The Cost of Risk Management: Evidence from a Quasi-Experiment

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Abstract

Do small, private firms benefit from financial derivative markets? In a specific but analytically useful setting, this paper suggests that they do not, and further shows how public policy can mitigate risk management frictions in product markets. The Kansas state government began to insure highway-paving firms against oil price in 2006. I use a difference-in-differences design to evaluate the effect of the policy in Kansas relative to Iowa, which never introduced it. With data from 1998 to 2012, this quasi-experiment finds that the insurance policy reduced procurement costs and increased competition. For the average firm, a 25% cost of capital equates the estimated value of risk management in this market with the approximated cost of hedging in financial markets. I find that the greatest value from insurance is derived by privately-owned firms with high credit risk and low industry diversification, with no effect at all for public firms. JEL codes: G13, G14, G38, G32, Q47

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1 Introduction

Whether private firms efficiently manage risk is economically important, as private firms are responsible for about half of U.S. GDP (Kobe 2012). To my knowledge, this paper offers the first comparison of the value of risk management across public, private, and family-owned firms. Further, it provides the first firm-level causal evaluation of a government policy seeking to mitigate financial frictions in hedging.

Financial constraints and distress costs can lead firms to value risk management, yet these frictions can prevent them from hedging in financial markets. In particular, a high cost of capital may lead firms to value risk management (Froot, Scharfstein, and Stein 1993). At the same time, costly capital can preclude firms from insuring in financial markets because of an inability to meet collateral requirements (Rampini and Viswanathan 2010, 2013). In response, firms may manage risk by employing alternatives to financial markets, like cash and fixed-price contracts (Bolton, Chen, and Wang 2011). The cost of these alternatives above the cost of hedging in financial markets may be passed on to the product market, creating a potential opportunity for a public hedging program to improve efficiency.

In 2006, the Kansas state government shifted oil price risk in highway procurement contracts from the private sector to the state. Specifically, the government offered an optional adjustment of payments to reflect changes in oil prices between the procurement auction date and the time of work. Kansas did not charge firms for this insurance. I assess the value to firms of the insurance policy in a difference-in-differences design using highway procurement auction data from Kansas and Iowa for 1998-2012. A nearby state with similar highway characteristics and spending trends, Iowa has never had the policy. I analyze firm bids in Iowa and Kansas procurement auctions for paving asphalt ("blacktop") roads, in which a petroleum product (bitumen) is the primary component.[1]

There is much evidence that firms do not operate in a frictionless world, so we should expect free insurance to reduce firm costs. However, the risk premium for holding crude oil futures should be quite small (see Section 6 and evidence in Gorton, Hayashi, and

[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).

Rouwenhorst [2012] and Ahn and Kogan [2011]). Therefore, if firms can efficiently hedge in derivative markets, the Kansas insurance policy should have had little effect. Instead, the policy had substantial effects on the state's cost of procurement and on firm sensitivity to risk. Relative to Iowa, I show that the insurance policy in Kansas reduced cost by about 9%, saving the government around $77 million over 6.5 years. The policy also increased competition, measured as the number of bidders per auction.

I modulate the difference-in-differences design with oil price volatility to estimate how bid sensitivity to risk changed after the policy. I show that a 100% increase in historical volatility after implementation of the insurance policy leads to bitumen bids in Kansas that are 14% lower than in Iowa, relative to their pre-policy difference. This translates to a 4.2% average cost of bearing oil price risk. This estimate is robust to placebo tests, falsification with non-oil bid items, and alternative volatility metrics.[2]

Establishing that the Kansas insurance policy reduced firm sensitivity to risk and procurement costs raises three questions. First, how do firms manage risk in Iowa and in pre-policy Kansas? Asphalt paving firms usually purchase physical forward (fixed-price) contracts from local bitumen suppliers at the time of the auction, thereby fully insuring but with no cash up front. Such fixed-price contracts with distributors are also common among farmers, electric utilities, and airlines. After the policy, asphalt paving firms in Kansas universally elected to use the state-provided insurance, which is free to them albeit with basis risk. Their revealed preference suggests that the state-provided insurance is cheaper than the physical forwards, which in turn are cheaper than hedging in financial markets. End users may perceive financial derivatives as costly because of their capital requirements, basis risk, economies of scale, daily marking to market, and complexity.

Second, how much did the policy cost Kansas? Administrative costs have been less than 1% of the estimated savings. The government has not hedged, but the cost of doing so with oil futures would be small because the state borrows at about 1%.[3] In contrast,

[2] I demonstrate parallel trends for key variables across Iowa and Kansas, even during the American Recovery and Reinvestment Act (ARRA) period, and also find that the main results are robust to omitting ARRA years.

[3] Kansas 10 year municipal highway revenue bonds were trading at YTM of between 0.6-1% in early November, 2015.

my findings indicate that for the average paving firm, the cost of capital that equates the per-ton cost of an average initial margin account with the estimated cost of risk management is about 25%. This difference highlights the desirability of assigning risk in a product market relationship to the party with the lower cost of managing it. The state has informational and enforcement advantages, and is the final consumer. In assuming the risk, it benefits from eliminating the profit and risk premium on the physical forward.

Third, did certain subsets of firms benefit from the insurance policy more than others? As a product, highway paving is essentially a commodity. Yet firms are diverse in their ownership, size, and industry diversification.[4] I show that the insurance policy led to an increase in the probability of winning for private and undiversified firms at the expense of public and diversified firms. I use two methods to address heterogeneity in the cost of risk. One is to split the sample in the volatility-modulated difference-in-differences design. The other is to measure risk as the time between the auction and work start interacted with oil price volatility, excluding post-policy Kansas. Both approaches reveal that private firms have a higher cost of risk than public firms. Within private firms, high credit risk, undiversified, and single-location firms have much higher costs than their respective counterparts.

Elevated value from risk management among private firms could have three sources. Fama and Jensen (1983) and Schulze et al. (2001) suggest that private firms may be more risk averse because poorly diversified owners smooth personal income through the firm. At odds with this view, I show that family-owned firms do not have a higher cost of risk than non family-owned firms. Second, some firms might have greater managerial agency and information problems (DeMarzo and Duffie 1995; Breeden and Viswanathan 1998). Third, some firms may face more severe financial constraints and distress costs (Froot et al. 1993, Purnandam 2008). In my data, high credit risk and low industry diversification are associated with the highest value of risk management, supporting the third mechanism.

Empirical work on risk management is mixed.[5] Géczy, Minton and Schrand (1997) and

[4] Of the 344 firms in the sample, six are public but account for almost 20% of bids. Among privately-owned firms, 264 are family-owned.

[5] Nance, Smith, and Smithson (1993), Allayannis and Weston (2001), and Carter, Rogers, and Simkins (2006) and find a positive association between risk management and firm value, while Brown, Crabb, and

Vickery (2008) find a positive relation between measures of financial constraints and hedging. Tufano (1996) and Panousi and Papanikolaou (2012) 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, while Stulz (1996) finds that larger firms hedge more. My results are broadly consistent with Mackay and Moeller (2007) and Acharya, Lochstoer, and Ramadorai (2013), part of a body of work asserting that public firms manage risk to reduce cash flow volatility (Smithson and Simkins 2005).

This paper complements Cornaggia (2013), who finds a positive association between an insurance policy and farm yields at the county level, as well as Pérez-González and Yun (2013), who examine electric utilities' response to the introduction of weather derivatives. It also contributes to the literature on private firm financial constraints (e.g., Saunders and Steffen 2011; Howell 2016). In addition, I measure the pass-through of input cost risk to the consumer. While there are studies of cost pass-through, particularly in the context of exchange rates (e.g., Campa and Goldberg 2005) and oil prices (e.g., Borenstein, Cameron, and Gilbert 1997), there is to my knowledge no causal estimate of risk pass-through.

Researchers examining risk management encounter a number of challenges, including the potential correlation of risk with other determinants of firm value, cross-sectional or survey-based data sources, hedging decisions that are endogenous to firm value, and conflation of speculation and hedging.[6] The highway procurement setting is useful because it does not face these challenges. However, this paper has several 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, I cannot address whether the findings apply beyond the context of imperfectly competitive procurement auction markets. Improving efficiency in government purchasing is important; public procurement constitutes about 10% of U.S. GDP (Cernat and Kutlina-Dimitrova

Haushalter (2006) and Jin and Jorion (2006) do not. Guay and Kothari (2003) argue that in general the magnitude of corporate derivative use is too small to affect firm value.

[6]On the last point, Cheng and Xiong (2014) show that derivative trading is conflated with speculation among commercial hedgers.

2015).

In Section 2, I introduce the setting and the insurance policy, and in Section 3 I discuss data. I propose the estimation strategies in Section 4. I describe the effects of the policy on real outcomes in Section 5, and the cost of risk in Section 6. I address heterogeneity in Section 7. Robustness tests are discussed in Section 8. Concluding remarks are in Section 9.

2 The Highway Procurement Setting and the Kansas Insurance Policy

Like in other U.S. states, the Iowa and Kansas Departments of Transportation (DOTs) use auctions to procure highway construction projects. DOTs initially prepare a public proposal for a project detailing the location and type of work, which includes estimated quantities of materials needed and the expected start date. For example, the proposal might include an estimated five miles of guardrail. Firms submit unit bids for each item, such as $10 per foot of guardrail. The bidder with the lowest vector sum of unit item bids times estimated quantities wins the auction.[7]

In asphalt paving, one of the construction materials (and unit items in contracts) is bitumen, a petroleum product. Also called asphalt binder or asphalt oil, bitumen is a black, sticky material that is mixed with rock pieces to make asphalt. Paving firms face cost uncertainty when they bid on a highway construction project. If oil prices rise between the auction and the start date of the project, the firm's bitumen cost will increase.[8] Auctions are

[7]Specifically, DOTs use simultaneous sealed-bid first-price auctions. DOTs also estimate 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. 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.

[8]I present a simple model of the firm's bidding decision in the Appendix. It shows how a risk premium is included in the bitumen bid markup. I do not address the risk of losing an auction. Interviews I conducted with paving firm executives suggest that paving firms are risk-averse towards input costs but risk-neutral towards an individual auction. Paving 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 upcoming construction season is highly correlated across projects.

mostly held in the winter, while work is done in warmer months. Paving firms are typically paid when work is underway, on average about six months after the auction.

Froot et al. (1993) show that hedging allows firms to invest even in bad cash flow states, so firms are most likely to hedge risk when cash flows are negatively correlated with investment opportunities. My setting exemplifies this situation; highway paving firms are often cash flow constrained at precisely the time of year when they are most exposed to oil price risk. Adam, Dasgupta, and Titman (2007) theorize that financially constrained firms are disincentivized from hedging when they can adjust output to reflect realized cost. In my setting, this cannot occur as output (road construction) is fixed.

In the early 2000s, state DOTs began to shift oil price risk from highway paving firms to the government, believing that any cost to the government of bearing oil price risk would be offset by lower bids (Skolnik 2011). Although most states have implemented such an insurance policy for petroleum products, there has been no quantitative analysis, to my knowledge, establishing that firms charge excessive oil price risk premiums. In the only analysis thus far, Kosmopoulou and Zhou (2014) examine one state, Oklahoma. They find that firms bid more aggressively after the policy, which they ascribe to the winner's curse effect. They assume firms are risk-neutral. To my knowledge, there is no public evidence about these policies' effects on procurement costs.

The Kansas DOT implemented its bitumen insurance policy (called a "price adjustment policy") in August 2006. The policy was motivated by the belief that "The volatile price of the asphalt oil has led contractors to make bids that are more costly than necessary" (Shaad 2006). The precipitating event, according to Kansas DOT 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 bitumen price from suppliers.

Iowa, which is northeast of Kansas, as of the fall of 2016 has not pursued an insurance policy. Iowa DOT officials told me that despite experiencing similar cost escalation, they were not interested in the policy. My interviews with both states' DOTs indicate that neither industry lobbying nor local economic or demographic factors played a role in Kansas' decision to adopt the policy and Iowa's decision not to.[9] There does not appear to by any industry or government motivation for the insurance policy in Kansas other than the circumstantial preference of middle-management DOT officials following the bidding incident described above. Iowa and Kansas were on similar economic growth paths before, around, and after the insurance policy was implemented in Kansas; they had parallel trends in highway spending, basic transportation statistics, and ARRA funding (see Section 4 for details).

The insurance policy operates as follows. The Kansas DOT purchases a regional bitumen price index from a private data firm. It then adjusts payments to the paving firm if the bitumen price index changes between the auction and the time the project begins. When bitumen prices go up, the paving firm is paid the amount of the bid plus the bitumen price index increase, and when prices go down, the paving firm receives the bid less the bitumen price index decrease.[10] Paving firms bidding in Kansas auctions choose whether or not to use the insurance policy when they submit their bids. There is no preferential treatment for certain types of firms. All bidders have opted for the policy (there are a few exceptions, but these appear to be mistakes). Appendix Figure 1 shows the ex-post contract price adjustments over time.

In accepting the bitumen price index, paving firms assume basis risk between the actual price of bitumen and the regional, survey-based index. Note that the physical forward contracts that firms usually sign in the absence of the policy with suppliers are full insurance with no basis risk. If the cost of a physical forward and the state-provided insurance were equal, firms would choose the forward because it is a perfect hedge. However, in Kansas they choose the state-provided insurance. Therefore, the cost of the forward must exceed

[9] Interviews in person, on the phone, or over email were conducted in 2012 with Steven Belzung, Roger Bierbaum, LouAnn Hughes, Kevin Martin, Abe Rezayazdi, Greg Sheiber, and Sandy Tommer.

[10] Specifically, each month the Kansas DOT publishes an Asphalt Material Index (AMI), which they purchase from Poten & Partners. Paving firms incorporate the current month's AMI into their bid for asphalt. The AMI for the month of the letting is the Starting Asphalt Index (SAI) for the contract. DOT technicians take samples from the mix being placed to monitor quality and to obtain a percentage 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 bitumen 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 cost of basis risk in the bitumen price index.

3 Procurement Auction Data

In this study, I employ comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012.[11] I focus on road paving projects, which are bitumen-intensive.[12] A primary outcome variable in the analysis is the unit item bitumen bid, which is the per ton bitumen bid within the larger total project bid. A secondary outcome variable is the total bid for the paving 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 (the overall bid for the project). Bitumen comprises 11.3% of the total bid amount on average for the contracts in my data, but can be up to 40%.[13] Figure 1 shows Iowa and Kansas bitumen bids over time, as well as the crude oil price and historical oil price volatility.

Although its price is highly correlated with crude oil (0.8 in my data), there is no liquid spot or futures market for bitumen in the U.S.[14] In practice, bitumen is purchased from local suppliers in one-off, non-public transactions. Examples of these contracts are in Figures 2 and 3. Suppliers purchase bitumen from refineries and store it. Bitumen is costly to transport and store, so suppliers naturally form a territorial oligopoly (Appendix Figure 2).

Auction data summary statistics are in Table 1. In both Iowa and Kansas the average number of bidders in an auction is 3.4. The time between an auction and the start of a paving project varies from less than a month to 16 months; on average, it is 4.6 months

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

[12] 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.

[13] These projects do not include bridge work or extensive earthwork. For Kansas, the work types I include are called overlay and surfacing. For Iowa, they are generally called paving and resurfacing.

[14] The closest traded commodity is Gulf Coast high sulfur fuel oil (correlation coefficient of 0.95).

in Iowa and 5.7 months in Kansas (this difference is not statistically significant). Iowa and Kansas are similar in their auction format, road characteristics, weather patterns, and firm type distribution. However, Iowa has more paving firms because its highway construction industry is larger. Firms select the projects they bid on, so I use extensive project controls in the analysis.[15]

I also employ data from four other sources. First, I obtain data on firm characteristics from Dunn & Bradstreet's (D&B) database, supplemented with manually collected information from firm websites. Second, 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, based in Iowa, is among the top three firms in number of total bids in the Iowa, and near the mean among regular Iowa bidders in win percentage. Third, I conduct a survey of 20 of the top bidders across both states.[16] Finally, I use oil price and volatility data from Bloomberg (summary statistics in Appendix Table 1).

I use firm characteristics relevant to financial constraints and risk aversion. As shown in Table 2 Panel 1, there are six publicly listed firms in my sample. Among private firms, the majority is family owned (71% in Kansas and 79% in Iowa). I identify a firm as diversified if its activities are not limited to asphalt highway paving, based on 8-digit SIC codes. Note that 60% of firms in Iowa are paving-only firms compared to just 22% in Kansas. I define credit risk to be high when D&B rates the firm as high or medium risk. Credit risk is also different across the states: 34% of asphalt paving firms in Iowa are rated as 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 in the cross-sectional D&B data.[17] The second is whether the paving firm has only one location and is not a subsidiary. Unfortunately, variables like investment and profitability are not available for privately held firms. The correlations

[15] 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.

[16] Interviews were conducted over the phone or in person in 2012. I spoke either with a president, a vice president, or an estimator (prepares bids for DOT auctions).

[17] 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.

among characteristics are shown in Table 2 Panel 2. All correlations are positive except for the one between family ownership and high risk, which is -.02. The highest is 0.49 between firms with a single location and small firms. Undiversified firms are also rough proxies for single location firms.

I use six month WTI oil futures as a measure of the expected oil price.[18] The measures of risk are historical volatility, which is an annualized standard deviation of daily returns, and implied volatility, which is derived from the Black-Scholes (1973) option pricing formula. In the analysis, I primarily use 12-week historical oil price volatility, but show robustness to 26-week and at-the-money implied volatility for oil futures options expiring in three months.

4 Estimation Strategy

I employ a difference-in-differences (DiD) design to estimate the insurance policy's effect. The first analysis asks whether the insurance policy affected the ex-post cost of bitumen for the government of Kansas. The average movement of oil prices between the auctions and the project start dates was positive in the post-policy period. This means that if firms were risk-neutral, Kansas should have experienced an increase in costs after implementation of the insurance policy in 2006.

I use equation 1, where i indicates bidders, j indicates projects (same as the specific auction/contract), and t indicates the day of the auction.

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

The dependent variable ($Cost_j$) is the price paid by the state, including any Kansas adjustments. I also examine the effect on bids and on the number of bidders. The number of bidders is a good proxy for the competitiveness of the auction. $\mathbf{I}_{Post\ Policy_t}$ is an indicator for whether

[18]This follows 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.

the auction took place after August, 2006. $\mathbf{I}_{Kansas_j}$ is an indicator for whether the auction took place in Kansas. The coefficient of interest (β_1) gives the mean difference across states in the actual price paid by the government after implementation of the insurance policy, controlling for the pre-policy difference.[19] The key identifying assumption is that nothing changed in Iowa *at the same time* as the 2006 implementation of the insurance policy in Kansas.

To estimate the effect of risk on bids, I modulate the DiD framework with oil price volatility and use the log bitumen bid ($\ln bid_{ijt}$) as the dependent variable:

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

Here, $price_t^{oil}$ is the oil futures price, and Vol_t^{oil} is its volatility. The coefficient of interest, β_1, is the effect of volatility on bids in Kansas relative to Iowa after oil price risk shifted to the public sector. The competitive equilibrium in Kansas among paving firms and between paving firms and suppliers changed after the policy. Changes unrelated to oil price risk should be subsumed by state and time fixed effects.

Next, I examine cross-sectional heterogeneity in two ways. First, I split the volatility modulated DiD by firm type. Second, I measure risk as the forward market interacted with oil price volatility. That is, I evaluate how oil price volatility affects bids in 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

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

equation is:

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

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. This analysis excludes post-policy Kansas, where there was no risk.

$Controls_{ij}$ 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-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. Except where otherwise noted, the analysis includes all auctions in Iowa and Kansas between 1998 and 2012.

The primary identification concern in the DiD analysis is a violation of the parallel trends assumption. I address this with three types of tests. First, I show that important observables do not exhibit major deviations across Iowa and Kansas around implementation of the insurance policy. Appendix Figure 3 shows that Iowa and Kansas were on similar GDP growth paths before, around, and after implementation of the policy. Appendix Figures 4-7 show parallel trends for total highway spending (capital and maintenance outlays), vehicle miles traveled, the number of DOT contracts, and the total quantity of bitumen DOT required.

Second, to directly test the validity of equation 2, I examine whether bidders in Iowa and Kansas responded to risk differently prior to the insurance policy. Column 1 in Table

10 shows no difference. Third, in robustness tests, I exclude certain years in which my results are likely to be impacted by the financial crisis or the ARRA (see Section 8). Iowa and Kansas received similar amounts of ARRA funding ($4.7 and $4.4 billion, respectively, relative to a national per-state average of $10 billion and standard deviation of $11 billion).[20]

5 Real Effects of the Insurance Policy

In Table 3, I show raw average bids, ultimate project costs, and number of bidders across Iowa and Kansas and around implementation of the insurance policy. Before the policy, Kansas paid $36 more per ton of bitumen than Iowa. After the policy, Kansas paid $28 less; this amount reflects the lowest bid and any price adjustment from the policy.

Iowa has more road paving projects and they are more bitumen-intensive (see Table 1). Since the per-ton cost decreases with scale, bitumen bids in Kansas were higher before the insurance policy than those in Iowa. Examining all bids, I find a narrowing difference around implementation of the policy. Bids in Kansas were $28 per ton higher before the policy and $15 higher after.

Table 4 shows results from estimating equation 1. Column 1 shows that Kansas' insurance policy yielded savings of $43 per ton of bitumen, or 9% of the average per-ton cost. The estimate implies that Kansas saved around $77 million in the 6.5 years after implementation of the policy, relative to total bitumen expenditure of about $820 million. The dependent variable in column 1 reflects both the bids and any adjustments from the insurance policy. Note that if realized bitumen prices after implementation of the policy were systematically lower than market expectations, the price paid could be lower for Kansas than Iowa without any risk premium change. However, as mentioned above, oil prices on average increased between the time of the auction and the time work began after the policy. Also, Kellogg (2010) and Alquist and Kilian (2010) find evidence that the current spot price is the best forecast of future oil prices.

The average bid also decreased after the policy; when I replace the dependent variable

[20]ProPublica Recovery Tracker, available at https://projects.propublica.org/recovery/.

in equation 1 with all bids, column 2 shows that the policy decreased the average bid by 7.6%. I also estimate a within-Kansas DiD comparing the bitumen-intensive contracts in the main analysis to contracts that include little bitumen (e.g., a contract for mainly bridge building). These estimates, in Appendix Table 4, reflect similar savings as a result of the policy of $49-$54 per ton of bitumen.

In a winner-take-all auction setting where firms face a common risk, Liu and Parlour (2009) argue that when firms invest in a hedging portfolio that is not contingent on the auction outcome, losing firms are over-hedged, and firms compete away the benefits of hedging. Hedging leads to a loss in social welfare borne by the seller. In highway paving, the forward bitumen contracts are contingent on winning the auction, allowing firms to hedge without competing away rents. Liu and Parlour conclude that "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, and benefited from eliminating firms' need to hedge.

In the second part of Table 4, I examine competition. Like in many industries, highway construction is characterized by imperfect competition. Inelastic demand, high barriers to entry, information asymmetry, easy defection detection, and a static market environment are all conducive to collusion and are features of highway procurement (Porter 2005). Bajari and Ye (2003) note the widespread incidence of cartels in procurement auctions, while Porter and Zona (1993), Pesendorfer (2000), Gupta (2002), and Ishii (2008) demonstrate collusive bidding in highway procurement specifically.

The insurance policy increased competition in Kansas relative to Iowa. Using the number of bidders in the auction as the dependent variable, the results in column 3 in Table 4 show that the insurance policy increased the number of bidders in auctions by 0.8, relative to an average of 3.4. The distribution of winning bids also changed after the policy. In Figure 4, the bar heights indicate the win percentages by number of firms in each category of auction. Kurtosis and skewness both declined significantly after the insurance policy; the former from 4.9 to 3.0. 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.

Paving firms and bitumen suppliers are in oligopolistic, territorial equilibria. Appendix Figures 8-12 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. Other major bidders exhibit similar patterns. Spatial oligopoly is a natural result of high transportation costs; even with perfect competition rents would be zero on territory boundaries and positive within. In an interview, a CEO said that imperfect competition permits even very risk averse pavers to stay in business.

The bitumen suppliers form 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 might serve as a signaling mechanism, as in Friedman (1971).[21] The suppliers apparently charge the pavers a large fraction of, if not their full, cost of risk.

Thus this context features imperfect competition in two layers of product markets. It seems likely that imperfect competition compounds financial frictions to impede efficient risk allocation, 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.

[21] Friedman (1971) writes: "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."

6 Insurance Policy Effect on Risk Pass-Through

The Kansas insurance policy reduced bid sensitivity to oil price volatility. Table 5 shows estimates of equation 2. The value of -0.14 for β_1 in column 1 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. Using the log total bid per ton of bitumen as the dependent variable (column 2) gives a similar coefficient of -0.15. Paving firms in Kansas faced zero oil price risk after implementation of the policy, so the difference between Iowa and Kansas indicates the implied cost of managing oil price risk over this period. Since the post-policy mean of historical volatility is 30%, the average cost to firms in my data of bearing oil price risk is 4.2% ($30 \cdot 0.14$).

Varying fixed effects sheds light on the mechanism. The primary specification includes county fixed effects, which permit recomposition (firm exit and entry) within a county. If excluding county fixed effects reduces the insurance policy's measured effect, the policy allowed new and more efficient firms to enter the county. In Table 9 column 4, I omit county effects and find a similar result of -.17. With firm instead of county fixed effects, the coefficient of interest on the triple interaction is slightly larger, at -.18 (Appendix Table 5 column IV). Thus the main result does not reflect firms expanding into new markets. The policy appears to create value for existing firms.

The large effect of the policy on risk sensitivity raises the question of how this industry manages risk in the absence of state-provided insurance. In general, firms can manage risk with hedges, insurance, diversification, or cash holdings. Paving firms typically fully insure by signing physical forward contracts with suppliers before the auction.[22] Sometimes paving firms wait to sign a physical forward contract in the period between the auction and the time work begins, and occasionally they buy bitumen at the time work begins with no prior fixed price. Very rarely, if ever, do paving firms hedge in financial markets. Interviewees

[22] 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. The supplier must have sufficient bitumen stored to cover all contracted supply. Suppliers buy bitumen from oil refineries, which produce it year-round as a byproduct.

suggested that public firm subsidiaries often wait to sign physical forwards. They likely are able to draw liquidity from their corporate parents if an oil price shock occurs. While the parent may trade derivatives at a global level, the subsidiary is not involved in that trading.

The physical forward contracts are a reservation price of hedging; if firms choose forward contracts rather than hedging in financial markets, the latter must be at least as costly. The counterparties in the forward contracts are suppliers. They buy and store bitumen year-round, so at the time of an auction, they are partially physically hedged against the short positions they are taking in their contracts with paving firms. Nonetheless, in the supplier-paver relationship, the supplier generally has downside risk while the paving firm has upside risk. If the supplier has total bargaining power, the forward price could include both sides' risk premiums. Volatility helps explain why the price in the 2009 contract in Figure 3 is so much higher than the 2008 contract in Figure 2, even though oil prices fell across the two dates. Volatility was quite low in early 2008 but peaked at over 70% in early 2009 (Figure 1).

I use the 105 Firm Z forward contracts to estimate the risk premium in the forwards relative to the bitumen index price.[23] This also gives an upper bound on the basis risk from using the index. 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 spring or summer). These risk premiums are graphed in Appendix Figure 13. The average risk premium is 24% of the forward contract price, and its standard deviation is 10%. By choosing the index over their forward contracts, paving firms avoided paying the premium but take on basis risk. Since paving firms use the index when it is available and forward contracts otherwise, the basis risk in the index can be inferred to be no more than 10%. Paving firms must perceive hedging in financial markets as costlier than both of these options.

[23]Firm Z's per ton contract prices for bitumen are graphed in panel A of Figure 5. The contracts are tied to a specific Iowa DOT paving project, so I observe the bid item markup over the contract price. The markup is stable at around $22 per ton regardless of oil prices or volatility (Figure 5, panel B). Interviewees indicate that this fixed markup reflects transportation costs, and profit margins are usually loaded on bid items for labor and overhead. Although not central to my analysis, this suggests that the cost of risk is embedded in the forward contract.

My result that paving firms place a high value on risk management is incongruous with two facts: (a) oil has notably liquid derivative markets; and (b) evidence indicates that excess returns to holding oil futures (the simplest hedge) should be quite small. There is no general consensus on the oil price risk premium, but researchers have been unable to reject a zero risk premium for long-only commodity portfolios (Erb and Harvey 2006; Basu and Miffre 2013). 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. Gorton, Hayashi, and Rouwenhorst (2012) show that commodity returns are negatively correlated with inventories. Ahn and Kogan (2011) report an oil equity beta of 0.01 between 1971 and 2010. One-factor betas change sign over time, and are rarely more than 0.5 (see Appendix Figure 14), implying a premium of at most 1.5%. Note that correlation between macroeconomic growth and oil prices may depend on the source of the shock. Economic growth may induce a positive demand shock, increasing prices, while a positive supply shock may decrease prices, having a positive effect on growth (Anderson, Kellogg, and Salant 2014).

The simplest hedging strategy is to purchase oil futures.[24] This requires a performance bond, or "margin," which is marked-to-market every day and changes with volatility.[25] A thought experiment supposing that an average firm in my data used oil futures to hedge its annual bitumen needs illustrates how much this might cost. Figure 6, using historical margin requirement data from CME, shows the results of this exercise.[26] The margin account averages about $150,000. The dots below zero are instances when oil prices declined and the

[24]The more complex 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 and complex strategy. 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. Second, the firm could invest in an ETF tied to oil prices. 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' use of these vehicles is information asymmetry. Large public companies have access to complex OTC tools, particularly collars and swaps, whose requisite scale makes them inaccessible to small, private firms.

[25]A bank or speculator may post collateral (e.g., Treasury bills or gold) initially and to maintain the margin, but a firm (especially a private one) would likely fund a margin uncollateralized.

[26]Contact the author for details.

account has no cushion. The firm must wire in money within 24 hours or have its positions liquidated. In the absence of a volatility-driven percentage change in margin, a $1 drop in the price of oil requires an immediate wire of $16,000.

The cost of hedging is the cost of capital in the margin account. A financially constrained firm by definition has a high cost of borrowing. If a firm were able to borrow at 5% (likely a low assumption), the cost of capital dedicated to hedging in our example is about $2.26 per ton of bitumen. A formal model for the cost of capital problem is Gârleanu and Pedersen's (2011) "margin CAPM." Although 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 account for the cost of risk that I observe. It does, however, confirm the relevance of funding constraints to derivative markets.

My regression results indicate a 4.2% average cost of risk (Table 5). The implied cost of capital that equates this cost of risk with the cost of hedging in futures markets is around 25%.[27] While this seems large, it implicitly includes other costs of hedging in financial markets that are essentially zero with physical forward contracts: exposure to cash flow risk during the hedge period, employee time to manage the account, basis risk, and transaction fees. Economies of scale have been shown to be further barriers to hedging in financial markets for small firms (Mian 1996, Géczy et al. 1997, Haushalter 2000). Interviewees consistently viewed hedging in financial markets as complicated and expensive gambling. This is another reason firms may not hedge in financial markets: information costs or lack of sophistication.

The Kansas DOT did not hedged its oil price risk between 2006 and the end of my sample in 2012. Administrative annual costs of the policy are around $36,750.[28] I repeat the

[27]Four percent of the overall average bid of $318 is $12.7. With an initial margin account of $150,00 to hedge 2,970 tons of bitumen with 16 oil futures contracts implies a 25% cost of capital $\left(\frac{1}{12.7} \cdot \frac{150{,}000}{2{,}970}\right)$.

[28]Interviews led to the following estimates. The insurance policy requires a $5,295 per year subscription

futures hedging thought experiment for the state instead of the firm. To hedge state-wide annual bitumen needs, Kansas would initially need \$3.2 million in its margin account (about one-fourth the annual savings from the insurance policy of \$12 million).[29] If the state can borrow at 1%, the cost of capital would \$21,250 per year on average, or about 46 cents per ton of bitumen.[30] This compares with \$2.26 per ton for the paving firm if it borrows at 5%. This calculation demonstrates the simple fact that all else equal, risk should be allocated to the party in a transaction with a lower cost of bearing it.

7 Heterogeneity in the Cost of Risk

State-provided insurance should disproportionately benefit paving firms with higher costs of bearing risk, but it is not immediately obvious which firms should derive the most benefit. One one hand, I expect private firms to have a higher cost of external finance than public firms and to be more risk averse because they have less diversified owners. On the other hand, there may be no difference if public firms have risk-averse managers and agency problems (Stulz 1984), or if firms hedge for informational reasons, such as to reduce noise in their accounting statements (DeMarzo and Duffie 1995, Breeden and Viswanathan 1998).

Predictions from theory are clearer for other firm dimensions. First, small firms usually have fewer collateralizable assets than large firms, so they face more severe financing constraints (Nance, Smith, and Smithson 1993; Hennessy and Whited 2007). Second, I expect that if distress costs are related to the value of insurance, as Froot et al. (1993) suggest, firms with higher credit risk or less industry diversification will likely benefit most from the insurance policy. Industry diversification is a natural hedge. Firms that only pave asphalt roads should face a higher probability of distress from an oil price spike.

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to Poten & Partner's bitumen price index, and about one hour of employee time per project. There were 166 projects post-policy. I assume employee time is valued at \$30/hr in real terms between 2006 and 2012.

[29] I assume the state buys 253 oil futures contracts, has a 10% margin and that oil is at its post-policy average of \$84 per barrel.

[30] The state can borrow with tax-exempt bonds at low interest 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.

Family-owned firms permit a rare test of owner diversification within private firms. Owners of family firms are usually also managers and have the bulk of their wealth tied to the firm. These manager-owners may maximize personal utility and smooth income through the firm (Shleifer and Vishny 1986; Schulze et al. 2001; Bertrand and Schoar 2006). If the undiversified ownership contributes to the risk premium, I expect family firms to have a higher cost of bearing oil price risk.

The insurance policy in Kansas seems to have increased competition. I estimate the effect of the policy on the probability that a certain type of firm won the auction. The dependent variable is 1 if the firm won the auction, and 0 if not. Columns 4 and 5 in Table 4 show that private firms are 19 percentage points more likely to win after implementation of the insurance policy than before, relative to a mean of 74%. Similarly, the policy increased the probability of winning for paving-only firms by 20 percentage points relative to diversified firms.[31] I do not find statistically significant differences in the probability of winning across the other characteristics.

I explore heterogeneity in the cost of risk across firm types in two ways. First, I split the sample. The results in column 3 of Table 5 show that the insurance policy's effect is -0.14 among private firms, and the results in column 4 show that it is -0.079 among public firms (significant at the 1% and 5% levels, respectively). Columns 5 and 6 show that the difference across family-owned and non-family-owned firms is much smaller, at -.12 and -.097.

Columns 1 and 2 in Table 6 show that within the sample of private firms, the insurance policy's effect is -.24 for high credit risk firms, while it is only -.12 for low credit risk firms. This implies a cost of oil price risk for high credit risk firms of 5.9%, compared to 3.1% for low credit risk firms.[32] The coefficient among single-location, non-subsidiary firms is -0.18, relative to an insignificant -0.0031 for other firms (Table 6, columns 3 and 4).

Similarly, the coefficient is -0.19, significant at the 1% level, for paving-only firms and an insignificant -0.084 for diversified firms (Table 6 columns 5 and 6). Mackay and

[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 versus public and paving-only versus diversified are 2.8 and 4, respectively (Appendix Table 6).

[32] This does not reflect an overlap with family ownership; in Appendix Table 7, I show a similar result when I compare high risk, non-family-owned firms with low risk, non-family-owned firms.

Moeller (2007) and Faccio, Marchica, and Mura (2011) also find that well-diversified firms are less risk-averse.[33] Finally, when I use the secondary size metric (based on revenue and employment), there is less variation; -.15 for small firms and -.091 for large firms (columns 7 and 8, respectively). Extensive project controls ensure that projects are not systematically and observably different across firm types (see also Appendix Tables 2 and 3). Equation 2 is too complex for an additional set of interactions, so I cannot test whether these differences are statistically significant.

To combine firm types in a single model, I turn to an alternative risk measure: the square root of months between auction and work start interacted with oil price volatility. I interact this risk object with an indicator for firm type (equation 3). Table 7 shows that public firms have a significantly lower cost of risk management than private firms; the coefficient on the triple interaction is -.065, significant at the 5% level (column 1). In the public-private case, credit risk creates noise within the private sample. When I limit the sample to low credit risk firms, the coefficient increases to -.09, significant at the 1% level (column 2).

In Table 7 columns 3-5, I find no difference between family and non-family owned firms. In Table 8, I find a coefficient of .04 for paving-only firms relative to diversified firms (column 1, significant at the 10% level), which increases to .06 and becomes highly significant when I limit the sample to low credit risk firms. I examine single location firms relative to multiple location firms, and find similar results in columns 4-6. Finally, I examine high versus low credit risk. As expected, the former have a much higher cost of risk, particularly when measured within private firms, as the results in columns 7 and 8 show.

Three mechanisms could drive heterogeneity in risk premiums: cost of capital, effective risk aversion, and risk-varying bargaining power. In the Froot et al. (1993) framework, the first two are sides of the same coin, because high external finance costs drive risk aversion. The third mechanism requires bargaining power to vary with risk, because the modulated DiD isolates the effect of risk. I find a much weaker effect of firm size on the cost of risk than other characteristics, making it unlikely that bargaining power alone explains the main

[33] Again, the diversification result is not driven by family owned firms (see Appendix Table 7 column I).

results. However, I cannot rule out that the mechanism is narrowly related to a certain product market equilibrium.

My results could reflect varying costs of capital if firms have homogenous risk aversion. Some paving firms may have the scale or liquidity to hedge more cheaply in financial markets. The interviewees with executives contradicted this hypothesis. They said that the variation reflects some firms' willingness to forego signing a forward contract at the time of the auction. By waiting to sign these contracts, they take on risk between the auction and the start of work. Other firms always insure, signing regardless of the price. In combination with my empirical results, the interview evidence suggests that while capital costs may contribute to why no firms in this market insure with financial derivatives, costly distress is most responsible for the within-sample heterogeneity.

Why don't public or private equity firms acquire the small, private firms with high costs of risk? One reason is the private and non-pecuniary benefits of control; many of the small family-owned firms are not for sale at a reasonable price. A second reason is state anti-trust measures. State governments take steps to try to achieve competitive bidding, and forbid subsidiaries of the same firm from competing with one another.

8 Robustness Tests

I begin with robustness tests of the policy effect on the costs to Kansas' DOT in Appendix Table 8 (main specification in Table 4 column I). First I consider a narrower bandwidth around the policy, only using years 2004-2009. The effect increases to $68 per ton (column I). The effect also increases when I omit controls (column II). Columns III-V show that the main result is robust to alternative fixed effects, although it decreases by about half when I omit month-of-year and year effects. Columns VI-IX show that the result remains highly significant with alternative assumptions about standard errors: robust with no clusters, and clusters in state-month, firm-month, and firm-state.

The most important robustness tests are for the modulated DD (main specification in Table 5 column I). This complex estimation rests on a number of assumptions. The first set of tests 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.

The main specification does not interact volatility with all right-hand side covariates. This assumes that the average of the non-interacted controls apply equally across volatility levels, which may not be the case. While there are too many fixed effects to interact each with volatility and maintain power, I do show in Table 9 column III that when auction and bidder controls are omitted, the coefficient on the modulated DD increases to -0.19. Therefore these controls do not independently determine the result. Column IV omits the county fixed effects, leaving only year effects. The result is essentially unchanged at -0.17.

Alternative specifications for standard errors are state-month clusters in Table 9 column V and no clusters in column VI. Further alternative error assumptions are in Appendix Table 9 columns I-IV; the significance at the 1% level is unchanged with firm-month, firm-month-of-year, firm-state, and month clusters. If there are unobserved firm-specific exposures, these alternative assumptions about the residual should have rendered the main effect less significant.

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. Table 10 column II shows that the effect is -0.13 excluding 2009. Column III excludes post-2009 years, due to any potential concerns with macroeconomic effects in this later period. Placebo tests are in columns IV and V, 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.

Despite the demonstration of parallel trends in Section 4, there may be concern that the results reflect unobservable time-varying differences across Kansas and Iowa. I conduct a within-Kansas modulated DD design comparing bitumen to non-bitumen items. Non-bitumen items are summed together, so that the total bid has two parts. The dependent variable is the item bid if $\mathbf{I}_{Bitumen}$=1, and the sum of the non-bitumen items if $\mathbf{I}_{Bitumen}$=0. The results are in Appendix Table 4. The effect of volatility on the bitumen relative to non-bitumen items after relative to before the policy is -.44 (column I). This indicates that a 100% increase in volatility had a 44% smaller effect on bitumen item bids after the policy, relative to the non-bitumen items. It is robust to including firm fixed effects (Appendix Table 4 column II).

Appendix Table 5 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 also conduct a falsification test, where the dependent variable is the total bid excluding the bitumen bid item. The coefficient on the triple interaction is now 0.06, likely reflecting oil intensity (e.g. in diesel fuel) throughout the project (column III). Column IV omits month-of-year fixed effects, which yields about the same result as the main specification (-.15).

Volatility is a continuous variable, and is thus sensitive to outliers; further, my specification assumes a linear effect. To ensure that neither non-linearity nor outliers explain the effect, I show similar results using quantile dummies. Appendix Table 9 columns V-VI use 10 and 20 quantiles of volatility, respectively, and finds that the triple interaction effect remains negative and highly significant.

There is concern that time-varying state highway spending or state-level construction activity could bias the results. These would not be captured with separate state and year fixed effects. Appendix Table 5 columns VI and VII use state-year and state-month fixed effects, respectively, which will control for this type of state-level time variation. The first specification finds a slightly larger result of -.2, while the second finds a somewhat smaller one of -.1. Both are highly significant. Column VIII uses quarter fixed effects. There may be concern that firm selection into auctions explains the result. While I do find that the policy changed the firm mix (see Table 4), firm selection does not explain the average risk pass-through result. Appendix Table 5 column IV uses firm fixed effects. Rather than the effect disappearing, there is actually a slightly larger effect than in the main specification.

Alternative oil measures are in Appendix Table 5 columns IX-XI. With implied volatility, the effect increases to -0.36, reflecting implied volatility's lower variability. The coefficient is unchanged using 26-week historical volatility instead of 12-week volatility. Column XI uses 5-month futures instead of 6-month, and finds a very similar coefficient of -0.13.

I test whether the effect of the policy is as strong for the 19 firms who bid in both states. Appendix Table 10 shows that the main effect is not statistically significant and has a magnitude of -0.7 among these firms. 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.

Last, I examine within-Kansas effects across firm types. My main heterogeneity findings should translate to certain Kansas firms being relatively less sensitive to volatility after the policy. Appendix Table 11 shows estimates in which the coefficient of interest interacts either $\mathbf{I}_{Public_j}$ or $\mathbf{I}_{High\ Risk_j}$ with the policy and volatility. As expected, public firms submitted relatively higher bids after relative to before the policy in response to additional volatility (columns I-II), and high risk firms submitted relatively lower bids (columns III-IV). I have much less power since there is less data, and I do not find statistically significant effects for the other characteristics.

9 Conclusion

In a highway procurement setting, I show that government-provided insurance against oil price risk is valuable to firms and reduces procurement costs. Financial constraints and costly distress best explain why some firms find value in relaxing constraints on risk management. Firms that are publicly listed, are diversified across industries, and have low credit risk charge lower risk premiums.

The value of government insurance depends on the cost of hedging privately. The combination of financial frictions and imperfect competition, which plague many sectors, may prevent product markets from exploiting efficient markets for risk. The market failure observed here is troubling given the liquidity and complexity of U.S. derivative markets. If credit constraints and other frictions prevent small firms from using derivatives, there may be demand for simple, low transaction-cost risk management markets or aggregation services.

When they support small firms, governments usually hope to foster entry, reduce price, or promote innovation. Kansas' insurance policy has a positive effect on the first two of these goals. Insurance may be an alternative to subsidies. Consider the standard mean-variance utility framework $V = \mathbf{E}(C) - \rho\sigma$. Small firm subsidies traditionally increase C. An alternative is a mean preserving spread to reduce ρ (Rothschild and Stiglitz 1970). Governments could exploit their risk neutrality and low cost of capital to transition some small business support from costly subsidies to costless risk management products. For example, firms could be insured against currency risk or weather disasters. Innovative startups with high-risk, high-return projects – a frequent target of government support – could be insured against observable sector or financing risks.

More generally, my results are relevant to settings where there is a question of which party in a transaction should bear risk. For example, a related policy question is capital requirements for banks hedging interest rate risk, currently under consideration by the Basil Committee on Banking Supervision (BIS 2015). Banks can issue fixed rate instruments (like mortgages) and hedge the risk in derivative markets. If they face surcharges in the form of capital requirements for their own hedging activities, they may forego fixed rate instruments. This may be costly if it forces a more risk averse customer to bear the risk.

Which party in a product market should provide insurance is related to the ability to enforce payment. In the market studied in this paper, the pecking order of enforcement ability is the state, local supplier, and finally derivative counterparty. Hedging is expensive due to default risk. To insure in financial markets, a firm must collateralize its promises in the form of a margin account. In such arm's length contracts, the counterparty does not know that the firm has a certain contract with the state. The state has no need for collateral, as it pays out insurance when it pays the firm.

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

Panel 1: Contracts (Auctions)

	Iowa		Kansas		Diff	All	
	Mean (sd)	N	Mean (sd)	N	Iowa-Kansas[†]	Mean (sd)	N
Number of 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		Diff	All	
	Mean (sd)	N	Mean (sd)	N	Iowa-Kansas[†]	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 auctions (synonym for contracts or projects) used in the analysis. Panel 1 is at the contract level, while panel 2 is at the bid level. I include only bitumen-intensive highway paving projects. [†]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 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. Panel 1 shows the number of firms in various categories (except for the bottom row, which summarizes firm age). Panel 2 shows the correlation of these characteristics across firms (each firm is one observation). †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 3: Summary Statistics of Iowa and Kansas Auction Data Before and After Price Adjustment Policy

	Before Policy					After Policy				
	Iowa mean (sd)	N	Kansas mean (sd)	N	IA-KS†	Iowa mean (sd)	N	Kansas mean (sd)	N	IA-KS†
Bitumen bid ($ per ton)	196 (44)	2,824	224 (73)	1,166	-28***	469 (95)	1,845	484 (125)	1,049	-15***
$/ton paid ex-post	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 4: Risk Shifting Policy Effect on Real Outcomes

Dependent variable:	$/ton to 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 Equation 1. 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. The number of bidders is also included in I and III. Standard errors clustered by firm. *** $p < .01$.

Table 5: Marginal Effect of Oil Price Volatility

Dependent variable: Log bitumen bid (except II)

	I: Full Sample	II. Dep Var=Log total bid per ton bitumen	Sample Split by Ownership Type 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***	-.079**	-.12**	-.097**
	(.035)	(.072)	(.049)	(.026)	(.059)	(.049)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.75***	.33***	.71***	.84***	.76***	.74***
	(.042)	(.089)	(.037)	(.17)	(.037)	(.076)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.44***	.44*	.43***	.17*	.37*	.29*
	(.12)	(.24)	(.16)	(.095)	(.2)	(.16)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.038	.17**	.04	-.073	.011	-.0081
	(.029)	(.068)	(.04)	(.045)	(.043)	(.045)
Vol_t^{oil}	.00068	.0056	-.009	.047	-.0075	.0048
	(.0092)	(.01)	(.0077)	(.041)	(.0071)	(.021)
$\mathbf{I}_{Kansas_j}$	-.017	2.1***	-.011	.42**	.07	.16
	(.096)	(.23)	(.13)	(.14)	(.13)	(.15)
$\mathbf{I}_{Post\ Policy_t}$	-2.3***	-.93***	-2.1***	-2.5***	-2.3***	-2.2***
	(.13)	(.25)	(.12)	(.48)	(.13)	(.23)
$\ln price_t^{\text{oil}}$	.27***	.14***	.24***	.29**	.27***	.26***
	(.032)	(.042)	(.032)	(.12)	(.041)	(.061)
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	4991	894	3609	2254
R^2	0.922	.97	0.930	0.896	0.939	0.906

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:

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

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. In III, V, and VI, $\mathbf{I}_{SmallFirm_i}$ is also a control. Standard errors clustered by firm. *** $p < .01$.

Table 6: Marginal Effect of Oil Price Volatility; Sample Splits within Private Firms

Dependent variable: Log bitumen bid

	Credit Risk		Single location, non-subsidiary		Diversification (Yes=paving only)		Size	
	I. High	II. Low	III. Yes	IV. No	V. Yes	VI. No	VII. Small	VIII. Large
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	-.24*	-.12**	-.18***	-.0031	-.19***	-.084	-.15***	-.091*
	(.12)	(.051)	(.052)	(.12)	(.056)	(.11)	(.048)	(.045)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.86***	.69***	.6***	.75***	.71***	.78***	.71***	.85***
	(.12)	(.038)	(.07)	(.045)	(.055)	(.058)	(.046)	(.069)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.79*	.35**	.58***	-.049	.61***	.24	.48***	.24
	(.43)	(.17)	(.17)	(.41)	(.19)	(.39)	(.16)	(.15)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.31***	.0067	-.011	.0071	.023	.057	.032	-.026
	(.062)	(.039)	(.048)	(.076)	(.043)	(.065)	(.039)	(.047)
Vol_t^{oil}	-.059***	-.0036	.039	-.011	-.014	-.0046	-.0098	.003
	(.017)	(.0084)	(.028)	(.0067)	(.013)	(.0093)	(.011)	(.014)
$\mathbf{I}_{Kansas_j}$	-.89***	.1	.087	.15	.038	-.067	.012	.21
	(.21)	(.13)	(.16)	(.24)	(.14)	(.19)	(.13)	(.16)
$\mathbf{I}_{Post\ Policy_t}$	-2.5***	-2.1***	-1.9***	-2.1***	-2.2***	-2.2***	-2.2***	-2.5***
	(.4)	(.12)	(.22)	(.14)	(.17)	(.19)	(.15)	(.21)
$\ln price_t^{\text{oil}}$	.17***	.25***	.099**	.33***	.18***	.33***	.21***	.35***
	(.06)	(.034)	(.043)	(.035)	(.041)	(.046)	(.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	633	4358	1584	3355	2795	1977	3498	2387
R^2	0.960	0.928	0.905	0.949	0.930	0.951	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. Only private firms are included. †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. In I-VI, $\mathbf{I}_{SmallFirm_i}$ is also a control. Standard errors clustered by firm. *** $p < .01$.

Table 7: Ownership Effects with 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:

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

Sample limited to certain types of firms (e.g. low credit risk firms in II). †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: Diversification, Size, and Risk Effects in Alternative Risk Measure

Dependent variable: Log bitumen bid

$X_j =$	Paving only (vs. diversified)			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:

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

Sample limited to certain types of firms (e.g. private firms in II). †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 (Part 1)

Dependent variable: Log bitumen bid

	Single Differences		Controls		Errors	
	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)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			-.19***	-.17***	-.14*	-.14***
			(.035)	(.037)	(.073)	(.04)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			.57***	.77***	.75***	.75***
			(.036)	(.041)	(.11)	(.036)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	-.017	-.097***	.58***	.54***	.44*	.44***
	(.016)	(.027)	(.12)	(.12)	(.24)	(.13)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$			.066**	.037	.034	.034
			(.031)	(.03)	(.054)	(.034)
Vol_t^{oil}	.052***	.013	-.026***	.0062	.00031	.00031
	(.013)	(.04)	(.0089)	(.0097)	(.023)	(.0078)
$\mathbf{I}_{Kansas_j}$	.12***	.12***	-.097	.0037	.0033	.0033
	(.012)	(.022)	(.099)	(.099)	(.17)	(.11)
$\mathbf{I}_{Post\ Policy_t}$	.11***	.69***	-1.7***	-2.3***	-2.2***	-2.2***
	(.032)	(.061)	(.12)	(.13)	(.34)	(.12)
$\ln price_t^{\text{oil}}$	.055*	.24***		.27***	.27***	.27***
	(.03)	(.038)		(.033)	(.059)	(.021)
Controls†	Y	Y	N	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	N	Y	Y
N	6111	1780	6111	6111	6111	6111
R^2	0.912	0.937	0.917	0.914	0.922	0.922

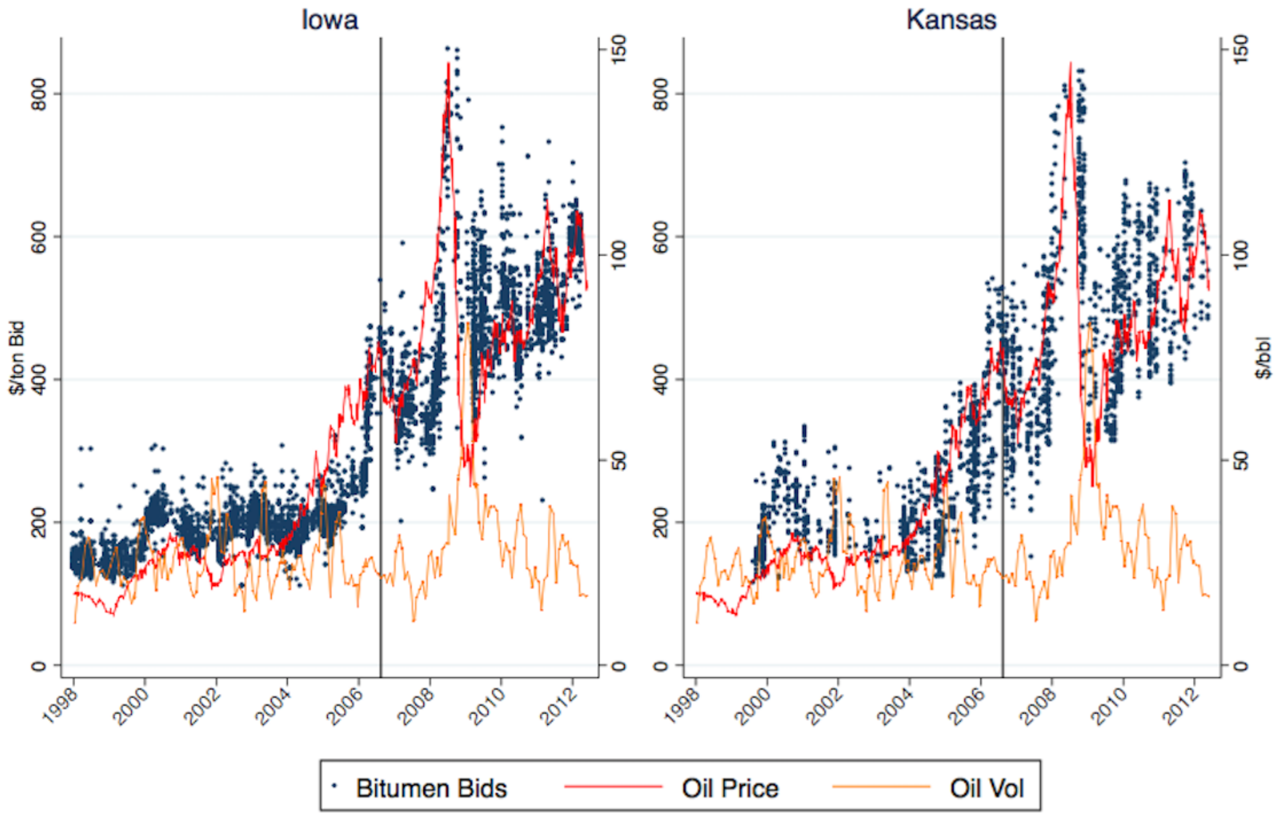
Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 2. The dependent variable is the log bitumen item bid. †Unreported controls are 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. *** $p < .01$.

Table 10: Select Robustness Tests (Part 2)

Dependent variable: Log bitumen bid	Time Frame			Placebos	
	I. Parallel trends (before policy)	II. Excluding 2009	III. Excluding post-2009	IV. 2002	V. 2008
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$		-.13***	-.15***	-.069*	-.071*
		(.05)	(.037)	(.039)	(.041)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$		.83***	.78***	-.031	.21***
		(.06)	(.047)	(.025)	(.032)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$		.42**	.45***	.23*	.22
		(.16)	(.13)	(.13)	(.14)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	-.013	.068**	.009	.086**	.054*
	(.032)	(.029)	(.032)	(.035)	(.027)
Vol_t^{oil}	.023***	.0042	.034**	.07***	-.014*
	(.0089)	(.0086)	(.014)	(.018)	(.0077)
$\mathbf{I}_{Kansas_j}$	.16	-.11	.081	-.17	-.06
	(.11)	(.097)	(.1)	(.11)	(.088)
$\mathbf{I}_{Post\ Policy_t}$		-2.5***	-2.3***	.1***	.11***
		(.18)	(.15)	(.032)	(.031)
$\ln price_t^{\text{oil}}$	.36***	.35***	.29***	.058*	.13***
	(.011)	(.034)	(.035)	(.032)	(.029)
Controls†	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y	Y
N	3532	5554	5111	6111	6111
R^2	0.549	0.915	0.896	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: 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

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

Sold To: 227
[redacted]

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

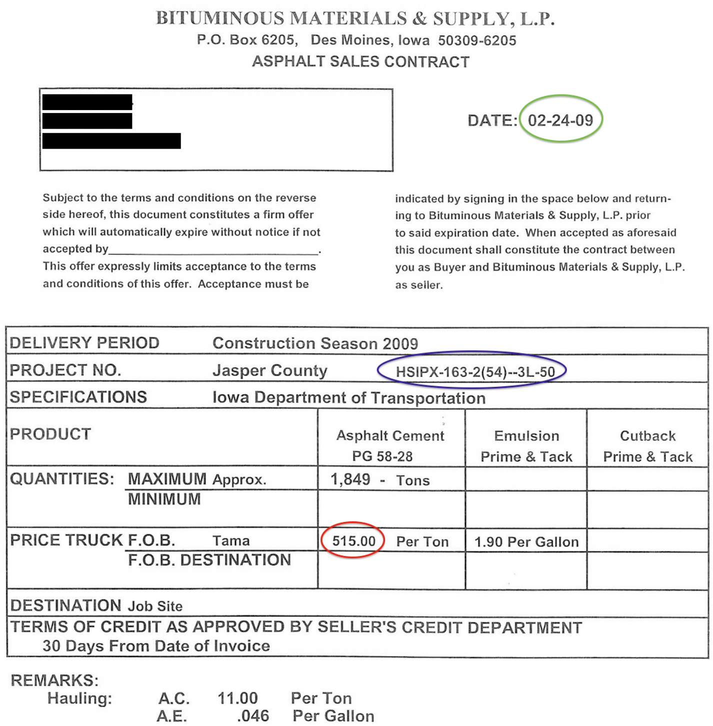
FLINT HILLS RESOURCES, LP ("Seller")

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 3: 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

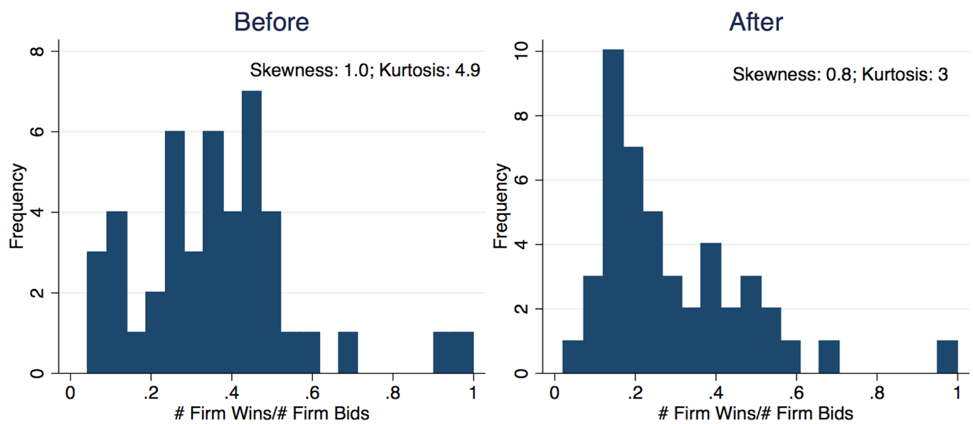
Subject to the terms and conditions on the reverse side hereof, this document constitutes a firm offer which will automatically expire without notice if not accepted by____________________.
This offer expressly limits acceptance to the terms and conditions of this offer. Acceptance must be indicated 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

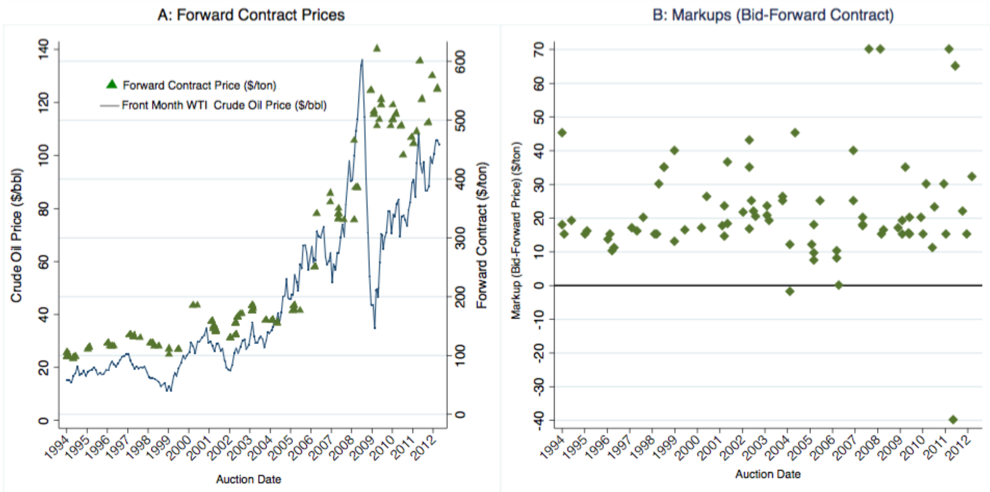
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 4: Kansas win distribution around risk shifting policy



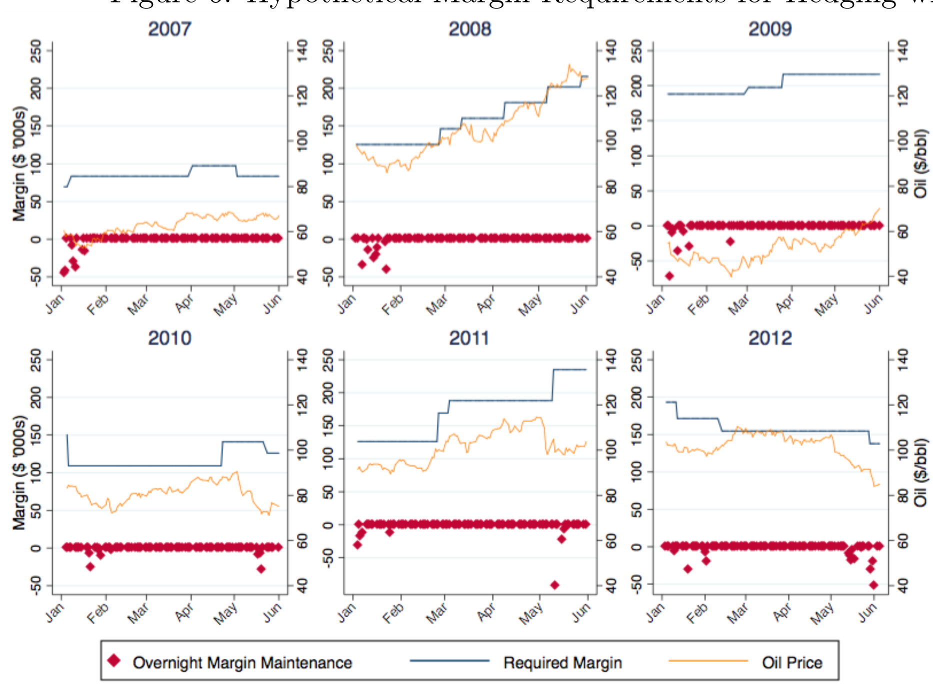
Note: These figures show the frequency of of firms by win percentage. The changing distributions indicate that after the policy wins were more evenly spread across firms.

Figure 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.