Relaxing Constraints on Risk Management:

Evidence from a Natural Experiment

Sabrina T. Howell*†

December 11, 2015

Abstract

Should government provide risk management services? I exploit a natural experiment in which the government fully insures highway paving firms against oil price risk. The data permit the first firm-level study of risk management among private firms. Surprisingly, the risk shifting policy reduces costs. Capital requirements and financial frictions prevent firms from accessing derivative markets. I show that private firms value hedging more than public firms, but that family owned firms are no more risk averse than non-family owned firms. I find that the cost of managing risk is especially high for high credit risk and undiversified firms. My results are consistent with financial constraints and distress costs leading firms to value hedging.

Click Here for Latest Version and Appendix.

JEL codes: G13, G14, G38, G32, Q47

*New York University. Contact: sabrina.howell@nyu.edu.

†I am grateful to Viral Acharya, Joe Aldy, John Campbell, Raj Chetty, Steve Figlewski, Xavier Gabaix, Stefano Giglio, Gary Gorton, Ryan Kellogg, Josh Lerner, Jonathan Levin, Greg Lewis, Holger Mueller, Ramana Nanda, Ariel Pakes, Robert Pindyck, Adriano Rampini, David Scharfstein, Johannes Stroebel, Tom Wollman, Kenny Tang, David Yermack, and the Harvard Finance and IO lunch communities. I also thank the Iowa and Kansas Departments of Transportation, in particular Steven Belzung, Roger Bierbaum, LouAnn Hughes, Kevin Martin, Abe Rezayazdi, Greg Sheiber, and Sandy Tommer for their extensive support. This project was funded by a National Science Foundation Graduate Research Fellowship.

1 Introduction

There are strong theoretical predictions about how private and family owned firms manage risk. However, it has been challenging to find data on private firm risk management. This paper exploits a natural experiment that permits me to measure the willingness to pay for insurance, and to conduct the first comparison of the value of risk management across public, private, and family ownership.

The highway procurement context is useful because (a) firms take on oil price risk between the auction and the start of work, and (b) highway demand is plausibly exogenous to oil prices.[1] Kansas shifted oil price risk in highway procurement from the private sector to the state in 2006. Its Department of Transportation implemented the policy because, according to the Operations Director, "The volatile price of the asphalt oil has led contractors to make bids that are more costly than necessary" (Shaad 2006). After the policy, the state hedged firms for free using a price index. Nearby Iowa has never implemented such a policy.

I use a difference-in-differences (DD) design to assess the value to firms of relaxing constraints on risk management. I analyze bids to pave asphalt ("blacktop") roads with detailed procurement auction data from Iowa and Kansas between 1998 and 2012. Asphalt's primary component is bitumen, an oil product. Private firms dominate the sample, and a majority of them are family-owned. These firm types are economically important; private firms account for 99.9% of U.S. firms, and family-owned firms account for over 60% of U.S. GDP and employment (Asker, Farre-Mensa, and Ljungqvist 2014, Schulze et al. 2001, Astrachan and Shanker 2003). The firms in my data also range in size and industry diversification.

The balance of evidence indicates that the risk premium for holding crude oil futures should be quite small.[2] If firms can efficiently hedge in derivatives markets, Kansas' policy should have had little effect. Further, during the period studied oil prices increased on average between the auction and work start, so the policy should have increased procurement

[1]The industry is not small; of the roughly $150 billion that the U.S. spends annually on public highway construction and maintenance, about 85% is for asphalt roads (CBO 2011).

[2]See Section 2.2 for discussion.

costs if firms were risk-neutral. Instead, I find that the policy reduced Kansas' average bitumen cost by 9% and increased competition. The policy also increased the probability of winning for private and undiversified firms at the expense of, respectively, public and diversified firms.

I modulate the DD with oil price volatility to show that fully hedged firm bids are less sensitive to risk. A 100% increase in historical volatility after the policy makes bitumen bids in Iowa 14% higher than in Kansas, relative to their pre-policy difference. This estimate is robust to a litany of tests, including placebo, falsification with non-oil bid items, and alternative volatility metrics. The result translates to a 4.2% average cost of risk management.

I use two methods to address heterogeneity. First, I split the sample using the volatility-modulated DD. Second, I measure risk as the hedge period interacted with oil price volatility, excluding post-policy Kansas. For example, when the project starts the month after the auction, there is little risk regardless of recent volatility. I show that private firms have a higher cost of managing risk than public firms, and this difference is robust to excluding high credit risk and small private firms. The sharpest difference is across credit risk, with the cost at 5.9% for high risk firms and 3.1% for low risk firms, but the difference is similar in magnitude across industry diversification and and size. In particular, single-location firms have a much higher cost than multiple-location firms. Family-owned firms do not have a statistically different higher cost than non family-owned firms.

My results are consistent with theories in which financial constraints and distress costs lead firms to value hedging (Froot, Scharfstein and Stein 1993, Bolton, Chen and Wang and Smith 2011, Purnanandam 2008). I do not find evidence that concentration of ownership or owner-managers lead firms to manage risk in order to smooth personal income (Schulze et al. 2001, Fama and Jensen 1983).

The firms in my data typically fully hedge by purchasing physical forward contracts from local suppliers at the time of the auction. End-user hedging through such fixed-price contracts with distributors or merchandisers is common in many industries, including agriculture, electric utilities, and airlines. After the policy, firms bidding in an auction in Kansas choose whether or not to take the policy. If they do, payments to the winner are adjusted to account for changes in a regional bitumen price index. With only a few exceptions, all bids have opted for the policy. In accepting the index, firms take on basis risk between the actual price and the regional, survey-based index. If the cost of the forward and the index were equal, firms should choose the forward because it is a perfect hedge. However, they choose the index, which is free. Therefore the cost of the forward must exceed the cost of basis risk in the index. Further, firms' revealed preference indicates that hedging in financial markets is more expensive than the forwards and the index.

High capital requirements, basis risk, economies of scale, and daily marking to market are barriers to hedging with derivatives. The same firm attributes that make hedging valuable also make borrowing expensive. Rampini and Viswanathan (2010, 2013) propose that constrained firms hedge less [*in financial markets*] because they have a high opportunity cost of capital. My setting is consistent with their theory, but the bracketed modifier is crucial. Firms continue to hedge, but choose forwards - which are more expensive but require no cash up front - over financial derivative hedging. Similarly, Bolton et al. (2011) theorize that firms manage risk with cash when the the capital intensity of derivative hedging increases.

Imperfect competition is a central feature of highway procurement. Evidence from one firm's forward contracts and a phone survey of bidders suggests that monopolistic counterparties (the upstream market) can charge just less than the firm's cost of hedging in financial markets. Imperfect competition and financial frictions impede efficient allocation of risk, allowing firms to pass high and heterogeneous insurance premiums to the consumer. Relatedly, Scharfstein and Sunderam (2013) find that imperfect competition in mortgage lending decreases the pass-through of lower mortgage-backed security yields to mortgage rates, vitiating government policies aimed at home buyers. Even more broadly, my results are relevant to settings where there is a question of which party in a transaction should bear risk. For example, the Basil Committee on Banking Supervision is currently considering capital requirements for bank interest rate risk (BIS 2015). Banks can issue fixed rate instruments (like mortgages) and hedge the risk in derivative markets, but if they are face surcharges for their own hedging activities, they are more likely to forego fixed rate instruments, forcing the customer - who is likely more risk averse - to bear the risk.

There are three possible channels for heterogeneous risk management costs: (1) effective risk aversion, (2) cost of capital, or (3) risk-varying bargaining power. In the Froot et al. (1993) framework, (1) and (2) are effectively two sides of the same coin, because high external finance costs drive risk aversion. My evidence favors (1), but I cannot affirmatively identify the channel. However, the policy implications are independent of the channel: the cost of managing risk varies by firm type and aggregation by the state is more efficient.

Kansas saved around $77 million in the 6.5 years after the policy. In a hypothetical margin account calculation, I show that the cost to the state of hedging using oil futures, since it can borrow at about 1%, is effectively zero. Meanwhile, the cost of capital for the firm must be about 30% to equate the per-ton cost of an average initial margin account with the estimated cost of risk management. My results suggest that it may be more efficient to reassign risk in a given product market relationship to the party with the lowest cost of managing it. Murfin and Njoroge (2014) make a similar point on the costs for small, constrained suppliers of providing trade credit to much larger customers.

Empirical work on risk management is mixed. Carter, Rogers and Simkins (2006), Allayannis and Weston (2001), and Nance, Smith and Smithson (1993) find a positive association between risk management and firm value, while Brown, Crabb and Haushalter (2006) and Jin and Jorion (2006) do not. This paper is broadly consistent with Mackay and Moeller (2007) and Acharya, Lochstoer and Ramadorai (2013), which are part of a body of work asserting that public firms manage risk to reduce cash flow volatility (Smithson and Simkins 2005).[3] However, Guay and Kothari (2003) argue that in general the magnitude of

[3]Mackay and Moeller (2007) find that the value of oil price risk management among oil refiners rises with firm energy intensity. Since they do not observe hedging behavior, they derive the value of hedging by estimating production functions. Acharya, Lochstoer and Ramadorai (2013) propose that end users may have limited ability to hedge because of counterparty (speculator) capital constraints, and show empirically

corporate derivative use is too small to affect firm value.

Vickery (2008) and Géczy, Minton and Schrand (1997) find a positive relationship between measures of financial constraints and hedging. Panousi and Papanikolaou (2012) and Tufano (1996) demonstrate a positive correlation between manager ownership and effective risk aversion, and Campello et al. (2011) associate derivative use with reduced borrowing costs. Yet Rampini, Sufi, and Viswanathan (2014) find that more constrained firms hedge less, and Stulz (1996) finds that larger firms hedge more.

The quasi-experiment in my setting is useful because it permits a causal interpretation of the value of risk management. Additionally, this paper seeks to address five gaps in the empirical literature. First, existing work almost exclusively addresses public firms. An exception is Cornaggia (2013), who finds a positive association between an insurance policy and farm yields. His analysis is at the county level while mine is at the firm level. The literature on private firm financial constraints is also small (e.g. Saunders and Steffen 2011, Howell 2015).

Second, most studies measure hedging with derivative use. Chen and Xiong (2014) show that derivative trading is conflated with speculation among commercial hedgers. An exception is the literature on liquidity and distress costs (Acharya, Almeida and Campello 2013, Acharya, Davydenko and Strebulaev 2012). Third, it is challenging to identify data sources that are not cross-sectional or survey-based. Fourth, the risk studied can be correlated with other determinants of firm value, especially demand. Fifth, the hedging decision is endogenous to firm value. An exception here is Pérez-González and Yun (2013), who examine electric utilities' response to the introduction of weather derivatives.

Despite its advantages along these dimensions, my setting has important limitations. In the primary analysis I do not observe hedging directly, so I cannot distinguish between hedging efficiency and risk aversion. I also do not quantify the effect of hedging on firm value. Last, my findings are limited to a procurement auction market, and may not be applicable

that oil producers with high default risk use more derivatives. My findings are also consistent with a negative correlation between idiosyncratic risk and firm value (Goyal and Santa Clara 2003).

to corporate finance more broadly. Further research is needed to identify risk preferences and establish external validity. That said, improving efficiency in government purchasing is important; public procurement constitutes about 15% of GDP in OECD countries and 25-30% elsewhere (UNDP 2012).

Section 2 introduces the data (2.1), discusses the industry (2.2 and 2.3), and describes the risk shifting policy (2.4). Section 3 proposes the estimation strategies. Section 4 presents the results, and Section 5 concludes.

2 Context: Risk Management and the Risk Shifting Policy

2.1 Data

In Iowa and Kansas, as in most states, the state Department of Transportation (DOT) uses auctions to procure highway construction projects.[4] Bidders submit itemized bids, including a per ton bid for bitumen. An oil product, bitumen (also called asphalt binder or asphalt oil) is a black, sticky material that is mixed with rock pieces to make asphalt. The bidder with the lowest vector sum of unit item bids wins the auction.[5] The Appendix contains a simple model of the firm's bidding decision that shows how a risk premium is included in the bitumen bid markup. In Adam, Dasgupta and Titman's (2007) model, financially constrained firms are disincentivized from hedging when they can adjust output to reflect realized cost. In my setting, this is not the case as output (the quantity of road to be paved) is fixed regardless of oil prices.

This paper uses data from five sources. First, I have comprehensive, detailed data on

[4]Specifically, DOTs use simultaneous sealed-bid first-price auctions. DOT prepares a public proposal for the project detailing the location and type of work, which includes estimated quantities of materials needed and the expected date of work start. DOT also estimates the cost of each item, but these estimates are not public either before or after the auction. There is no reserve price; the secret estimate serves as a guide for what is reasonable.

[5]The unit item bids are analytically meaningful. Bid skewing (over/underbidding on items that DOT has under/overestimated) is forbidden and bids are sometimes rejected for this reason. Skewing incentives do not bias my risk management findings.

Iowa and Kansas DOT auctions and payments between 1998 and 2012.[6] Second, I use firm characteristics from Dunn & Bradstreet's database, supplemented with information from firm websites. Third, I observe actual hedging behavior in the form of 105 forward physical contracts between paving firm Z (identity protected) and all four regional bitumen suppliers. Firm Z is among the top three firms in number of total bids submitted, and near the mean among regular bidders in win percentage. I also conducted a survey of twenty of the top bidders in the data.[7] Fourth, I use oil price and volatility data from Bloomberg (summary statistics in Appendix Table 1).

I focus on paving projects, which are bitumen-intensive.[8] Although its price is highly correlated with crude oil (0.8 in my data span), there is no liquid spot or futures market for bitumen in the U.S.[9] In practice, bitumen is purchased from local suppliers in one-off, non-public transactions. Examples of these contracts are in Figures 3 and 4. Suppliers purchase bitumen from refineries and store it. Bitumen is very costly to transport and store, so suppliers naturally form a territorial oligopoly.

Bitumen cost comprises 11.3% of the total bid on average for the contracts in my data, but can be up to 40%.[10] Figure 1 shows Iowa and Kansas bitumen bids (per ton bid items within the larger total project bid) over time, as well as the crude oil price and historical oil price volatility. Summary statistics of the auction data are in Table 1, with two-tailed p-tests for difference of means across states. Iowa and Kansas are very similar in their auction format, road characteristics, and firm type distribution. They are also in close proximity geographically. However, they are not the same. My analysis relies on the

[6]These novel data were provided to me by the two DOTs, and are proprietary. My research is fully independent and not subject to review by the DOTs.

[7]I spoke either with a President, a Vice President, or an Estimator (who writes up the bids for DOT auctions).

[8]In order to ensure that bitumen is a meaningful part of the project, I only use projects in which the portion of the total bid that is bitumen is at least $50,000. I do not study diesel, another oil product used in highway paving, because it is much smaller as a percentage of the total bid, and is not a bid line item but rather goes into a line item for general overhead.

[9]The closest traded commodity is Gulf Coast high sulfur fuel oil, with which it has a correlation coefficient of 0.95.

[10]These projects do not include bridge work or extensive earthwork. For Kansas, the work types I include are called overlay and surfacing, codes 20, 53, 55, 64, 65, 66, and 67. For Iowa, they are generally called paving and resurfacing, codes 1521, 1522, 1523, 1524, 1525, 1021 and 1022.

assumption that unobservable differences across states are constant around the policy.

In both states the average number of bidders in an auction is 3.4. The time between the auction and the start of paving varies from less than a month to sixteen months. On average it is 4.6 months in Iowa and 5.7 months in Kansas, though these are not statistically different. Iowa has more paving projects and they are more bitumen-intensive, which is why before the policy bitumen bids in Kansas were higher than those in Iowa. Table 2 contains relevant pre- and post-risk shifting policy statistics. The difference between average per ton bitumen bids narrowed after the policy; Kansas bids were \$28 higher before and only \$15 higher after. The real benefit is in the actual amount paid ex-post, which changed from \$36 more in Kansas before to \$28 less after the policy (the wider swing is because the amount paid reflects the lowest bid).

I use two primary dependent variables. One is the unit item bid on bitumen, which is depicted in Figures 1 and 2. The second is the total bid for the project per ton of required bitumen, which accounts for the possibility that different strategies for allocating profit among items could distort the true effect of volatility on the metric that matters to DOT, which is the overall bid for the project.

Table 3 shows firm type summary statistics. It is challenging to obtain data on private firms (one reason the literature has largely avoided them). While not ideal, the variables I obtained speak to theory about financial constraints and risk aversion. There are six publicly listed firms. The majority of firms are family owned (71% in Kansas, and 79% in Iowa). My measure of diversification is whether or not the firm does construction beyond asphalt highway paving (based on 8-digit SIC codes). This is notably different across the two states: 60% of firms in Iowa are paving-only compared to 22% in Kansas. I define credit risk to be high when D&B rates the firm high or medium risk.[11] Credit risk is also different across the

[11]Where D&B does not cover a Kansas firm, I define the firm high risk if it has an annual bidding cap below the 25th percentile. The bidding cap is based on Kansas DOT knowledge of the firm's cash flow and credit risk, but Kansas was not able to share this data with me. Iowa would not provide the bidding cap itself. I use the 25th percentile because most firms effectively do not have a cap; Kansas enters \$99 million into the field. Where there is no cap and no D&B rating, I assign the firm high risk, because firms that opt not to report to D&B are generally those for whom the result would not reflect well on them (based on conversation with data consultant Donald Walls).

states: 34% of Iowa firms are high risk, compared to 13% of Kansas firms.I use two measures of size. The first is based on the number of employees and revenue. D&B does not provide a time series, so this is the latest figure, generally from 2012-2014. This is not unreasonable as the industry is quite static, with relatively little growth, entry, or exit. The second measure is whether the firm has only one location firm and is not a subsidiary of a larger business. Overall, there are more firms in Iowa (213 relative to 131 in Kansas) because it has a larger construction industry.[12] Nineteen firms bid in both states.

Within the private firms, some of these characteristics obviously proxy for each other. Panel 2 of Table 3 shows correlations among the key variables. The correlation between family ownership and high risk is -.02. All the others are positive and less that 0.5; the highest is 0.49 between firms with a single location and small firms. Undiversified firms are also rough proxies for single location firms. Firms select into bidding on projects, so I use extensive project controls. Notable differences are that private firms bid on projects slightly further away than public firms (94 miles on average compared to 83 miles), and public firms tend to bid in more competitive auctions. Large, multiple location, and low risk firms bid on much larger projects than their small, single location, and high risk counterparts. There are no significant differences across firm types in months to start.[13]

To control for the expected oil price, I use six month WTI oil futures.[14] The measures of risk are historical volatility, which is an annualized standard deviation of daily return, and implied volatility, which is derived by plugging option prices into the numerically inverted Black-Scholes (1973) option pricing formula.[15] I use historical volatility over the past 12

[12]Iowa's GDP (highway spending) in 2013 (at the end of my data span) was $167 billion ($594 million), relative to $142 billion ($490 million) for Kansas. (See:BEA)

[13]Appendix Tables 2 and 3 show selection across the firm characteristics for key control variables: bitumen quantity, miles between the firm and the project, number of bidders in the auction, and months between the auction and work start.

[14]There is disagreement about whether the futures price or the current spot price is the best forecast of future oil prices (Alquist and Kilian 2010, Kellogg 2010). Here I use the six month futures price, following convention in the literature on volatility and the fact that the average time to work start is five months. Futures contracts not purchased for physical delivery close or roll over at the end of the month prior to the delivery month.

[15]This is: $V_t^H = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}\left(O_t - E(O_t)\right)^2} \cdot \sqrt{T}$ where T is the number of trading days in the year (∼252) and N is the period over which volatility is measured. O_t are returns, or daily percent changes in the

weeks, and at-the-money implied volatility for options expiring in three months (these are considered directly comparable). Historical volatility is the more natural measure, as paving firms are cognizant of recent oil price trends but do not report looking at options on oil futures, much less implied volatility. I focus on results using 12-week historical volatility, but show robustness to 26-week and implied volatility.

2.2 Risk Management

Paving firms face cost uncertainty when they bid - if oil prices rise between the auction and work start, the firm's bitumen cost will increase.[16] It is not obvious that managing this risk should be costly; there is no consensus on the oil price risk premium, but conventional asset pricing models fail to explain returns and a number of recent studies were unable to reject a zero risk premium for long-only commodity portfolios (Basu and Miffre 2013, Erb and Harvey 2006). Gorton, Hayashi and Rouwenhorst (2012) show that commodity returns are negatively correlated with inventories. Oil prices are close to a random walk; Alquist and Kilian (2010) show that the no-change forecast is much more accurate than forecasts based on oil futures or oil futures spreads. Ahn and Kogan (2011) report an oil equity beta between 1971 and 2010 at 0.01. One-factor betas change sign over time, and are rarely more than 0.5 (see Appendix Figure 1), implying a premium of at most 1.5%. Note that macroeconomic growth can correlate with oil prices moving up or down, depending on the source of the shock: growth may cause a positive demand shock, increasing prices, while a positive supply shock decreases prices, which has a positive effect on growth (Anderson, Kellogg and Salant 2014).

Although there is no obvious benchmark, the balance of evidence therefore indicates

---

price: $O_t = 100 \cdot \ln\left(\frac{p_t}{p_{t-1}}\right)$ where p_t is the daily futures contract price. "Model-free" option-implied volatility metrics have been developed to deal with perceived issues with Black-Scholes, but these are beyond the scope of this paper (see Bollerslev et al. 2011).

[16] I do not address the risk of losing the auction. Anecdotal evidence from interviews suggests that paving firms are risk-averse towards input costs but risk-neutral towards an individual auction for a particular project. Firms participate in many auctions and treat them as a portfolio. While the risk of losing any given auction is idiosyncratic, oil price risk for the coming construction season is highly correlated across projects.

that excess returns to holding oil futures (the simplest hedge) should be quite small. Firms can manage risk with hedges, insurance, or diversification. The highway pavers in my data often fully insure by signing physical forward contracts with suppliers before the auction. If the firm wins, the contract binds. Sometimes they wait to sign later, and occasionally they don't hedge at all or, very rarely, hedge in financial markets.[17] The forward contracts are essentially a reservation price of hedging; if firms choose forwards rather than hedging in financial markets, the latter must be at least as costly.

Figures 3-4 show actual forward contracts from Firm Z with two of the local suppliers. A February 2008 contract for delivery in summer 2008 is priced at $330 per ton (Figure 3), while a February 2009 contract for delivery in summer 2009 is $515 per ton (Figure 4). The price of oil had crashed from around $100 per barrel in February 2008 to $43 in February 2009. Volatility helps explain the difference. It was quite low in early 2008 and rose to an all-time peak of over 70% in early 2009 (Figure 1). Firm Z's per ton contract prices are graphed in Figure 5 panel A. The contracts are tied to a specific Iowa DOT paving project, so I observe the markup on the bid item over the contract price. These are stable at around $22 per ton regardless of oil prices or volatility (Figure 5 panel B). Survey evidence indicates that this fixed markup reflects transportation costs, and profit margins are usually loaded on bid items for labor and overhead. The cost of risk is most likely embedded in the forward contract, though this is not critical to interpreting my results.

Suppliers buy and store bitumen year-round, so at the time of the auction they are partially physically hedged against the short positions they are taking in their contracts with paving firms. However, in the supplier-paver relationship, the supplier generally has downside risk while the paver has upside risk. If the supplier has total bargaining power,

[17] The physical forward contracts are based on quotes that paving firms request from bitumen suppliers before the auction. The paving firm typically signs a contract with one supplier committing to purchase the bitumen at the quoted price at the time of work start should he win the project. The price is good only for the DOT project specified in the contract, but the bitumen can be taken typically any time during the construction season (roughly mid-April to the end of October, because paving requires a road temperature no less than 55º F). The supplier must have sufficient bitumen stored to cover all contracted supply. Although end-use demand for bitumen only exists for half the year, oil refineries produce bitumen year-round as a byproduct. The refineries typically don't store bitumen, so they sell it to third parties who own terminals (storage capacity).

the forward price could include *both* sides' risk premiums.

Hedging is sometimes considered a zero-cost transaction on an expected value basis, but in practice hedging in financial markets creates exposure to cash flow risk. To illustrate, consider Southwest Airlines, whose 2014 Annual Report states: "The Company is also subject to the risk that cash collateral may be required to be posted to fuel hedge counterparties, which could have a significant impact on the Company's financial position and liquidity." Southwest paid $60 million in premiums to hedge 34% of its 2014 jet fuel consumption using option collars and swaps. Despite instruments that should minimize losses and much less hedging than usual, Southwest lost $256 million on its positions, bringing fuel hedging costs to 28% of net income.[18]

Southwest's hedging instruments require payment up front and scale. The alternative is to hedge in futures markets, which require a performance bond, or "margin," which is marked-to-market every day and changes regularly to reflect volatility.[19] Suppose that an average firm in my data used oil futures to hedge its annual bitumen needs, choosing a hedge ratio to minimize basis risk. It would purchase about 16 six month WTI crude oil futures contracts in January (auctions are usually held in the winter, and paving done in the summer). Figure 6 shows the results of this exercise for years for which I was able to gather historical margin requirement data.[20] The dots below zero are instances when oil prices go down and the margin account does not have a large cushion, so the firm must wire in money or have its positions liquidated. The graphs show that the margin account requirement varies, and on average is about $150,000.[21] This does not include margin calls

[18] Southwest Airlines 2014 Annual Report.

[19] Clearinghouses minimize defaults by requiring both parties on a futures contract to post "initial" cash, set as a dollar amount per futures contract. If the account declines below a "maintenance" amount (slightly below the initial amount), the exchange initiates a margin call. A bank or speculator may post collateral (e.g. T-bills or gold) initially and to maintain the margin, but a firm (especially a private one) would likely fund a margin uncollateralized.

[20] Sixteen contracts (where contracts are denominated in 1,000 barrels) is the rough oil equivalent of 2970 tons of bitumen, which is the average project amount (928 tons) times the number of projects the average firm wins (3.2). (For conversion rates, see EIA). The margin account requirement is the CME spec amount for 5-10 month CL6 contracts.

[21] Margin data from Esben Hedegaard at AQR and Thomas Kilmer at CME; and discussion with Kenny Tang, a commodity trader at Kotke Associates, and Joe Brogden, a broker at retail brokerage OptionsXpress.

from intermediate price drops. Even in the absence of high volatility and no margin change, a $1 drop in the price of oil requires an immediate wire of $16,000.[22]

The cost of hedging is the cost of capital in the margin account, abstracting away from employee time and transaction fees. A financially constrained firm by definition has a high cost of borrowing. Suppose the firm borrows at 5%. Then the cost of the capital dedicated to hedging in our example is about $2.26 per ton of bitumen. A formal model for this cost of capital problem is Gârleanu and Pedersen's (2011) "margin CAPM." Though they do not address hedging, they show that securities with the same cash flows but different margin requirements can have different returns, and empirically demonstrate a margin premium based on the cost of capital for investors who borrow to fund their margin accounts. Hedegaard (2014) uses data on commodity futures to show that margin changes affect open interest and prices, and concludes that margins matter for liquidity. Given the relatively low margins for oil futures, the margin premium cannot fully explain the cost of risk that I observe. It does, however, confirm the relevance of funding constraints to derivative markets.

Economies of scale and basis risk are further barriers to hedging in financial markets for small firms (Mian 1996, Géczy et al. 1997, Haushalter 2000). Investing in a fund may not be ideal either. Bhardwaj, Gorton and Rouwenhorst (2014) show that commodity trading advisors on average provide excess returns (after fees) to investors of roughly zero. They conclude that the best rationale for investors' continued use of these vehicles is information asymmetry. In interviews, executives of firms in my data consistently viewed hedging in financial markets as complicated and expensive gambling. A final reason the firms may not hedge in financial markets is information costs or lack of sophistication. They are mostly small, local, and do not have in-house financial expertise.

[22]The alternative financial markets hedge strategy is to purchase call options on futures. Although the firm loses at most the cost of the options and has upside potential, this is on average a more costly strategy (and more complex). The firm must purchase more options than the underlying oil quantity to achieve a 1-to-1 hedge, navigating the declining delta of the option as it moves out of the money.

2.3 An Imperfectly Competitive Environment

In a competitive environment high cost of risk firms would be bid out of the market. Like many industries, highway construction is characterized by imperfect competition. Inelastic demand, high barriers to entry, information asymmetry, easy defection detection, auction setups where phony bids are possible, and a static market environment are all conducive to collusion and are features of highway procurement (Porter 2005). Porter and Zona (1993), Ishii (2008), and Pesendorfer (2000) demonstrate collusive bidding in highway procurement, and Bajari and Ye (2003) note the widespread incidence of cartels in procurement auctions more generally. Gupta (2002) finds collusion in Florida highway procurement and estimates that this type of auction is not competitive until there are 8 bidders. In my data, the average is 3.4.

In an interview, one CEO told me that imperfect competition permits even very risk averse pavers to stay in business. Paving firms and bitumen suppliers are in oligopolistic, territorial equilibria. This illustrated in Appendix Figures 6-10, which show the location of auction wins and losses for five large bidders. Wins are concentrated in a portion of the state while losses predominate outside that territory. Unreported maps for other major bidders show a similar pattern. Spatial oligopoly is a natural result of high transportation costs; with perfect competition rents are zero on territory boundaries and positive within.

The bitumen suppliers are a second layer of imperfect competition. Like the paving firms, suppliers enjoy markups within their territories at least as large as the differential transportation cost for the next-closest supplier. Suppliers provide quotes to paving firms before each auction, and itemized bids are published immediately afterwards. In interviews, the suppliers suggested that recent auctions may provide a signaling mechanism, as in Friedman's (1971).[23] The suppliers charge the pavers if not their full cost of risk, at least a significant portion. Thus this context features imperfect competition in two layers of prod-

[23]"...It seems unsatisfactory for firms to achieve only the profits of the Cournot point when each firm must realize more can be simultaneously obtained by each. This line of argument often leads to something called 'tacit collusion' under which firms are presumed to act as if they colluded. How they do this is not entirely clear, though one explanation is that their market moves are interpretable as messages" (Friedman 1971).

uct markets.

2.4 The Natural Experiment

The federal government has urged state DOTs to remove oil price risk from highway contractors since the early 1970s, but the policy only became widespread in the mid-2000s. To my knowledge there is no quantitative analysis of whether, in fact, private firms were charging the government excessive risk premiums, nor has there been any effort to evaluate the policies' effectiveness. Risk shifting policies are now used in most states and there seems to be consensus in the policy community that any cost to the government of bearing oil price risk is offset by lower bids (Skolnik 2011). In the only analysis thus far, Kosmopoulou and Zhou (2014) examine one state, Oklahoma, so they cannot control for economic and other factors. They attribute their finding that firms bid more aggressively after the policy to the winner's curse effect, and assume firms are risk-neutral. There has been no analysis of whether this policy produced cost savings for Kansas or any other state.

The Kansas DOT implemented its bitumen risk shifting policy (called a "price adjustment policy") in August 2006. The precipitating event, according to senior KDOT officials, was a contractor bidding an outrageously high price for a contract in which he was the only bidder, claiming that he could not get a firm price from suppliers. Kansas uses a price index, which it purchases from a private data firm, to adjust its payments to account for changes in bitumen prices between the auction and the time of work. When prices go up, the firm is paid his bid plus the index increase, and when prices go down, the firm receives his bid less the index decrease.[24]

[24]Specifically, each month KDOT publishes an Asphalt Material Index (AMI), which they purchase from Poten & Partners. Bidders incorporate the current month's AMI into their bid for asphalt. The AMI for the month of the letting becomes the Starting Asphalt Index (SAI) for the duration of the contract. KDOT technicians take samples from the mix being placed. This serves both to monitor quality and to obtain a percent bitumen content to adjust payment based on the change in the AMI. The difference between the SAI and the AMI to the nearest dollar becomes the adjustment factor, applied to work completed during that month. The adjustment only occurs when the AMI differs from the SAI by $10 or more. The Kansas price index is almost identical to the Argus Media spot price index I use elsewhere in the paper. Both are created from surveys of recent bilateral transactions. The KDOT index is for PG 64-22 but KDOT applies it to all grades. For the index, see: http://www.ksdot.org/burconsmain/ppreq/asphaltpriceindex.asp. For the specifications, see: http://www.ksdot.org/burconsmain/specprov/pdf/90m-0295-r01.pdf.

Iowa has not pursued such a policy, apparently because officials never became interested despite experiencing similar cost escalation. Iowa, located immediately to the northeast of Kansas, has similar weather patterns, road systems, and auction characteristics.

Since the policy, Kansas firms are fully hedged for free, except for basis risk. This is not automatic; firms must agree to participate when they submit their bid. However, there have only been one or two instances (out of about 500 bids) in which a contractor has not opted for the index. Appendix Figure 2 graphs the ex-post contract price adjustments over time. In accepting the index, firms are not eliminating all risk; in fact they are accepting an inferior instrument to the forward contract, which is full insurance with no basis risk.

I use the 105 Firm Z forward contracts to provide an anecdotal measure of the risk premium in the forwards relative to the index price, which also provides an upper bound on the basis risk. Specifically, the risk premium is the forward contract price less the realized index price in the week that work starts (typically, the forward contract price is dated in the winter, and work starts the following summer).[25] The individual premiums are graphed in Appendix Figure 11. The average risk premium is 24% of the forward contract price, and its standard deviation is 10%. By choosing the index over their forwards, firms avoided paying the premium but took on basis risk. Since firms use the index when it is available and forwards otherwise, we can infer that the basis risk in the index is no more than 10%, and that hedging in financial markets must be costlier than both of these options.

3 Estimation Strategy

I use a difference-in-differences design to ask whether the policy affected firms in Kansas. The key identifying assumption is that nothing changed in Iowa *at the same time* as the 2006 risk shifting policy in Kansas. The DD intuition is that if two groups are ex-ante similar and one is subject to treatment in the second of two time periods, then

[25] I use the Argus Media Iowa spot index price, which exists for the entire period for which I have Firm Z contracts. It is almost identical to the Poten & Partners Kansas index used in Kansas after the policy. Firm Z is in Iowa, and never faces the policy.

with controls for treatment and group the estimated coefficient on the treated group should be the average difference between treatment and control, without bias from time trends and permanent differences between groups. I estimate the following regression, where the dependent variable is the price that Kansas paid after adjusting the winning bid to account for oil price changes:

$$Cost_{sj} = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} + \beta_2 \mathbf{I}_{Post\ Policy_t} + \beta_3 \mathbf{I}_{Kansas_j} + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}. \quad (1)$$

The coefficient of interest (β_1) gives the mean difference across states ($s \in Kansas,\ Iowa$) in the actual price paid by the government after the policy, controlling for the pre-policy difference.[26] Since the policy, oil prices have increased on average between the auction and work start, so the policy should have increased procurement costs if firms were risk-neutral.

I estimate the effect of risk by modulating the DD framework with oil price volatility. The competitive equilibrium in Kansas among pavers and between pavers and suppliers may have changed after the policy. However, changes that are unrelated to oil price risk should be controlled for by state and time fixed effects. Interacting volatility with the DD design provides some of the superior robustness of a triple differences design (Imbens and Wooldridge 2007). The regression, where i indexes bidders, j indexes auctions, and t indexes letting day, is

$$\ln bid_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{Kansas_j} + \beta_4 \mathbf{I}_{Post\ Policy_t} + \beta_5 \mathbf{I}_{\text{policy}_t} \cdot \ln Vol_t^{oil} + \beta_6 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} + \beta_7 \mathbf{I}_{\text{Kansas}_j} \cdot \ln Vol_t^{oil} + \beta_8 \ln price_t^{oil} + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij} \quad (2)$$

The dependent variable is the log bitumen bid, $price_t^{oil}$ is the 6-month WTI crude oil futures price, and $\ln Vol_t^{oil}$ is its volatility. The coefficient of interest, β_1, represents the effect of

[26]This is: $\hat{\beta}_1 = \left(\overline{Cost}_{Kansas,Post\ pol} - \overline{Cost}_{Iowa,Post\ pol}\right) - \left(\overline{Cost}_{Kansas,Pre\ pol} - \overline{Cost}_{Iowa,Pre\ pol}\right).$

volatility on bids in Kansas relative to Iowa after oil price risk shifted to the public sector.

I examine cross-sectional heterogeneity in two ways. First, I split the volatility modulated DD by firm type. However, the data does not permit adding a fourth interaction and the additional three- and two-way control interaction, which limits the ability to interpret differences across models. Therefore, the second approach is to measure risk as the forward market interacted with oil price volatility. Specifically, I exclude post-policy Kansas (where there was no risk) and evaluate how oil price volatility affects bids that are submitted at auctions with varying distances in time from the work start date. For example, when the project starts the month after the auction, there is little risk regardless of recent volatility. The estimating equation is:

$$\begin{aligned}\ln bid_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \mathbf{I}_{Public_j} + \beta_3 \sqrt{Wait_j} + \beta_4 \ln Vol_t^{oil} \\ + \beta_5 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} + \beta_6 \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_7 \mathbf{I}_{Public_j} \cdot \ln Vol_t^{\text{oil}} + \beta_8 \ln price_t^{oil} \\ + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij} \quad (3)\end{aligned}$$

The risk metric is the square-rooted number of months between the auction and work start times logged oil price volatility $\left(\text{Risk} = \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}}\right)$. I use the square root of $Wait_j$ because volatility moves at the square root of time.

The data, spanning 1998 to 2012, includes auctions (same as contracts/projects) j and firms i. $Controls_{ij}$ are as follows. At the auction level I control for project size using the log average total bid and log bitumen tons proposed. I also control for the number of bidders in the auction, county times year, and month-of-year fixed effects. Controlling for the month of the year is important because of capacity constraints that firms face as the construction season progresses. At the firm level, I control for the firm's log total non-bitumen bid and the log Vicenty distance from the firm to the project, using latitude and longitude data provided with the auction data. Following Bertrand et al. (2004), I cluster standard errors by firm in my primary specification. Unless otherwise specified, all discussed results are statistically significant at conventional levels.

4 Results

4.1 Real Effects of the Policy in Kansas

Estimates of Equation 1 are in Table 4. Column I shows that Kansas' policy yielded savings of $43 per ton depending on controls, or 9% of the average per-ton cost. The estimate implies that Kansas saved around $77 million in the 6.5 years after the policy, relative to total bitumen expenditure of about $820 million.[27]

KDOT officials report essentially no costs of bearing the risk; the annual cost is about $36,750.[28] Although the state does not do any hedging or set aside specific funds to cover oil price spikes, we can conduct the same thought experiment from Section 2.2 for the state instead of the firm. To hedge state-wide annual bitumen needs, Kansas would need to deposit a $3.2 million performance bond.[29] If the state can borrow money at 1%, the cost of capital is $21,250 per year on average, or about 46 cents per ton bitumen (relative to $2.26 per ton for the firm).[30] This calculation suggests that the annual savings from the policy of about $12 million are nearly four times the capital required to hedge in financial markets. Aggregating the risk also generates economies of scale, drastically reducing the administrative cost of maintaining margin accounts (i.e. the daily wiring). The average bid also decreased after the policy; column II replaces the dependent variable in Equation 1 with all bids, and shows

[27]Kansas used 1.79 million tons of bitumen across all post-policy projects. The price paid in Equation 1 is from payments data rather than bid data, which is used below.

[28]The costs of the policy have been about 1 hr of employee time per project, of which there were 166 post policy, plus a $5,295 per year subscription to Poten & Partner's bitumen price index. I assume employee time is valued at $30/hr in real terms between 2006 and 2012. Rising oil prices led to cost escalation post-2006. On average Kansas paid $489 per ton after the policy, while Iowa paid $513. This compares to pre-policy average prices of $210 and $205, respectively.

[29]I assume the state buys 253 oil futures contracts, a 10% margin and $84 oil (the average post-policy).

[30]The state can borrow with tax-exempt bonds at low rates. Iowa and Kansas have had S&P state credit ratings of AA+ or AAA throughout my data span. Kansas 10 year municipal highway revenue bonds were trading at YTM of between 0.6-1% in early November, 2015. See e.g. Here

that the policy decreased the average bid by 7.6%.

If certain types of firms have higher costs of bearing risk, then removing barriers to hedging should benefit these firms at the expense of their counterparts and increase competition. Indeed, I find that the policy increased competition in Kansas relative to Iowa, and benefited privately owned and non-diversified firms at the expense of public firms and diversified firms. Using the number of bidders in the auction as the dependent variable, column III of Table 4 shows that the policy increased the number of bidders in auctions by 0.8, relative to an average of 3.4.

Liu and Parlour (2009) argue that hedging should lead to greater competition and lower rents if firms commit to a hedge prior to participating in an auction. They use a winner-take-all auction setting where firms face a common risk. When firms invest in a hedging portfolio that is *not* contingent on the auction outcome, competition in the auction increases. The losing firms are now over-hedged. In highway paving, the forward bitumen contracts *are* contingent on winning the auction, unlike financial futures or options. Thus firms can hedge using physical forwards without competing away rents. Liu and Parlour's conclusions explain why competition increased after the policy. They show that hedging leads to a loss in social welfare borne by the seller, and conclude: "it is to the seller's advantage to...reduce the bid-to-award period or to hedge the common value of the project himself." Kansas (the "seller") pursued precisely the latter strategy in 2006. My results show that fully insuring the pavers - eliminating any need to hedge - benefited Kansas, despite oil prices generally increasing between the auction and the time of work. This supports Liu and Parlour's theory that when hedges are contingent on winning (as is the case when firms must hedge themselves), firms do not compete away the benefits of hedging. Instead, they capture them at the expense of the seller.

The policy seems to have increased competition by leveling the playing field. Columns IV and V of Table 4 show that after the policy, private firms are 19 percentage points more likely to win after the policy than before, relative to an average of 74%. The dependent variable is an indicator for winning, and the estimating equation is a triple differences design, where the coefficient of interest is on $\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$. All six individual and single difference interactions are included. Bids are the unit of observation rather than auctions.

The average probabilities in each state moved in opposite directions: the probability that a private firm won in Kansas increased from 71% before the policy to 77% after, while it decreased from 91% to 81% in Iowa. Volatile oil prices in Iowa in 2008 and 2009 seem to have favored the public firms, while private firms in Kansas were protected and increased market share. I find the same effect (20 percentage points) for firms that are only in the asphalt paving business relative to diversified firms. On average, Kansas paving-only firms' probability of winning increased from 33% to 60%, while this chance decreased for Iowa paving-only firms from 45% to 26%. Here, the controls decrease the average cross-stage change.[31] Logit specifications produce similar results, but they are magnified because logit drops groups (e.g. county-months) with no "successes" (e.g. paving-only firm wins). The odds ratios for private vs. public and paving-only vs. diversified are 2.8 and 4, respectively (Appendix Table 4).

The distribution of winning bids changed after the policy. In Figure 7, the bar heights indicate the number of firms in each category of auction win percentage. Kurtosis, or peakedness and fatness of tails, declined from 4.9 to 3, where 3 is precisely the kurtosis of the normal distribution. Skewness also declined.[32] This means that the "winningness" of firms was more evenly distributed across firms after the policy. The distributional changes are consistent with a more competitive market. There was little firm entry or exit.

[31] I do not find statistically significant effects for other firm characteristics.

[32] Skewness measures a distribution's symmetry, where a normal distribution has a skewness coefficient of 0. When the coefficient is positive, the median is less than the mean and the distribution is skewed right, and vice versa when it is negative. A skewness coefficient greater than 1 indicates that the distribution is highly skewed. Kurtosis measures the peakedness of the distribution, where the normal distribution has kurtosis of 3. Kurtosis greater than 3 has more observations closer to the mean and fatter tails than the normal distribution.

4.2 Cost of Risk

The Kansas risk shifting policy reduced the responsiveness of bids to oil price volatility, relative to the "control" state of Iowa. Table 5 shows the results using the primary specification and historical volatility. The value of -0.14 for β_1 in Column I means that a one standard deviation increase in volatility, or a 14% increase, decreases bids in Kansas relative to Iowa by 2%, relative to their pre-policy difference.[33] Using the log total bid per ton bitumen as the dependent variable (column II) gives a very similar coefficient of -0.15.

Kansas firms faced zero oil price risk after the policy, so the difference between Iowa and Kansas provides an implied cost of managing oil price risk over this period. The post-policy mean of historical volatility is 30%. The average cost of bearing risk is then 4.2% (30·0.14). Returning back to the hedging with futures hypothetical from Section 2.2, the implied cost of capital to make a 4.2% cost of risk cheaper than hedging in futures markets is around 30%.[34] Note that this does not include exposure to cash flow risk during the hedge period, nor does it includes costs of learning about derivatives, basis risk, or transaction costs, all of which are essentially zero with the physical forwards.

4.3 Heterogeneity in the the Cost of Risk

I expect external finance to be more costly for private firms, and testing whether this is the case is a main contribution of this paper. I also confirm that within privately owned investigate size, which is a The widely usedSize is a widely used proxy for financial constraints in the literature. Small firms usually have less collateralizable assets than large firms, so are often assumed to face more severe financing constraints (Hennessy and Whited 2007, Nance, Smith and Smithson 1993). Industry diversification should also lead to a lower cost of oil price risk; firms that only pave asphalt roads should face a higher probability of distress from

[33]Both variables are log-transformed, so multiplying volatility by e leads to a multiplicative $e^{\hat{\beta}_1}$ increase in bids. More intuitively, a 10% increase in volatility multiplies bids by $e^{\hat{\beta}_1 \cdot \ln(1.1)}$, in this case decreases Kansas bids by 1.4% relative to Iowa.

[34]Four percent of the overall average bid of $318 is $12.7. Section 2.2 calculated an initial margin account of $134,400 to hedge 2,970 tons of bitumen with 16 oil futures contracts. To borrow $134,400 at a cost of $12.7 per ton implies a 30% cost of capital.

an oil price spike. Last, credit risk is a direct measure of the probability of distress; I expect that if distress costs help explain the value of insurance, as suggested in Froot et al. (1993), these firms will find the risk shifting policy particularly helpful.

I examine owner diversification using the family-owned firms, which make up 78% of private firms in the data. Owners of family firms are usually also managers and have the bulk of their wealth in the firm. These undiversified manager-owners may maximize personal utility and smooth income through the firm (Bertrand and Schoar 2006, Shleifer and Vishny 1986, Schulze et al. 2001). If this undiversified-owner phenomenon explains the risk premium, I would expect family firms to charge a higher risk premium.

I explore heterogeneity across firm types in two ways. First, I split the sample, as the specification is too complex for an additional set of interactions. Table 5 columns III and IV find that the policy's effect is -0.14 for private firms and -0.11 for public firms (significant at the 1% and 10% levels, respectively). Though in the expected direction, the difference is small in magnitude and they are not statistically different with a high level of confidence. This is also true for the coefficients separating family- and non-family-owned firms.

A sharper difference is between high and low credit risk firms. The coefficients, in Table 6 columns I-II, are -0.25 and -0.12, respectively, implying a cost of oil price risk for high credit risk firms of 5.9%, compared to 3.1% for low risk firms. This does not simply reflect an overlap with family ownership; in Appendix Table 5, I show a similar result when I compare high risk, non-family-owned firms with low risk, non-family-owned firms. A natural hedge is diversification away from oil-intensive construction to projects like sewers or concrete highways. Indeed, diversification also offers a sharp contrast; the coefficients of -0.19 for paving-only firms and -0.09 for diversified firms (Table 6 columns V and VI). Similarly, Mackay and Moeller (2007) and Faccio, Marchica and Mura (2011) find that well-diversified firms are less risk averse. The diversification result is not driven by family owned firms (see Appendix Table 5 column I).

The coefficient among single-location, non-subsidiary firms is -0.18, relative to an insignificant -0.08 for other firms (Table 6 columns III and IV). The other size metric, dividing the sample based on revenue and employment (Table 6 columns VII-VIII), yields little variation. The $R^2$is over .9 for all the estimates in Tables 5 and 6, indicating that Equation 3 captures over 90% of the variation in bitumen bids. The extensive project controls ensure that projects are not systematically and observably different across firm types.

I turn to an alternative risk measure in order to combine firm types in a single model and establish statistical significance of differences across coefficients. This approach calculates risk as the square root of months between auction and work start) interacted with oil price volatility (Equation 3). The results, in Tables 7 and 8, show that public firms have a significantly lower cost of risk management than private firms; using the whole sample, the coefficient on the triple interaction of being public with risk (time to start times log volatility) is -.065 using the whole sample, significant at the 5% level (column I). When I limit the sample to low credit risk firms, the coefficient increases to -.09 and is significant at the 1%. High risk firms are by definitely closer to distress and naturally have a higher cost of risk. They create noise within the public-private comparison, and for other characteristics create a concern that any effect may reflect correlation with high credit risk.

The following columns compare family and non-family owned firms. There is no effect, regardless of the sample. Here and for subsequent characteristics, I also include a specification limiting the sample to private firms. In Table 8 I find a coefficient of .04 for paving only firms relative to diversified firms (column I, significant at the 10% level), which increases to .06 and becomes highly significant when I limit the sample to low risk firms. Columns IV-VI look at single location firms relative to multiple location firms, and yield very similar and highly significant coefficients. Finally, I examine high vs. low credit risk in columns VII-VIII. As expected, high risk firms are more risk averse than low risk firms. This effect is very strong and significant when I limit the sample to private firms.

These coefficients are challenging to interpret, so I graph marginal effects of the public-private and single-multiple location relationships (including high risk firms to be conservative) in Figures 8 and 9. These permit me to decompose the marginal effect of the two elements of risk: oil price volatility and the hedge period. Each panel of Figure 8 holds volatility fixed at its 10th, 50th, and 90th percentiles and allows the time between the auction and work start to increase. The regression demonstrated that public firms bid less then private firms at high levels of risk. The graphs show that this negative effect is driven by the time between the auction and work start, but only at high levels of volatility. Figure 9 holds fixed time to start at 6 months (panel A) and 12 months (panel B). It shows how the effect of being a single location firm relative to a multiple-location firm varies with oil price volatility. As risk increases, single location firms bid relatively more. The effect is exaggerated when there is a long hedge period.

In part because I do not directly observe all paver-supplier contracts, I cannot identify the channel of heterogeneity in risk premiums. The channel is either effective risk aversion, cost of capital, or risk-varying bargaining power. In the Froot et al. (1993) framework, the first two are effectively two sides of the same coin, because high external finance costs drive risk aversion. A narrow interpretation of my results is that I identify varying costs of capital. That is, firms may or may not have varying risk aversion, but some do not have the scale or liquidity to hedge in financial markets. However, the consensus among the executives that I interviewed was that some firms are more risk averse and thus less likely to buy spot. These firms continue to sign forwards at very high prices when oil is volatile, while others are more willing to wait, and sign in the intervening period between the auction and the work.

A third explanation is that my result reflects varying bargaining power with suppliers. The modulated DD isolates the effect of risk, so this interpretation requires bargaining power to vary with risk. Again, because I find a much weaker effect of firm size on the cost of risk than other characteristics, it seems unlikely that bargaining power alone explains my results. However, it if does, the implications are the same: in this setting, the cost of risk varies by firm type and aggregation is more efficient. The channel is simply more narrowly related to a certain product market equilibrium.

4.4 Robustness Tests

I conducted a rich array of robustness tests. An important subset for the full sample modulated DD (Table 5 column I) is in Table 9. Columns I and II show the single-difference impact of being in Kansas after the policy, controlling separately for oil price volatility. The mean effect of the policy is an insignificant -0.02. When I limit the sample to periods of high volatility (column II), the coefficient becomes -0.1, significant at the 1% level. This confirms the main result that volatility drives the triple difference coefficient.

Column III omits auction and bidder controls, which increases the coefficient to -0.19. Column IV omits the county fixed effects, which leaves the result essentially unchanged at -0.17. Alternative specifications for standard errors are state-month clusters in V and no clusters in VI. Column VII tests for parallel trends, and shows that there was no difference across states in their response to risk prior to the policy.

An alternative explanation for my results is that high volatility periods coincided with relatively low spot prices for Kansas firms, while Iowa firms had locked in high prices from the previous period. The year 2008 had unprecedented volatility, with a spike at the end of the year and then a dramatic fall in 2009. During 2009, any such price differential should have been highest. Column VIII shows that the effect is -0.13 excluding 2009. Placebo tests are in columns IX and X, where the policy implementation year is artificially set to 2002 or 2008. The effect decreases to -0.07 in both specifications, and is significant only at the 10% level. Note that both of these include the policy, so these results are to be expected.

Appendix Table 6 contains additional robustness checks. With no interactions (column I), there are robust positive effects of being in Kansas, oil price volatility, and the policy. There is also a strong positive effect of the $\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$ interaction when the triple interaction is omitted (column II). I conduct a falsification test, where the dependent variable is the total bid excluding the bitumen bid item (column III) . The coefficient on the triple interaction is now 0.06, likely reflecting oil intensity (e.g. in diesel fuel) throughout the project. Column IV omits month-of-year fixed effects, which yields about the same result as the main specification (-.15).

Further alternative error assumptions are in columns V-VII; the significance at the 1% level is unchanged with firm-month, firm-month-of-year, and firm-state clusters. Alternative oil measures are in columns VIII-X. With implied volatility, the effect increases to -0.35, reflecting implied volatility's lower variability. Column IX shows that the coefficient is unchanged using 26-week historical volatility instead of 12-week volatility. Column X uses 5 month futures instead of 6 month, and finds a very similar coefficient of -0.13. All of the Appendix Table 6 results are significant at the 1% level, except for columns III and X, which are significant at the 5% level. Last, I test whether the effect of the policy is as strong for the 19 firms who bid in both states. Appendix Table 7 shows that the main effect is not statistically significant and has a magnitude of -0.7 among these firms, which makes sense since they continue to face risk in Iowa, but are also larger and better diversified to begin with. The effect is much larger, at -0.19 and significant at the 1% level, for firms that bid in only one state.

5 Conclusion

Froot et al. (1993) show that hedging allows firms to invest even in bad cash flow states, so firms are most likely to hedge when cash flows are negatively correlated with investment opportunities. My setting exemplifies this situation; highway contractors tend to be cash flow constrained at precisely the time of year when they are most exposed to oil price risk. I show that these firms charge a large premium for bearing an idiosyncratic risk. There may be demand among small firms for simple, low transaction-cost risk management markets or aggregation services.

Firms that are publicly listed, diversified, and not family-owned charge lower risk premiums relative to their counterpart firms. These results support the hypothesis that undiversified owners and financial constraints generate greater demand for risk management either because these characteristics are associate with greater risk aversion or a higher cost of capital.

A limitation of this analysis is its industry-specific focus on public procurement and asphalt paving. However, the firms in my sample much more adequately represent the size and ownership distribution of U.S. firms than the majority of past studies on risk management, which mostly address only large, publicly listed corporations. Imperfect competition in product markets combined with financial frictions - both of which prevail in many sectors - prevent the consumer from getting the benefit of efficient markets for risk.

Table 1: Summary Statistics of Iowa and Kansas Auction Data, 1998-2012

Panel 1: Contracts (Auctions)

	Iowa		Kansas			All	
	Mean (sd)	N	Mean (sd)	N	Diff Iowa-Kansas †	Mean (sd)	N
# bidders	3.4 (2.0)	1,363	3.4 (1.6)	433	-0.08	3.4 (2.0)	1796
Months from auction to work start	4.6 (2.8)	1,363	5.7 (9.7)	433	-1.1	4.7 (2.8)	1796
Money on the table††	0.06 (0.07)	1187	0.04 (0.09)	433	0.02***	0.06 (0.08)	1796

Panel 2: Bids

	Iowa		Kansas			All	
	Mean (sd)	N	Mean (sd)	N	IA-KS†	Mean (sd)	N
Total bid ($ millions)	2.3 (3.3)	4,669	2.6 (4.5)	2,215	-0.3***	2.4 (3.9)	6,884
Bitumen bid item ($ bid per ton)	304 (150)	4,669	347 (164)	2,215	-43***	318 (156)	6,884
Bitumen fraction of total bid $\left(\frac{\text{tons*bid item}}{\text{total bid}}\right)$	.14 (.11)	4,669	.16 (.13)	2,394	-.02***	0.15 (0.11)	6,884
Total bid per ton bitumen ($ thousands)	10 (29)	4,669	17 (82)	2,394	-7***	12 (53)	6,884
Miles to project	75 (57)	4,669	111 (182)	2,394	-36***	87 (117)	6,884

Note: This table summarizes the bitumen-intensive projects (highway paving) used in the regression analysis. †2 tailed p-tests give significance on difference of means, *** indicates 1% level. ††% difference between the second lowest and winning bid (excludes auctions with one bidder): $100 * \frac{(B^{Second} - B^{Win})}{B^{Win}}$. Miles to project is Vicenty distance calculated using the latitude and longitude of the project site.

Table 2: Summary Statistics of Iowa and Kansas Auction Data Before and After Price Adjustment Policy

	Before Policy					After Policy				
Mean (sd)	Iowa	N	Kansas	N	IA-KS†	Iowa	N	Kansas	N	IA-KS†
Bitumen bid ($ bid per ton), mean over bids	196 (44)	2,824	224 (73)	1,166	-28***	469 (95)	1,845	484 (125)	1,049	-15***
$/ton paid ex-post, mean over tons per contract	195 (46)	736	231 (80)	188	-36***	487 (97)	563	458 (103)	150	28***
KS Price Adjustment								0.3 (75)	52	
Number of Bidders	3.6 (2.2)	736	3.4 (1.6)	188	0.2	3.0 (1.8)	563	3.5 (1.6)	150	-0.48***

Note: This table summarizes key variables before and after Kansas implemented its price adjustment policy in August 2006. †2 tailed p-tests give significance on difference of means, *** indicates 1% level.

Table 3: Summary Firm Characteristics

Panel 1: Number of Firms by State and Attribute

	Iowa	Kansas	All	No Data
All	221	142	344	
Bids in both states			19	
Privately-owned	217	138	337	
Public†	4	3	6	
Family-owned	176	101	264	
Privately- but not family-owned	41	38	74	
Paving asphalt is primary business (paving-only) ‡	134	31	157	98††
High risk‡‡	77	18	91	84
Small business†††	178	88	266	45
Single location & non-subsidiary business (Single loc)	143	80	216	46
Mean age at auction in years	47 (sd: 27)	35 (sd: 17)		

Panel 2: Correlation Matrix of Key Attributes

	High risk	Paving-only	Small firm	Single loc
Family-owned	-0.02	0.20	0.07	0.14
High risk		0.24	0.12	0.03
Paving-only			0.37	0.38
Small firm				0.49
Single location & non-subsidiary business				

Note: This table summarizes firm characteristics used in the heterogeneity analysis. †Public firms purchased private firms during span of data. ‡ Based on 8-digit SIC codes. ††Heavily concentrated in Kansas. ‡‡Credit risk is high when D&B rates the firm high or medium risk, or Kansas assigns the firm a max bidding cap <25th pctile. Low is a D&B "Low Risk" rating. †††Size is small if the firm is below the median number of employees/sales (75 employees, $31 million in sales), and large if above the 75th percentile.

Table 4: Effect of risk shifting Policy on Real Outcomes

Dependent variable:	\$/ton paid by DOT	Log Bids	# Bidders	Prob. of winning across firm type	
	I.	II.	III.	IV. Private vs. public	V. Paving-only vs. div.
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	**-43*** **	**-.076*** **	**.8*** **	-.12	-.083
	(13)	(.025)	(.21)	(.11)	(.062)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$				**.19***	
				(.11)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Paving\ Only_i}$					**.2*** **
					(.073)
$\mathbf{I}_{Kansas_j}$	39***	.15***	-.35	.21*	.14***
	(8.8)	(.018)	(.22)	(.12)	(.046)
$\mathbf{I}_{Post\ Policy_t}$	273***	.83***	-.54***	.017	.014
	(7.2)	(.012)	(.14)	(.093)	(.039)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Privately-owned_i}$				-.15	
				(.11)	
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$				-.023	
				(.1)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Paving\ Only_i}$					-.067
					(.063)
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Paving\ Only_i}$					-.0038
					(.026)
$\mathbf{I}_{Privately-owned_i}$				.039	
				(.11)	
$\mathbf{I}_{Paving\ Only_i}$					-.064***
					(.018)
Controls†	Y	Y	Y	Y	Y
Month-of-year f.e.	N	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y	Y
N	1637	6111	1794	6324	5921
R^2	0.798	0.818	0.288	0.220	0.225

Note: This table reports estimates of the effect of the risk shifting policy in Kansas vs. Iowa after vs. before the policy, using variations on:

$$Cost_{sj} = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} + \beta_2 \mathbf{I}_{Post\ Policy_t} + \beta_3 \mathbf{I}_{Kansas_j} + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}.$$

Each observation is an auction in I and III, and a bid in II, IV, V. The dependent variable in IV and V is 1 if the firm won the auction, and each column interacts the policy effect with a firm type. N is lower in I because KDOT lost some payments data. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, oil price, and the number of bidders (in I,III). Standard errors clustered by firm. *** $p < .01$.

Table 5: Marginal Effect of Oil Price Volatility After Policy

Dependent variable: Log bitumen bid (except II)

			Ownership Type			
	I: Full Sample	II. Dep Var=Log total bid per ton bitumen	III. Private	IV. Public	V. Family	VI. Non-Family
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	**-.14*** **	**-.15** **	**-.14*** **	**-.11** **	**-.16*** **	**-.093* **
	(.035)	(.072)	(.043)	(.037)	(.056)	(.049)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.75***	.33***	.69***	.85***	.73***	.74***
	(.042)	(.089)	(.037)	(.16)	(.039)	(.074)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.44***	.44*	.44***	.27*	.52***	.28*
	(.12)	(.24)	(.15)	(.13)	(.19)	(.16)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.038	.17**	.047	-.041	.051	.00041
	(.029)	(.068)	(.033)	(.047)	(.045)	(.044)
Vol_t^{oil}	.00068	.0056	-.0042	.047	-.004	.01
	(.0092)	(.01)	(.0079)	(.039)	(.0076)	(.02)
$\mathbf{I}_{Kansas_j}$	-.017	2.1***	-.04	.32*	-.066	.13
	(.096)	(.23)	(.11)	(.16)	(.14)	(.15)
$\mathbf{I}_{Post\ Policy_t}$	-2.3***	-.93***	-2.1***	-2.5***	-2.2***	-2.2***
	(.13)	(.25)	(.12)	(.45)	(.13)	(.23)
$\ln price_t^{\text{oil}}$	.27***	.14***	.24***	.29**	.26***	.27***
	(.032)	(.042)	(.03)	(.11)	(.038)	(.058)
Controls†	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y	Y	Y
N	6111	4542	5186	925	3757	2354
R^2	0.922	.97	0.926	0.902	0.935	0.903

Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on:

$$\ln b_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{Kansas_j} + \beta_4 \mathbf{I}_{Post\ Policy_t} + \beta_5 \mathbf{I}_{\text{policy}_t} \cdot \ln Vol_t^{oil}$$
$$+ \beta_6 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} + \beta_7 \mathbf{I}_{\text{Kansas}_j} \cdot \ln Vol_t^{oil} + \beta_8 \ln price_t^{oil} + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}$$

The dependent variable is the log bitumen item bid except in II, where it is the total bid divided by the tons of bitumen used. III-VI divide the sample by firm ownership type. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 6: Marginal Effect of Oil Price Volatility after the Policy

Dependent variable: Log bitumen bid

	Credit Risk[†]		Single location, non-subsidiary		Diversification		Size[††]	
	I. High	II. Low	III. Yes	IV. No	V. Paving only	VI. Divers.	VII. Small	VIII. Large
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	**-.25*** **	**-.12** **	**-.18*** **	**-.084**	**-.19*** **	**-.091** **	**-.15*** **	**-.091* **
	(.05)	(.045)	(.052)	(.056)	(.056)	(.041)	(.048)	(.045)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.75***	.67***	.6***	.83***	.71***	.87***	.71***	.85***
	(.094)	(.04)	(.07)	(.047)	(.055)	(.051)	(.046)	(.069)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.78***	.36**	.58***	.22	.6***	.24*	.48***	.24
	(.16)	(.15)	(.17)	(.19)	(.19)	(.14)	(.16)	(.15)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.096*	.02	-.011	.013	.02	.0095	.032	-.026
	(.056)	(.034)	(.048)	(.046)	(.043)	(.041)	(.039)	(.047)
Vol_t^{oil}	-.013	-.0045	.039	-.0076	-.014	-.005	-.0098	.003
	(.023)	(.0088)	(.028)	(.0078)	(.013)	(.0099)	(.011)	(.014)
$\mathbf{I}_{Kansas_j}$	-.22	.047	.087	.098	.046	.093	.012	.21
	(.18)	(.11)	(.16)	(.15)	(.14)	(.14)	(.13)	(.16)
$\mathbf{I}_{Post\ Policy_t}$	-2.2***	-2***	-1.9***	-2.4***	-2.2***	-2.5***	-2.2***	-2.5***
	(.29)	(.13)	(.22)	(.15)	(.18)	(.16)	(.15)	(.21)
$\ln price_t^{\text{oil}}$	.2***	.25***	.099**	.34***	.17***	.34***	.21***	.35***
	(.037)	(.034)	(.043)	(.037)	(.041)	(.045)	(.037)	(.056)
Controls[†]	Y	Y	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
N	1037	4455	1584	4280	2803	2902	3498	2387
R^2	0.913	0.923	0.905	0.938	0.930	0.933	0.922	0.936

Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on:

$$\ln b_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{Kansas_j} + \beta_4 \mathbf{I}_{Post\ Policy_t} + \beta_5 \mathbf{I}_{\text{policy}_t} \cdot \ln Vol_t^{oil}$$
$$+ \beta_6 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} + \beta_7 \mathbf{I}_{\text{Kansas}_j} \cdot \ln Vol_t^{oil} + \beta_8 \ln price_t^{oil} + \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}$$

The dependent variable is the log bitumen item bid except in II, where it is the total bid divided by the tons of bitumen used. III-VI divide the sample by firm characteristics (see Table 2 for descriptions). [†]Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 7: Alternative Risk Measure

Dependent variable: Log bitumen bid

$X_j =$	Public vs. private		Family		
Sample:	I. All	II. Low risk	III. All	IV. Private	V. Low risk
$\mathbf{I}_{X_j} \cdot \sqrt{Wait_j} \cdot Vol_t^{\text{oil}}$	**-.065****	**-.09*****	**-.012**	**.0063**	**.013**
	(.028)	(.031)	(.023)	(.024)	(.023)
$\mathbf{I}_{X_j} \cdot \sqrt{Wait_j}$	.2**	.28**	.041	-.02	-.043
	(.1)	(.12)	(.074)	(.078)	(.075)
$\sqrt{Wait_j} \cdot Vol_t^{\text{oil}}$	.006	.0028	.0039	-.013	-.014
	(.013)	(.013)	(.018)	(.019)	(.019)
$\mathbf{I}_{X_j} \cdot Vol_t^{\text{oil}}$	.18***	.23***	.019	-.012	-.025
	(.047)	(.042)	(.053)	(.057)	(.055)
$\mathbf{I}_{X_j}$	-.6***	-.74***	-.051	.048	.096
	(.16)	(.15)	(.17)	(.18)	(.18)
$\sqrt{Wait_j}$	-.022	-.0084	-.016	.041	.048
	(.042)	(.044)	(.059)	(.062)	(.06)
Vol_t^{oil}	.00083	.014	.015	.05	.055
	(.027)	(.028)	(.048)	(.052)	(.05)
$price_t^{\text{oil}}$	.17***	.17***	.17***	.17***	.17***
	(.035)	(.038)	(.037)	(.041)	(.041)
Controls†, county·year f.e., month-of-year f.e.	Y	Y	Y	Y	Y
N	4744	4054	4711	4029	4054
R^2	0.937	0.938	0.938	0.940	0.938

Note: This table reports estimates of the effect of the risk by firm type, where risk is measured as volatility interacted with the time between the auction and work start, using variations on:

$$\ln b_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \mathbf{I}_{Public_j} + \beta_3 \sqrt{Wait_j} + \beta_4 \ln Vol_t^{oil}$$
$$+ \beta_5 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} + \beta_6 \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_7 \mathbf{I}_{Public_j} \cdot \ln Vol_t^{\text{oil}} + \beta_8 \ln price_t^{oil}$$
$$+ \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}$$

I limit the sample to certain types of firms in some specifications (e.g. high credit risk). †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 8: Alternative Risk Measure

Dependent variable: Log bitumen bid

$X_j =$	Paving only vs. div.			Single loc.			High risk	
Sample:	I. All	II. Private	III. Low risk	IV. All	V. Private	VI. Low risk	VII. All	VIII. Private
$\mathbf{I}_{X_j} \cdot \sqrt{Wait_j} \cdot Vol_t^{\text{oil}}$	**.041***	**.05****	**.061*****	**.072*****	**.071*****	**.078*****	**.077***	**.15*****
	(.024)	(.021)	(.022)	(.025)	(.025)	(.029)	(.043)	(.051)
$\mathbf{I}_{X_j} \cdot \sqrt{Wait_j}$	.29*	-.16**	-.2***	-.24***	-.24***	-.26***	-.28*	-.52***
	(.16)	(.068)	(.073)	(.084)	(.082)	(.098)	(.15)	(.18)
$\sqrt{Wait_j} \cdot Vol_t^{\text{oil}}$	-.043**	-.028*	-.041**	-.022	-.022	-.029**	-.022	.0039
	(.014)	(.015)	(.015)	(.014)	(.014)	(.014)	(.015)	(.014)
$\mathbf{I}_{X_j} \cdot Vol_t^{\text{oil}}$	-.083*	-.086**	-.11**	-.096*	-.097*	-.1*	-.1	-.23**
	(.048)	(.04)	(.046)	(.054)	(.053)	(.062)	(.11)	(.093)
$\mathbf{I}_{X_j}$	.29*	.29**	.38**	.36**	.36**	.39*	.39	.81**
	(.16)	(.13)	(.15)	(.18)	(.18)	(.21)	(.4)	(.34)
$\sqrt{Wait_j}$	.13***	.091*	.13***	.069	.069	.093**	.065	-.011
	(.047)	(.049)	(.05)	(.045)	(.045)	(.046)	(.049)	(.046)
Vol_t^{oil}	.1***	.058**	.1***	.057*	.059*	.075**	.045	.0043
	(.032)	(.029)	(.034)	(.032)	(.032)	(.032)	(.029)	(.03)
$price_t^{\text{oil}}$	.15***	.15***	.16***	.17***	.17***	.17***	.1***	.12***
	(.037)	(.033)	(.041)	(.036)	(.036)	(.04)	(.036)	(.036)
Controls†, county·year f.e., Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
N	4582	4079	4007	4653	4660	4019	3624	3353
R^2	0.945	0.944	0.941	0.939	0.939	0.941	0.939	0.940

Note: This table reports estimates of the effect of the risk by firm type, where risk is measured as volatility interacted with the time between the auction and work start, using variations on:

$$\ln b_{ijt} = \beta_0 + \beta_1 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \mathbf{I}_{Public_j} + \beta_3 \sqrt{Wait_j} + \beta_4 \ln Vol_t^{oil}$$
$$+ \beta_5 \mathbf{I}_{Public_j} \cdot \sqrt{Wait_j} + \beta_6 \sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}} + \beta_7 \mathbf{I}_{Public_j} \cdot \ln Vol_t^{\text{oil}} + \beta_8 \ln price_t^{oil}$$
$$+ \gamma' \cdot Controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{sij}$$

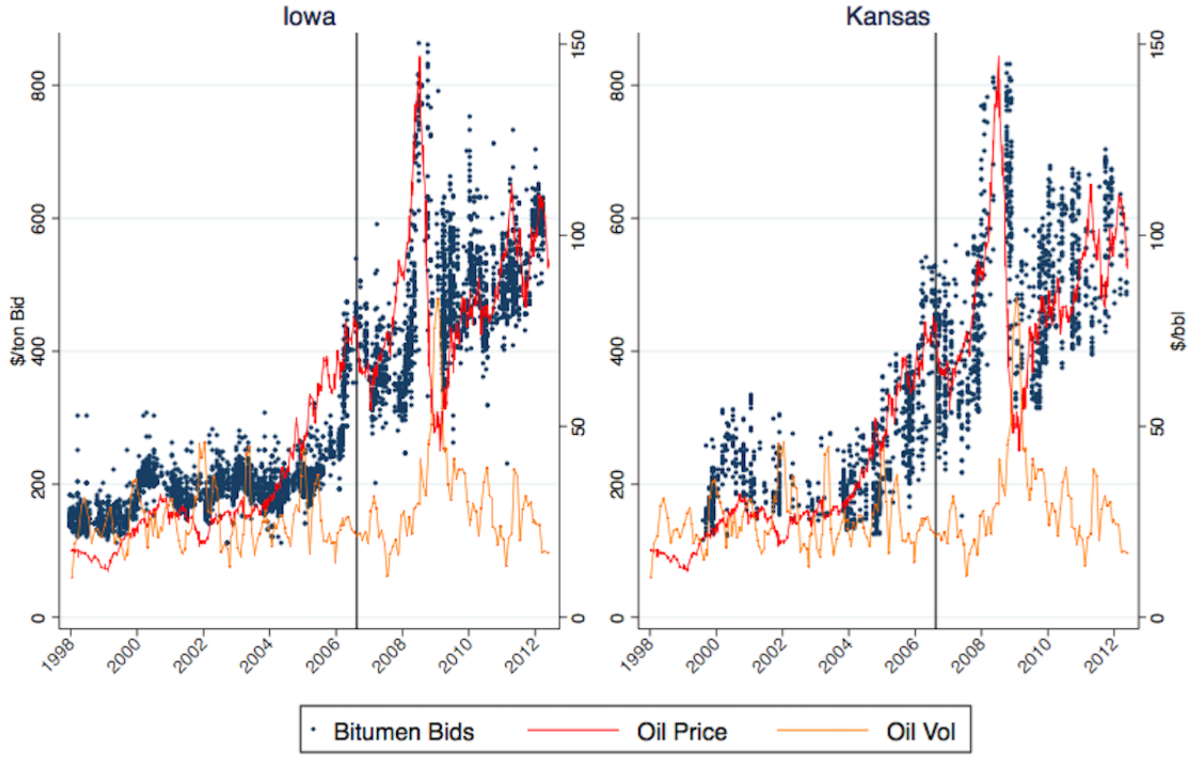
I limit the sample to certain types of firms in some specifications (e.g. high credit risk). †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 9: Select Robustness Tests

Dependent variable: Log bitumen bid	Single Differences		Controls		Errors		Time Frame		Placebos	
	I. Kansas-policy	II. Kansas-policy (vol>75th pctile)	III. No controls	IV. No county f.e.	V. State-month clusters	VI. Robust (no clusters)	VII. Parallel trends (before policy)	VIII. Excluding 2009	IX. 2002	X. 2008
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			**-.19*** **	**-.17*** **	**-.14***	**-.14*** **		**-.13*** **	**-.069***	**-.071***
			(.035)	(.037)	(.073)	(.04)		(.05)	(.039)	(.041)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			.57***	.77***	.75***	.75***		.83***	-.031	.21***
			(.036)	(.041)	(.11)	(.036)		(.06)	(.025)	(.032)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	**-.017**	**-.097*** **	.58***	.54***	.44*	.44***		.42**	.23*	.22
	(.016)	(.027)	(.12)	(.12)	(.24)	(.13)		(.16)	(.13)	(.14)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$			.066**	.037	.034	.034	**-.013**	.068**	.086**	.054*
			(.031)	(.03)	(.054)	(.034)	(.032)	(.029)	(.035)	(.027)
Vol_t^{oil}	.052***	.013	-.026***	.0062	.00031	.00031	.023***	.0042	.07***	-.014*
	(.013)	(.04)	(.0089)	(.0097)	(.023)	(.0078)	(.0089)	(.0086)	(.018)	(.0077)
$\mathbf{I}_{Kansas_j}$	.12***	.12***	-.097	.0037	.0033	.0033	.16	-.11	-.17	-.06
	(.012)	(.022)	(.099)	(.099)	(.17)	(.11)	(.11)	(.097)	(.11)	(.088)
$\mathbf{I}_{Post\ Policy_t}$	.11***	.69***	-1.7***	-2.3***	-2.2***	-2.2***		-2.5***	.1***	.11***
	(.032)	(.061)	(.12)	(.13)	(.34)	(.12)		(.18)	(.032)	(.031)
$\ln price_t^{\text{oil}}$	.055*	.24***		.27***	.27***	.27***	.36***	.35***	.058*	.13***
	(.03)	(.038)		(.033)	(.059)	(.021)	(.011)	(.034)	(.032)	(.029)
Controls†	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
N	6111	1780	6111	6111	6111	6111	3532	5554	6111	6111
R^2	0.912	0.937	0.917	0.914	0.922	0.922	0.549	0.915	0.912	0.914

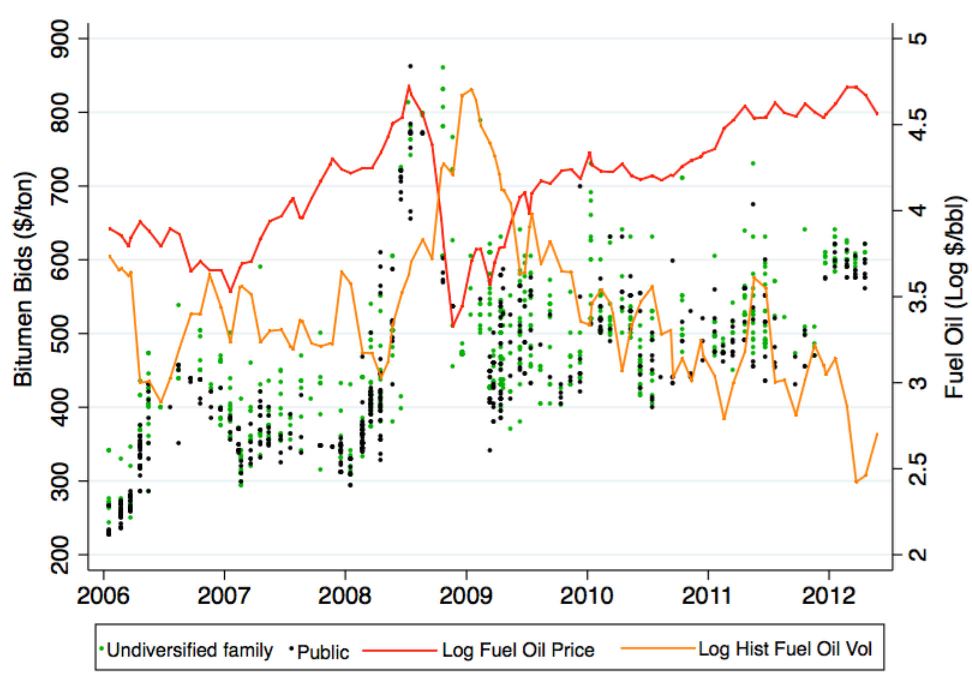
Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 2. The dependent variable is the log bitumen item bid. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Figure 1: Bitumen Bids in Iowa and Kansas



Note: This figure shows all bitumen bids in Iowa and Kansas between 1998 and 2012.

Figure 2: Bitumen Bids in Iowa by Firm Type, and Oil Prices and Volatility



Note: This figure shows Iowa bitumen bids for two subsets of firms: those that are family-owned and are undiversified (only do paving); and those that are publicly listed.

Figure 3: Example Firm Z Physical Forward Contract, February 2008

Sales Agreement

FLINT HILLS RESOURCES

FLINT HILLS RESOURCES, LP
501 EAST FRONT STREET
DAVENPORT, IA 52804
(563) 324-3766 x

Page 1
Sales Agreement NO. 66870

Sold To: 227
[redacted]

Date February 25, 2008
Terms 1% 10 DAYS, EFT
Sales Rep ROBERT RIUTTA

Line No: 1

Effective Period **May 1, 2008 - November 1, 2008**

Project #
Project Name IOWA COUNTY FEB 08
Project Reference IM-080-6(242)210-13-48

FOB Location ORIGIN **Freight Terms** COLLECT

Product PG 58-28

Qty	UOM	Price USD	Freight	Delivered	Destination	Ship From
640	TON	$330.00				DAVENPORT,IA

Line No: 2

Product PG 64-22

1	TON	$330.00				DAVENPORT,IA

Shipments from this Sales Agreement will be taxed, unless you provide us with a sales exemption certificate. Please return the appropriate completed tax exemption form along with a signed copy of this Sales Agreement.

NOTE: Buyer hereby accepts the conditions of sale accompanying this agreement.

Accepted

[redacted]

Accepted

FLINT HILLS RESOURCES, LP ("Seller")

By ROBERT RIUTTA

Title

Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 4: Example Firm Z Physical Forward Contract, February 2009

BITUMINOUS MATERIALS & SUPPLY, L.P.
P.O. Box 6205, Des Moines, Iowa 50309-6205
ASPHALT SALES CONTRACT

[redacted]

DATE: 02-24-09

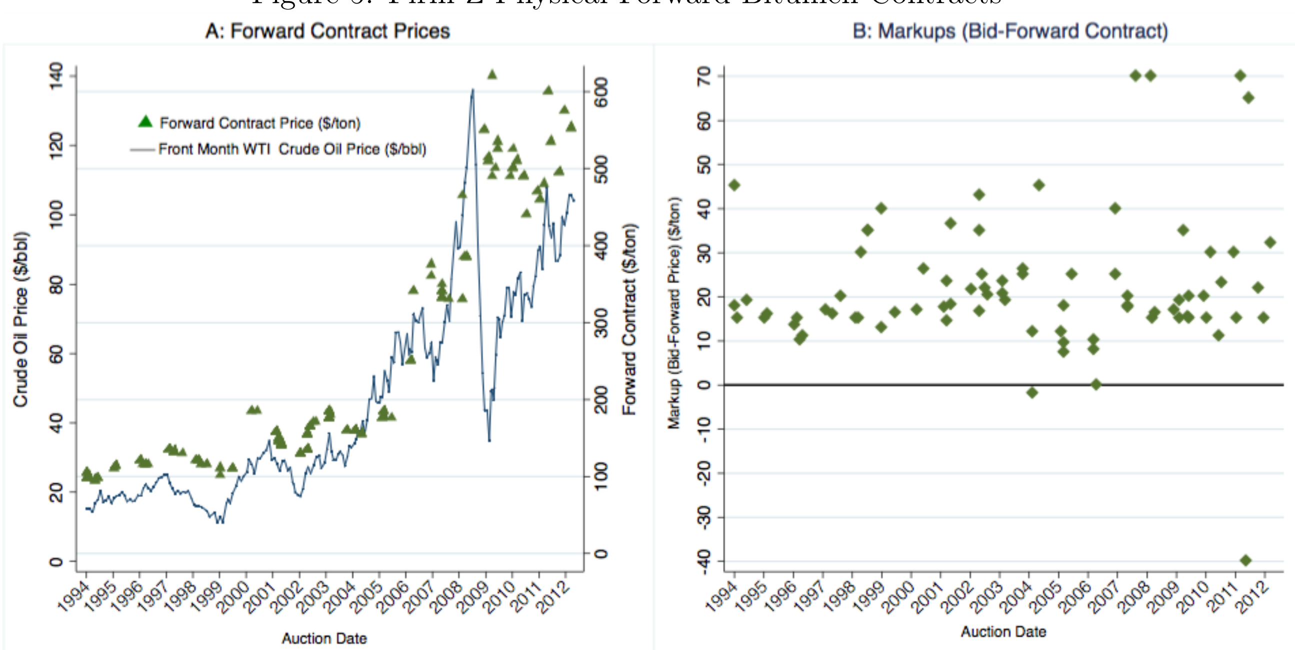
Subject to the terms and conditions on the reverse side hereof, this document constitutes a firm offer which will automatically expire without notice if not accepted by________________________. This offer expressly limits acceptance to the terms and conditions of this offer. Acceptance must be indicated by signing in the space below and returning to Bituminous Materials & Supply, L.P. prior to said expiration date. When accepted as aforesaid this document shall constitute the contract between you as Buyer and Bituminous Materials & Supply, L.P. as seller.

DELIVERY PERIOD	Construction Season 2009			
PROJECT NO.	Jasper County HSIPX-163-2(54)--3L-50			
SPECIFICATIONS	Iowa Department of Transportation			
PRODUCT		Asphalt Cement PG 58-28	Emulsion Prime & Tack	Cutback Prime & Tack
QUANTITIES:	MAXIMUM Approx.	1,849 - Tons		
	MINIMUM			
PRICE TRUCK	F.O.B. Tama	515.00 Per Ton	1.90 Per Gallon	
	F.O.B. DESTINATION			
DESTINATION Job Site				
TERMS OF CREDIT AS APPROVED BY SELLER'S CREDIT DEPARTMENT 30 Days From Date of Invoice				

REMARKS:
Hauling: A.C. 11.00 Per Ton
A.E. .046 Per Gallon

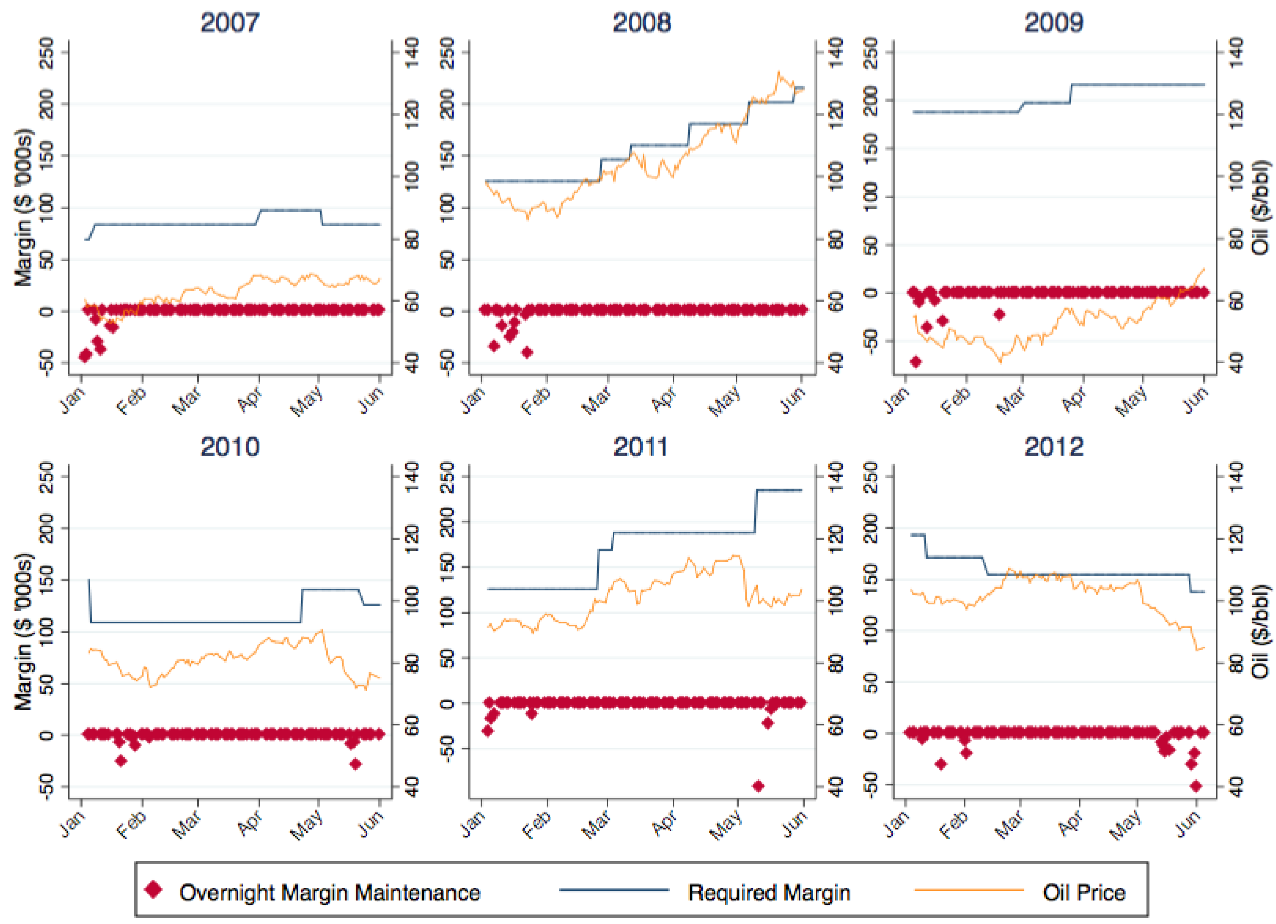
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 5: Firm Z Physical Forward Bitumen Contracts



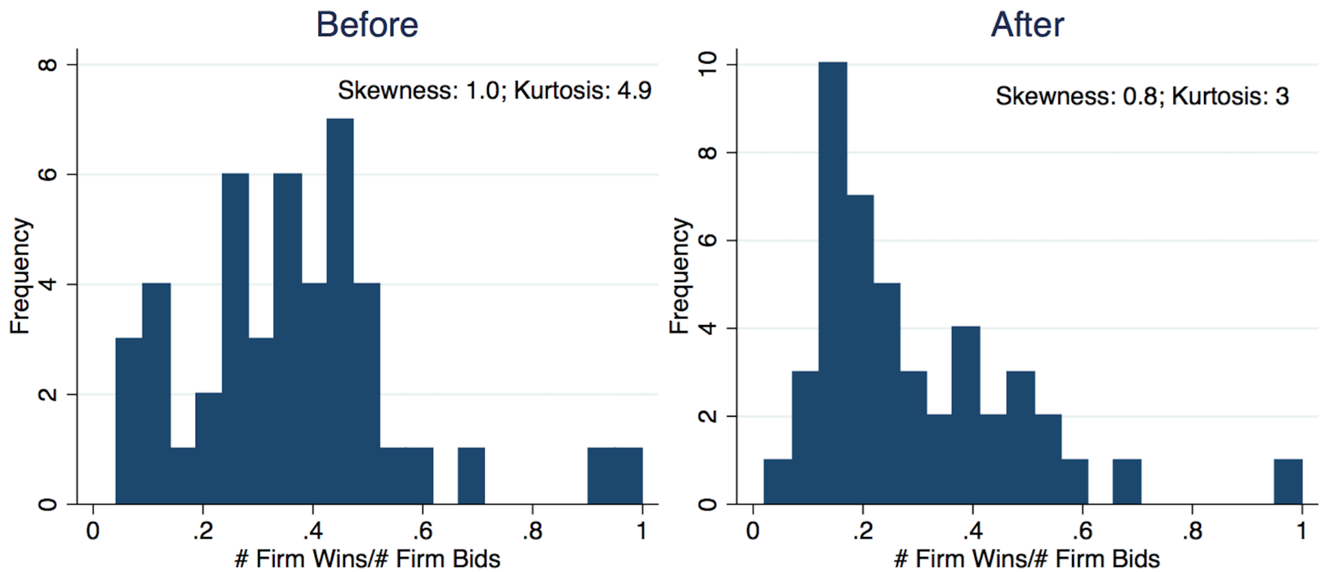
Note: This figure shows the bitumen prices in 100 forward physical contracts between one large paving firm and bitumen suppliers, as well as the spot oil price.

Figure 6: Hypothetical Margin Requirements for Hedging with Oil Futures



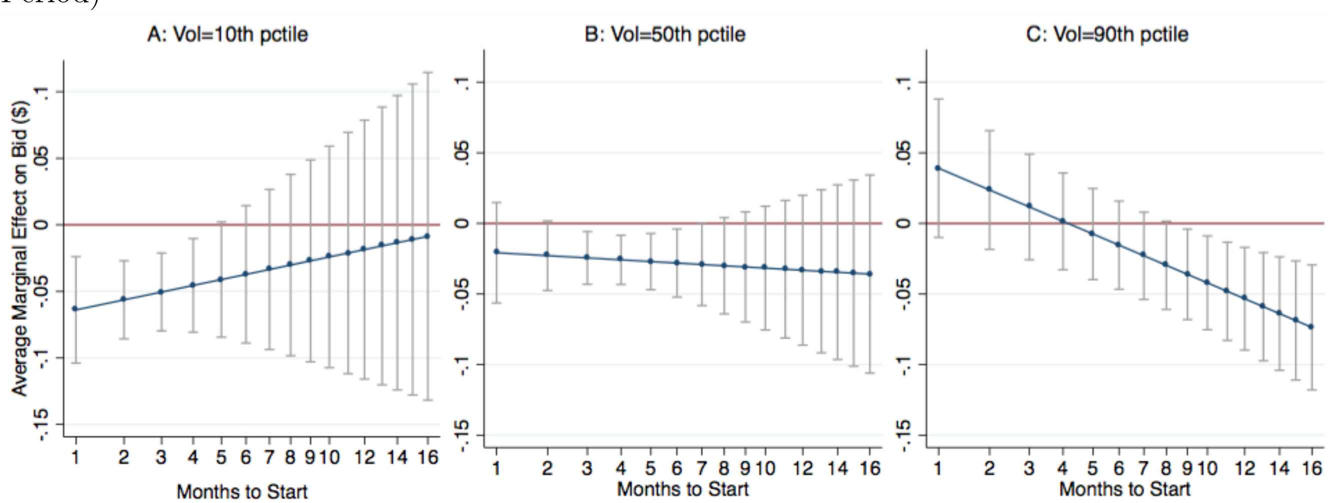
Note: This figure shows the capital an average firm needs to hedge annual bitumen (purchase 16 6 month crude oil futures contracts in Jan., as auctions are usually in winter, work in summer). Overnight maintenance is the amount the firm needs to deposit overnight to maintain its margin.

Figure 7: Kansas win distribution around risk shifting policy



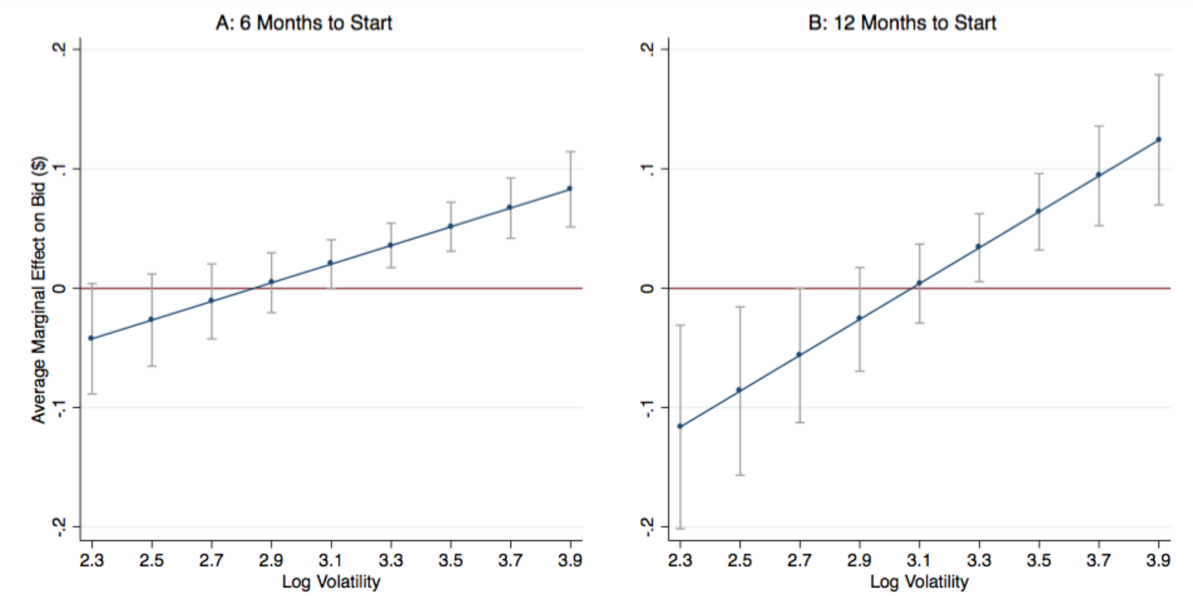
Note: These figures show the frequency of of firms by win percentage. The changing distributions indicate that after the policy wins were more evenly spread across firms.

Figure 8: Marginal Effect of Public Ownership on Bids at Varying Risk (Volatility and Hedge Period)



Note: These figures graph marginal effects from the regression in Table 7 Column I. Each panel holds volatility fixed at a certain level and shows how the effect of being public relative to private varies with the time between the auction and work start. As risk increases, public firms bid less than private firms, and these graphs show that this negative effect is driven by the time between the auction and work start, but only at high levels of volatility.

Figure 9: Marginal Effect of Single Location, Non-subsidiary Status on Bids at Varying Volatility Levels



Note: These figures graph marginal effects from the regression in Table 7 Column III. The panels hold time to between the auction and work start fixed at 6 and 12 months respectively, and show how the effect of being a single location firm relative to a multiple-location firm varies with oil price volatility. As risk increases, single location firms bid relatively more. The effect is exaggerated when there is a long hedge period.

References

Acharya, V. V., Almeida, H., & Campello, M. 2013. Aggregate risk and the choice between cash and lines of credit. The Journal of Finance, 68(5), 2059-2116.

Acharya, V., Davydenko, S. A., & Strebulaev, I. A. 2012. Cash holdings and credit risk. Review of Financial Studies, 25(12), 3572-3609.

Adam, T., Dasgupta, S., Titman, S., 2007. Financial constraints, hedging and competition in industry equilibrium. Journal of Finance 62, 2445–2473.

Ahn, D., & Kogan, L. 2010. Crude or Refined: Identifying Oil Price Dynamics through the Crack Spread. Working paper.

Allayannis, G., & Weston, J. P. 2001. The use of foreign currency derivatives and firm market value. Review of financial studies, 14(1), 243-276.

Alquist, R., & Kilian, L. 2010. What do we learn from the price of crude oil futures? Journal of Applied Econometrics 25.

Anderson, R. & D. Reeb. 2003. Founding family ownership and firm performance: Evidence from the S&P 500. Journal of Finance 58.

Anderson, S. T., Kellogg, R., & Salant, S. W. 2014. Hotelling under pressure. NBER Working Paper No. w20280.

Asker, J., Farre-Mensa, J., & Ljungqvist, A. 2014. Corporate Investment and Stock Market Listing: A Puzzle? Review of Financial Studies.

Astrachan, J. H., & Shanker, M. C. (2003). Family businesses' contribution to the US economy: A closer look. Family business review, 16(3), 211-219.

Bajari, P. & L. Ye. 2003. Deciding between Competition and Collusion. The Review of Economics and Statistics 85.

Bank for International Settlements (BIS). 2015. Interest rate risk in the banking book. Consultative Document. June. Available here.

Basu, D., & Miffre, J. 2013. Capturing the risk premium of commodity futures: The role of hedging pressure. Journal of Banking & Finance, 37(7), 2652-2664. Chicago

Bhardwaj, G., G. Gorton & K. Rouwenhorst. 2014. Fooling Some of the People All of the Time: The Inefficient Performance and Persistence of Commodity Trading Advisors. Review of Financial Studies 27(11).

Bertrand, M., & Schoar, A. 2006. The role of family in family firms. The Journal of Economic Perspectives 73-96.

Black, F. & M. Scholes. 1973. The Pricing of Options and Corporate Liabilities. Journal of Political Economy 81.

Bollerslev, T., Gibson, M., & Zhou, H. 2011. Dynamic estimation of volatility risk premia and investor risk aversion from option-implied and realized volatilities. Journal of econometrics, 160(1), 235-245.

Bolton, P., Chen, H., & Wang, N. (2011). A unified theory of Tobin's q, corporate investment, financing, and risk management. The journal of Finance, 66(5), 1545-1578.

Bond, S. & J. Cummins. 2004. Uncertainty and company investment, an empirical model using data on analysts' profits forecasts, Mimeo, Institute for Fiscal Studies.

Brown, G. W., Crabb, P. R., & Haushalter, D. 2006. Are Firms Successful at Selective Hedging? The Journal of Business, 79(6).

Campello, M., Lin, C., Ma, Y., & Zou, H. 2011. The real and financial implications of corporate hedging. The Journal of Finance, 66(5), 1615-1647.

Carter, D. A., Rogers, D. A., & Simkins, B. J. 2006. Does hedging affect firm value? Evidence from the US airline industry. Financial Management, 35(1), 53-86.

Cheng, I. H., & Xiong, W. (2013). Why Do Hedgers Trade So Much? (No. w19670). National Bureau of Economic Research.

Congressional Budget Office. 2011. Spending and Funding for Highways. Economic and Budget Issue Brief.

Cornaggia, J. 2013. Does risk management matter? Evidence from the US agricultural industry. Journal of Financial Economics, 109(2).

Erb, C. and Harvey, C. 2006. The strategic and tactical value of commodity futures, Financial Analysts Journal 62, 69–97.

Faccio, M., Marchica, M. T., & Mura, R. 2011. Large shareholder diversification and corporate risk-taking. Review of Financial Studies, hhr065.

Fama, E. F., & Jensen, M. C. (1983). Separation of ownership and control. Journal of law and economics, 301-325.

Friedman, J. W. 1971. A non-cooperative equilibrium for supergames. The Review of Economic Studies 38.

Froot, K. A., Scharfstein, D. S., & Stein, J. C. 1993. Risk management: Coordinating corporate investment and financing policies. the Journal of Finance, 48(5), 1629-1658.

Garleanu, N., & Pedersen, L. H. (2011). Margin-based asset pricing and deviations from the law of one price. Review of Financial Studies, hhr027.

Géczy, C., Minton, B. A., & Schrand, C. 1997. Why firms use currency derivatives. The Journal of Finance, 52(4), 1323-1354.

Gorton, G. B., Hayashi, F., & Rouwenhorst, K. G. (2013). The fundamentals of commodity futures returns. Review of Finance, 17(1), 35-105.

Goyal, A., & Santa-Clara, P. (2003). Idiosyncratic Risk Matters!. Journal of Finance, 58(3), 975-1008.

Guay, W., & Kothari, S. 2003. How much do firms hedge with derivatives?. Journal of Financial Economics 70.

Gupta, S. 2002. Competition and collusion in a government procurement auction market. Atlantic Economic Journal 30.

Haushalter, G. 2000. Financing policy, basis risk, and corporate hedging: Evidence from oil and gas producers. The Journal of Finance, 55.

Hedegaard, E. (2014). Causes and Consequences of Margin Levels in Futures Markets. Working Paper, Arizona State University.

Hennessy, C., & Whited, T. 2007. How costly is external financing? Evidence from a structural estimation. The Journal of Finance, 62(4).

Imbens, G. & J. Wooldridge. 2007. Difference-in-differences estimation. NBER Summer 2007, What's New in Econometrics? Lecture Notes 10.

Ishii, R. 2008. Collusion in repeated procurement auction: A study of a paving market in Japan. Osaka University Institute of Social and Economic Research Discussion Paper 710.

Jin, Y., & Jorion, P. 2006. Firm value and hedging: Evidence from US oil and gas producers. The Journal of Finance 61.

Kellogg, R. 2010. The Effect of Uncertainty on Investment: Evidence from Texas Oil Drilling. NBER Working Paper 1641.

Kosmopoulou, G., & X. Zhou. 2014. Price Adjustment Policies in Procurement Contracting: An Analysis of Bidding Behavior. The Journal of Industrial Economics, 62(1).

Liu, T., & Parlour, C. A. 2009. Hedging and competition. Journal of financial economics, 94(3), 492-507. Chicago

MacKay, P., & Moeller, S. B. 2007. The value of corporate risk management. The Journal of Finance, 62(3).

Merton, R. 1995. A functional perspective of financial intermediation. Financial Management, 23-41.

Mian, S. 1996. Evidence on corporate hedging policy. Journal of Financial and Quantitative Analysis 31.

Nance, D. R., Smith, C. W., & Smithson, C. W. 1993. On the determinants of corporate hedging. The Journal of Finance, 48(1), 267-284.

Panousi, V. & D. Papanikolaou, 2012. Investment, idiosyncratic risk, and ownership. The Journal of Finance 67.

Pérez-González, F., & Yun, H. (2013). Risk Management and Firm Value: Evidence from Weather Derivatives. Journal of Finance, 68(5), 2143-2176. Chicago

Pesendorfer, M. 2000. A Study of Collusion in First-Price Auctions. Review of Economic Studies, 67.

Porter, R. & J. Zona. 1993. Detection of Bid Rigging in Procurement Auctions. Journal of Political Economy 101.

Porter, R. 2005. Detecting collusion. Review of Industrial Organization 26.

Purnandam, Amiyatosh. 2008. Financial distress and corporate risk management: Theory and evidence. Journal of Financial Economics, 87.

Rampini, A. A., Sufi, A., & Viswanathan, S. 2014. Dynamic risk management. Journal of Financial Economics, 111(2), 271-296.

Rampini, A. A., & Viswanathan, S. 2010. Collateral, risk management, and the distribution of debt capacity. The Journal of Finance, 65(6).

Rampini, A. A., & Viswanathan, S. 2013. Collateral and capital structure. Journal of Financial Economics, 109(2),.

Saunders, A., & Steffen, S. 2011. The costs of being private: Evidence from the loan market. Review of Financial Studies, 24(12), 4091-4122.

Scharfstein, D, & Sunderam, A. 2013. Concentration in Mortgage Lending, Refinancing Activity and Mortgage Rates. NBER Working Paper 19156.

Schulze, W. S., Lubatkin, M. H., Dino, R. N., & Buchholtz, A. K. 2001. Agency relationships in family firms: Theory and evidence. Organization science, 12(2), 99-116.

Shaad, J. 2006. Asphalt Price Indexes Smooth Process for Road Project Bids. Kansas City Business Journal, July 30.

Shleifer, A., & R. Vishny. 1986. Large shareholders and corporate control. The Journal of Political Economy 94.

Skolnik, J. 2011. Price Indexing in Transportation Construction Contracts. Jack Faucett Associates, in Association with Oman Systems.

Smithson, C., & Simkins, B. J. (2005). Does risk management add value? A survey of the evidence. Journal of Applied Corporate Finance, 17(3), 8-17.

Stulz, R. 1996. Rethinking risk management. Journal of applied corporate finance 9.

Tufano, P. 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. The Journal of Finance 51.

UNDP. 2012. "Sustainable Public Procurement Briefing Note." http://www.unpcdc.org/media/390120/spp_brief_en_2012-02-06.pdf

Vickery, J. 2008. How and why do small firms manage interest rate risk? Journal of Financial Economics 87.