454	1024	83.25	22.44
3rd year	314	570	46.34	5.75
4th year	126	256	20.81	1.99
5th year	89	130	10.57	0.60
6th year	25	41	3.33	0.16
7th year	10	16	1.30	0.07
8th year	6	6	0.49	0.02

Table 2 – Hedging maturities

This table provides an overview of the hedging maturities associated to our sample firms. *Hedging maturity* is calculated as the weighted average of the firm's hedging horizons, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q. *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 (in barrels of oil equivalent).

Panel A		
Hedging maturity (years)	**N. obs**	**% N. obs**
<= 0.5	206	16.75
0.5 - 1	653	53.09
1 - 1.5	256	20.81
> 1.5	133	10.81

Panel B			
Hedge ratio (terciles)	**Hedge ratio thresholds**	**Hedging maturity (mean)**	**Difference in maturity 1st - 3rd Tercile**
1st Tercile	<= 0.3256	0.7374	
2nd Tercile	0.3259 - 0.6246	0.8839	
3rd Tercile	>= 0.6247	1.1894	
			-0.4520 ***

Table 3 – Summary statistics – Hedging maturity (overall and by instrument)

This table reports summary statistics for the hedging maturity variables used in the study. These statistics are based on the same sample described in tables 1 and 2 and are used in the regression analyses. *Hedging maturity* is calculated as the weighted average of the firm's hedging horizons, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q. *Linear maturity* and *Option maturity* is the average weighted maturity calculated only for linear hedging contracts and put options contracts, respectively.

	N.obs	**Mean**	**p25**	**p50**	**p75**	**Sd**
Hedging maturity	1230	0.9369	0.6316	0.8113	1.0963	0.4539
Linear maturity	1097	0.9286	0.5743	0.7769	1.1077	0.4799
Option maturity	841	0.8610	0.5	0.7596	1.0265	0.3835

Table 4– Summary statistics – Independent variables

This table reports summary statistics for variables used in the study. These statistics are based on the data included in the regression analysis. *Cash* is defined as cash and cash equivalents scaled by total assets. *Asset tangibility* is defined as plant, property, and equipment scaled by total assets. *Debt maturity* is defined as long-term interest-bearing liabilities scaled by total interest-bearing liabilities. *Investment maturity* is equal to Tobin's Q, defined as assets minus book value of equity plus the market value of equity, divided by the book value of assets. *Operating flexibility* is the log of the number of times the word 'shale' appears in the firm's quarterly report (10Q). *Investment flexibility* is defined as the exploration expenses scaled by capital expenditures. *Size* is the natural logarithm of the total book of assets. *Capex* is capital expenditures scaled by total assets. *Total debt ratio* is the ratio of total debt to total assets. *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). All variables are winsorized at the 1% level.

	N. obs	Mean	p25	p50	p75	Sd
Variables of interest						
Cash	1230	0.0406	0.0024	0.0132	0.0534	0.0629
Asset tangibility	1230	0.8291	0.7780	0.8544	0.9094	0.1046
Debt maturity	1230	0.8458	0.9961	1	1	1.4156
Investment maturity	1230	1.3950	1.0292	1.2579	1.6383	0.5446
Operating flexibility	1230	1.0432	0	0	1.9459	1.3082
Investment flexibility	1230	0.0311	0	0	0.0114	0.1684
Control variables						
Size	1230	7.5813	6.6711	7.7262	8.6667	1.6608
Capex	1230	0.0600	0.0276	0.0478	0.0714	0.0581
Total debt ratio	1230	0.4348	0.2748	0.3948	0.5112	0.2579
Hedge ratio	1230	0.47062	0.2355	0.4718	0.7004	0.2893

Table 5 – Hedging maturity and collateral, matching maturity and flexibility hypotheses

This table reports the coefficients of unbalanced panel estimations of equation (1). Models (1)-(2)-(3) report our findings for each hypothesis separately (collateral, matching maturity and flexibility hypotheses, respectively). Model (4) reports our findings for the three hypotheses together. The dependent variable, *Hedging maturity* is calculated as the weighted average of the firm's hedging horizons, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q. *Cash* is defined as cash and cash equivalents scaled by total assets. *Asset tangibility* is defined as plant, property, and equipment scaled by total assets. *Debt maturity* is defined as long-term interest-bearing liabilities scaled by total interest-bearing liabilities. *Investment maturity* is equal to Tobin's Q, defined as assets minus book value of equity plus the market value of equity, divided by the book value of assets. *Operating flexibility* is the log of the number of times the word 'shale' appears in the firm's quarterly report (10Q). *Investment flexibility* is defined as the exploration expenses scaled by capital expenditures. *Size* is the natural logarithm of the total book of assets. *Capex* is capital expenditures scaled by total assets. *Total debt ratio* is the ratio of total debt to total assets. *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). All variables are winsorized at the 1% level. All our specifications include firm and quarter fixed effects. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

	(1)	(2)	(3)	(4)
Variables of interest				
Cash	0.6406**			0.5507**
	(0.301)			*(0.251)*
Asset tangibility	0.5821**			0.5703**
	(0.250)			*(0.248)*
Debt maturity		0.0211**		0.0211**
		(0.009)		*(0.009)*
Investment maturity		0.0690**		0.0697**
		(0.030)		*(0.028)*
Operating flexibility			-0.0190	-0.0244*
			(0.013)	*(0.013)*
Investment flexibility			-0.0163	0.0043
			(0.051)	*(0.053)*
Control variables				
Size	-0.0357	-0.0210	-0.0382	-0.0204
	(0.051)	*(0.047)*	*(0.052)*	*(0.044)*
Capex	0.2948**	0.1974*	0.3305***	0.1694
	(0.122)	*(0.101)*	*(0.120)*	*(0.107)*
Total debt ratio	-0.1638**	-0.2241***	-0.2074**	-0.1563**
	(0.078)	*(0.083)*	*(0.081)*	*(0.077)*
Hedge ratio	0.1103*	0.1235**	0.1135*	0.1199**
	(0.062)	*(0.059)*	*(0.062)*	*(0.057)*
Constant	0.7149	1.0207***	1.2763***	0.5202
	(0.461)	*(0.388)*	*(0.413)*	*(0.406)*
Observations	1,230	1,230	1,230	1,230
R-squared	0.100	0.110	0.086	0.132
Firm FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm	Firm

Table 6 – Hedging maturity and collateral, matching maturity and flexibility hypotheses (per instrument type)

This table reports the coefficients of unbalanced panel regressions of *Linear maturity* (Panel A) and *Option maturity* (Panel B). Models (1)-(2)-(3) report our findings for each hypothesis separately (collateral, matching maturity and flexibility hypotheses, respectively). Model (4) reports our findings for the three hypotheses together. *Linear maturity* and *Option maturity* are calculated as the weighted average of the firm's hedging horizons for linear and put option contracts, respectively, where each hedging horizon is multiplied by the volume hedged in each maturity over the total hedged volume. To identify the firm's hedging horizons, we use the midpoint of each of the maturity horizon reported in the 10-Q. The dependent variables are defined as in Table 5. All variables are winsorized at 1% level. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

Panel A – Linear contracts

	(1)	(2)	(3)	(4)
Variables of interest				
Cash	0.9841**			0.7985**
	(0.376)			*(0.313)*
Asset tangibility	0.8770***			0.8659***
	(0.303)			*(0.295)*
Debt maturity		0.0313***		0.0315***
		(0.010)		*(0.009)*
Investment maturity		0.1190***		0.1140***
		(0.038)		*(0.038)*
Operating flexibility			0.0009	-0.0077
			(0.016)	*(0.019)*
Investment flexibility			-0.0028	0.0331
			(0.048)	*(0.048)*
Control variables				
Size	-0.0375	-0.0204	-0.0441	-0.0199
	(0.061)	*(0.055)*	*(0.064)*	*(0.049)*
Capex	0.3396**	0.2179*	0.3988**	0.1658
	(0.150)	*(0.130)*	*(0.155)*	*(0.135)*
Total debt ratio	-0.1737	-0.2752**	-0.2640**	-0.1809*
	(0.111)	*(0.113)*	*(0.115)*	*(0.107)*
Hedge ratio	-0.0070	0.0275	0.0030	0.0182
	(0.088)	*(0.084)*	*(0.090)*	*(0.082)*
Constant	0.5352	1.0085**	1.3800**	0.2367
	(0.543)	*(0.463)*	*(0.541)*	*(0.462)*
Observations	1,097	1,097	1,097	1,097
R-squared	0.076	0.088	0.049	0.113
Firm FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm	Firm

Panel B – Option contracts

	(1)	(2)	(3)	(4)
Variables of interest				
Cash	0.2176			0.3001
	(0.471)			*(0.483)*
Asset tangibility	0.5874			0.5861
	(0.496)			*(0.487)*
Debt maturity		0.0165***		0.0164**
		(0.006)		*(0.007)*
Investment maturity		0.0179		0.0332
		(0.049)		*(0.051)*
Operating flexibility			-0.0476**	-0.0489**
			(0.022)	*(0.022)*
Investment flexibility			-0.0736	-0.0869
			(0.076)	*(0.075)*
Control variables				
Size	-0.0720	-0.0528	-0.0638	-0.0606
	(0.087)	*(0.095)*	*(0.090)*	*(0.091)*
Capex	0.1524	0.1381	0.1875	0.0703
	(0.221)	*(0.191)*	*(0.199)*	*(0.208)*
Total debt ratio	-0.2729*	-0.3461**	-0.3266**	-0.2496*
	(0.143)	*(0.144)*	*(0.137)*	*(0.138)*
Hedge ratio	0.0643	0.0592	0.0537	0.0566
	(0.125)	*(0.121)*	*(0.126)*	*(0.122)*
Constant	0.9982	1.3442*	1.5104**	0.8975
	(0.877)	*(0.748)*	*(0.689)*	*(0.884)*
Observations	841	841	841	841
R-squared	0.078	0.074	0.087	0.102
Firm FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm	Firm

Table 7 – Matching maturity hypothesis and financial distress

This table reports the coefficients of unbalanced panel regressions of *Hedging maturity* on proxies for the matching maturity hypothesis conditional on the firm financial distress. *Hedging maturity* is defined as in Table 5. *Distance-to-Default* is defined as in Badoer et al. (2020) and is a measure of the firm's financial condition. *Distance-to-Default_median* is a dummy equal to one if the measure of the firm's *Distance-to-Default* is higher than the sample median. All the other variables are defined as in Table 5. Controls (coefficients unreported) are *Size*, *Capex*, *Total debt ratio* and *Hedge ratio*. All our specifications include firm and quarter fixed effects. All variables are winsorized at the 1% level. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

	(1)	(2)
Debt maturity	0.0615***	0.0289**
	(0.007)	*(0.015)*
Investment maturity	0.0033	0.0311
	(0.040)	*(0.046)*
Distance-to-Default	-0.0038	
	(0.008)	
Distance-to-Default*Debt_maturity	0.0178***	
	(0.004)	
Distance-to-Default*Inv_maturity	-0.0023	
	(0.003)	
Distance-to-Default_median*Debt_maturity		0.1902**
		(0.093)
Distance-to-Default_median*Inv_maturity		-0.0143
		(0.042)
Constant	0.8991**	0.7539*
	(0.407)	*(0.420)*
Observations	1,111	1,111
R-squared	0.127	0.101
Controls	Yes	Yes
Firm FE	Yes	Yes
Quarter FE	Yes	Yes
SE clustering	Firm	Firm

Table 8 – The collateral hypothesis and the oil price shock

This table reports the coefficients of unbalanced panel regressions of *Hedging maturity* (Model 1), *Linear maturity* (Model 2) *and Option maturity* (Model 3), which are calculated as defined in Table 5, Table 6 (panel A) and Table 6 (panel B), respectively. *Post* is a dummy equal to 1 from 2014Q2 onwards. The dependent variables are defined as in Table 5. Controls (coefficients unreported) are *Size*, *Capex*, *Total debt ratio* and *Hedge ratio*. All our specifications include firm and quarter fixed effects. All variables are winsorized at 1% level. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

	(1)	(2)	(3)
Cash	0.0380	0.2190	-0.3235
	(0.419)	*(0.510)*	*(0.516)*
Asset tangibility	0.1324	0.3028	0.2686
	(0.299)	*(0.327)*	*(0.586)*
Post	-0.5867**	-0.7334***	-0.3353
	(0.247)	*(0.257)*	*(0.413)*
Post*Cash	0.8402*	1.0487*	0.5126
	(0.472)	*(0.543)*	*(0.662)*
Post*Asset tangibility	0.5636**	0.6963**	0.2211
	(0.275)	*(0.288)*	*(0.456)*
Constant	0.9109*	0.7718	0.9575
	(0.529)	*(0.606)*	*(0.907)*
Observations	1,230	1,097	841
R-squared	0.140	0.123	0.116
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm

Table 9 – Hedging maturity and collateral, matching maturity and flexibility hypotheses – Quarter-Year fixed effects

This table reports the coefficients of unbalanced panel regressions of *Hedging maturity* on proxies for the collateral, matching maturity and flexibility hypotheses adding quarter-year fixed effects. Specifically, Model (1)-(2)-(3)-(4) replicate the models reported in Table 5 but replacing quarter fixed effects with quarter-year fixed effects. All the variables are defined as in Table 5. Controls (coefficients unreported) are *Size*, *Capex*, *Total debt ratio* and *Hedge ratio*. All our specifications include firm fixed effects. All variables are winsorized at 1% level. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

	(1)	(2)	(3)	(4)
Cash	0.6613**			0.6424**
	(0.310)			*(0.262)*
Asset tangibility	0.5998**			0.6174**
	(0.257)			*(0.257)*
Debt maturity		0.0217***		0.0205**
		(0.008)		*(0.008)*
Investment maturity		0.0294		0.0412
		(0.037)		*(0.032)*
Operating flexibility			-0.0230*	-0.0264*
			(0.013)	*(0.014)*
Investment flexibility			-0.0228	-0.0016
			(0.063)	*(0.064)*
Constant	0.1490	0.6446	0.7143*	0.0830
	(0.489)	*(0.435)*	*(0.423)*	*(0.472)*
Observations	1,230	1,230	1,230	1,230
R-squared	0.184	0.182	0.172	0.206
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Quarter*year FE	Yes	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm	Firm

Table 10 – Hedging maturity and collateral, matching maturity and flexibility hypotheses – Further robustness tests

This table reports the coefficients of unbalanced panel estimations of equation (1). Specifically, Model (1) replaces *Investment maturity* with *Investment maturity_2*, which is the ratio of undeveloped oil reserves to developed reserves. Model (2) replaces *Operating flexibility* with *Operating flexibility_2*, which is the log of the number of times the word "fracturing" or "fracking" appears in the firm's quarterly report (10Q). Model (3) reports the marginal effects of probit estimation where the dependent variable is *Maturity_over5*. *Maturity_over5* is a dummy that is equal to 1 if the longest hedging horizon of the firm is equal or more than 5 years. All the remaining variables are defined as in Table 5. Controls (coefficients unreported) are *Size*, *Capex*, *Total debt ratio* and *Hedge ratio*. All variables are winsorized at 1% level. Standard errors are in parentheses and are clustered at firm level. ***, ** and * denote significance at the 1, 5, and 10% level, respectively.

	(1)	(2)	(3)
Cash	0.5452*	0.5166**	0.3681
	(0.289)	*(0.244)*	*(0.2030)**
Asset tangibility	0.5744**	0.5656**	0.2630
	(0.288)	*(0.246)*	*(0.2025)*
Debt maturity	0.0115*	0.0184**	0.0693
	(0.006)	*(0.007)*	*(0.0371)**
Investment maturity		0.0696**	0.0183
		(0.030)	*(0.0166)*
Investment_flexibility	-0.0092	0.0063	-0.1782
	(0.041)	*(0.052)*	*(0.0602)****
Operating flexibility_2		-0.0504*	
		(0.027)	
Investment maturity_2	0.3484***		
	(0.120)		
Operating flexibility	-0.0179		-0.0064
	(0.011)		*(0.0100)*
Constant	0.9303**	0.5536	
	(0.434)	*(0.406)*	
Observations	1,142	1,230	1,230
R-squared (Pseudo R-squared)	0.140	0.138	(0.139)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm