Relaxing Constraints on Risk Management:

Evidence from a Natural Experiment

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Abstract

Financial constraints and distress costs can lead firms to value risk management, yet these same frictions can prevent them from hedging in financial markets. In turn, firms may pass these frictions on to the product market. This creates a potential opportunity for a public hedging program to improve efficiency. I use a quasi-experiment in which a state government insured highway-paving firms against oil price risk to tease out these frictions. I show that the insurance policy reduced procurement costs and increased competition. Consistent with financial frictions having restricted firm access to hedging, I find that the greatest value from insurance is derived by firms with private ownership, high credit risk, and low industry diversification; with no effect at all for public firms. My estimates imply a cost of capital of 25% for the affected firms.
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1 Introduction

Frictions related to the cost of capital may lead firms to value risk management (Froot, Scharfstein, and Stein 1993), but these same frictions can preclude them from insuring in financial markets because of inability to meet collateral requirements (Rampini and Viswanathan 2010, 2013). In response, firms may manage risk with alternatives to financial markets, like cash and fixed-price contracts (Bolton, Chen, and Wang 2011). I integrate these economic insights in an empirical context, and show how public policy may mitigate the negative externality that risk management frictions engender in product markets.

I use a quasi-experiment in which the Kansas state government shifted oil price risk in highway procurement from the private sector to the state. After this policy, implemented in 2006, a price index adjusts payments so that both sides have zero expected cost. I assess the value to firms of free insurance with a difference-in-differences (DD) design using detailed procurement auction data from Kansas and Iowa, which has never had the policy, between 1998 and 2012.

Relative to Iowa, I find that Kansas' policy reduced cost and increased competition. I show that the policy benefited private, undiversified, and high credit risk firms. My results suggest that capital markets at best serve only the largest end-use hedgers. To my knowledge, this paper provides the first firm-level study of private firm risk management, and the first comparison of the value of risk management across public, private, and family-owned firms.

Private firms may be risk averse because poorly diversified owners smooth personal income through the firm (Schulze et al. 2001, Fama and Jensen 1983). My evidence is inconsistent with this channel, as family-owned firms do not have a higher cost of risk than non family-owned firms. There are two alternative hypotheses. First, demand for risk management may emerge from managerial agency and information problems (Stulz 1984, DeMarzo and Duffie 1995, Breeden and Viswanathan 1998). Second, financial constraints and distress costs may explain it (FSS, Purnanandam 2008). My results are consistent with the latter mechanism.

The highway procurement context is useful because (a) firms take on oil price risk between the auction and the start of work, and (b) highway demand is plausibly exogenous to oil prices.[1] The risk management literature has faced a number of challenges, including the potential correlation of risk with other determinants of firm value, cross-sectional or survey-based data sources, and hedging decisions that are endogenous to firm value. An advantage of my setting is that it does not face these challenges.

I analyze bids to pave asphalt ("blacktop") roads, in which an oil product (bitumen) is the primary component.[2] Relative to Iowa, Kansas' policy reduced average bitumen cost by 9% and increased competition. Fully insured bids are less sensitive to risk; by modulating the DD design with oil price volatility, I show that a 100% increase in historical volatility after the policy makes bitumen bids in Kansas 14% lower than in Iowa, relative to their pre-policy difference. This estimate is robust to placebo tests, falsification with non-oil bid items, and alternative volatility metrics. The result translates to a 4.2% average cost of bearing oil price risk. While it is not surprising that firm costs decline when they receive free insurance, the risk premium for holding crude oil futures should be very small.[3] If firms can efficiently hedge in derivative markets, Kansas' policy should have had little effect.[4]

In highway paving, the product is essentially a commodity, but firms are quite diverse

[1] I show parallel trends in Iowa and Kansas, even during the Stimulus Act period, and further demonstrate robustness of the main results to omitting Stimulus Act years.

[2] 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).

[3] Oil has perhaps the world's best-securitized and most deeply traded derivatives. See Section 6 for discussion.

[4] During the period examined, oil prices increased on average between the auction and work start, so the policy should have increased procurement costs if firms were risk-neutral.

in their ownership, size, and industry diversification. Private firms dominate the sample, and a majority is family-owned.[5] These firm types are economically important; 99.9% of U.S. firms are private, and family-owned firms account for over 60% of U.S. GDP and employment (Asker, Farre-Mensa, and Ljungqvist 2014, Astrachan and Shanker 2003).

I show that the policy increased the probability of winning for private and undiversified firms at the expense of, respectively, public and diversified firms. I use two methods to address heterogeneity in the cost of risk. First, I split the sample in the volatility-modulated DD, and second, I measure risk as the time between auction and work start interacted with oil price volatility, excluding post-policy Kansas. I find that private firms have a higher cost of risk than public firms. The sharpest difference is across credit risk, with the cost at 5.9% for high risk firms and 3.1% for low risk firms. I also find that undiversified firms and single-location firms have higher cost of risk than, respectively, diversified firms and multiple-location firms. These differences do not reflect one characteristic correlated with the others. For example, the public-private difference is robust to excluding high credit risk and small private firms.

In the absence of state-provided insurance, paving firms usually purchase physical forward contracts from local suppliers at the time of the auction, thereby fully insuring. Such fixed-price contracts with distributors are also common among farmers, electric utilities, and airlines. After the policy, Kansas firms universally chose the state insurance, which is free albeit with basis risk. Their revealed preference indicates that hedging in financial markets is costlier than the forwards, which in turn are costlier than the state-provided insurance.

Derivatives are unappealing to many end users because of capital requirements, basis risk, economies of scale, daily marking to market, and complexity. Most importantly, the

[5]The private firms are small relative to the average publicly traded company, it is not clear that they are too small to benefit from oil derivatives; the median firm has 75 employees and $31 million in sales.

same firm attributes that make hedging valuable also make borrowing expensive. Rampini and Viswanathan (2010, 2013) propose that constrained firms hedge less [*in financial markets*] because they have a high opportunity cost of capital. My setting is consistent with their theory, but the bracketed modifier is crucial. Firms continue to hedge, but choose forwards - which require no cash up front - over financial derivatives.

My setting sheds light on how enforcement advantages and capital costs help determine the most efficient insurance provider. To insure with an arm's length financial counterparty, a firm would need to collateralize its promises. The local supplier knows that the firm is certain to be paid once it builds the road. This information, together with the benefits of a longstanding relationship and local market power, permits the supplier to offer a forward contract with no cash up front. The state insurance is similar to a firm financing itself with trade credit rather than a bank loan. The state has informational and enforcement advantages, and is the final consumer. In assuming the risk, it benefits from eliminating the profit and the risk premium on the forward.

The policy saved Kansas around $77 million over 6.5 years. Although Kansas did not hedge, the cost of doing so with oil futures would be small as it borrows at about 1%. For the firm, the cost of capital that would equate 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. Murfin and Njoroge (2014) make a similar point about the costs to small, constrained suppliers of providing trade credit to much larger customers.

Empirical work on risk management is mixed. Carter, Rogers, and Simkins (2006), Allayannis and Weston (2001), and Nance, Smith, and Smithson (1993) find a positive association between risk management and firm value, while Brown, Crabb, and Haushalter

(2006) and Jin and Jorion (2006) do not. Guay and Kothari (2003) argue that in general the magnitude of corporate derivative use is too small to affect firm value. Vickery (2008) and Géczy, Minton and Schrand (1997) find a positive relationship between measures of financial constraints and hedging. Yet Rampini, Sufi, and Viswanathan (2014) find that more constrained firms hedge less and 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).[6]

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 contributes to the small literature on private firm financial constraints (e.g. Saunders and Steffen 2011, Howell 2016). As in Acharya, Almeida, and Campello (2013), an advantage of my setting is that I do not rely on derivative use. Chen and Xiong (2014) show that derivative trading is conflated with speculation among commercial hedgers. Finally, this paper measures 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.

Despite its advantages along these dimensions, my setting has important limitations. In the primary analysis I do not observe hedging directly, so I cannot distinguish between hedging efficiency and risk aversion. I also do not quantify the effect of hedging on firm value.

[6]Relatedly, Panousi and Papanikolaou (2012) and Tufano (1996) demonstrate a positive correlation between manager ownership and effective risk aversion, and Campello et al. (2011) associate derivative use with reduced borrowing costs.

As most of the firms in my data are private, I do not observe profitability or investment. Last, my findings are limited to an imperfectly competitive procurement auction market, and should only cautiously be applied to other settings.[7] That said, improving efficiency in government purchasing is important; public procurement constitutes about 15% of GDP in OECD countries and 25-30% elsewhere (UNDP 2012).

Section 2 introduces the risk shifting policy, and Section 3 the data. Section 4 proposes the estimation strategies and demonstrates parallel trends across the two states. I describe the effects of the policy on real outcomes in Section 5, and the cost of risk in Section 6. Section 7 addresses heterogeneity. Robustness tests are in Section 8.

2 The Natural Experiment

Like other states, the Iowa and Kansas Departments of Transportation (DOTs) use auctions to procure highway construction projects. DOT initially prepares a public proposal for the project detailing the location and type of work, which includes estimated quantities of materials needed and the expected date of work start. Firms submit itemized bids, and the bidder with the lowest vector sum of unit item bids times estimated quantities wins the auction.[8]

In asphalt paving, one of the items is bitumen, an oil 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. If oil prices rise between

[7] Section 5 discusses the imperfectly competitive nature of the market at length.

[8] Specifically, DOTs use simultaneous sealed-bid first-price auctions. DOT also estimates the cost of each item, but these estimates are not public either before or after the auction. There is no reserve price; the secret estimate serves as a guide for what is reasonable. The unit item bids are analytically meaningful. Bid skewing (over/underbidding on items that DOT has under/overestimated) is forbidden and bids are sometimes rejected for this reason. Skewing incentives do not bias my risk management findings.

the auction and work start, the firm's bitumen cost will increase.[9] Auctions are mostly held in winter, while work is done in the warmer months. Firms are paid when work is underway, on average about six months after the auction. FSS show that hedging allows firms to invest even in bad cash flow states, so firms are most likely to hedge when cash flows are negatively correlated with investment opportunities. My setting exemplifies this situation; highway contractors tend to be cash flow constrained at precisely the time of year when they are most exposed to oil price risk.

I present a simple model of the firm's bidding decision in Part 1 of the Appendix. It shows how a risk premium is included in the bitumen bid markup. 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 (the quantity of road to be paved) is fixed.

In the early 2000s, state DOTs began to remove oil price risk from highway contractors, believing that any cost to the government of bearing oil price risk is offset by lower bids (Skolnik 2011). Although most states have implemented a risk shifting policy, there has been no quantitative analysis, to my knowledge, establishing that firms charge excessive risk premiums. In the only analysis thus far, Kosmopoulou and Zhou (2014) examine one state, Oklahoma. They attribute their finding that firms bid more aggressively after the policy to the winner's curse effect, and 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 risk shifting policy (called a "price adjustment policy") in August 2006. The policy was motivated by the belief that "The volatile

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

price of the asphalt oil has led contractors to make bids that are more costly than necessary" (Shaad 2006). The precipitating event, according to officials, was a contractor bidding an outrageously high price for a contract in which he was the only bidder, claiming that he could not get a firm price from suppliers. Iowa, located immediately to the northeast of Kansas, has not pursued such a policy, apparently because officials never became interested despite experiencing similar cost escalation.

Iowa and Kansas were on similar economic growth paths before, around, and after the policy; they had parallel trends in highway spending, basic transportation statistics, and Stimulus funding (see Section 4 for details). 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. While the two states are clearly not identical, I can identify no industry or government motivation for the policy other than the circumstantial preference of middle-management DOT officials in Kansas following the bizarre bidding incident described above.

The policy operates as follows. Kansas purchases a regional bitumen price index from a private data firm. It then adjusts payments to the paving firm if the price index changes between the auction and the time of work. When prices go up, the firm is paid his bid plus the index increase, and when prices go down, the firm receives his bid less the index decrease.[10] Firms bidding in Kansas auctions choose whether or not to take the policy when

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

they submit their bids. There is no preferential treatment for certain types of firms. All bids have opted for the policy (there are a few exceptions, but these appear to be mistakes). Appendix Figure 1 graphs the ex-post contract price adjustments over time.

In accepting the index, firms take on basis risk between the actual price and the regional, survey-based index. Note that the 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 the forward and the state insurance were equal, firms should choose the forward because it is a perfect hedge. However, they choose the state insurance, which is free. Therefore the cost of the forward must exceed the cost of basis risk in the index.

3 Procurement Auction Data

I employ comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012.[11] I focus on paving projects, which are bitumen-intensive.[12] The primary dependent variable is the unit item bitumen bid, which is the per ton bitumen bid within the larger total project bid. I also use the total bid for the project per ton of required bitumen, which accounts for the possibility that different strategies for allocating profit among items could distort the true effect of volatility on the metric that matters to DOT (the overall bid for the project). Bitumen comprises 11.3% of the total bid on average

the specifications, see: http://www.ksdot.org/burconsmain/specprov/pdf/90m-0295-r01.pdf.

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

[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, and is not a bid line item but rather goes into a line item for general overhead.

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 span), 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 very costly to transport and store, so suppliers naturally form a territorial oligopoly (see Appendix Figure 2).

Auction data summary statistics are in Table 1, with two-tailed p-tests for differences of means across states. In both states the average number of bidders in an auction is 3.4. The time between the auction and the start of paving varies from less than a month to sixteen months. On average it is 4.6 months in Iowa and 5.7 months in Kansas (this difference is not statistically significant). Iowa and Kansas are similar in their auction format, road characteristics, weather patterns, and firm type distribution, but they are by no means identical. For example, Iowa has more firms because its highway construction industry is larger. My analysis assumes that unobservable differences across states are constant around the policy (see Section 4 for parallel trends analysis).

Four other sources complement the auction data. First, I obtained firm characteristics from Dunn & Bradstreet's (D&B) database, supplemented with 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 is among the top three firms in number of total bids, and near the mean among

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

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

regular bidders in win percentage. Third, I conducted a survey of twenty of the top bidders in the data.[15] Finally, I use oil price and volatility data from Bloomberg (summary statistics in Appendix Table 1).

I use firm characteristics, summarized in Table 2, that are relevant to financial constraints and risk aversion. There are six publicly listed firms. 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 compared to just 22% in Kansas. I define credit risk to be high when D&B rates the firm high or medium risk.[16] Credit risk is also different across the states: 34% of Iowa firms are high risk, compared to 13% of Kansas firms. I use two measures of size. The first is based on the number of employees and revenue in the cross-sectional D&B data.[17] The second is whether the firm has only one location and is not a subsidiary. Unfortunately, variables like investment and profitability are not available for privately held firms. Table 2 Panel 2 shows correlations among characteristics. All are positive except that 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.

Firms select into bidding on projects, so I use extensive project controls. Notable differences are that private firms bid on projects slightly further away than public firms (94

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

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

[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.

miles on average compared to 83 miles), and public firms tend to bid in more competitive auctions. Large, multiple location, and low risk firms bid on larger projects than their small, single location, and high risk counterparts. There are no significant differences across firm types in months to start.[18]

To control for the expected oil price, I use six month WTI oil futures.[19] 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.[20] Historical volatility is the more natural measure, as paving firms are cognizant of recent oil price trends but do not report looking at options on oil futures, much less implied volatility. I focus on results using 12-week historical volatility, but show robustness to 26-week and at-the-money implied volatility for options expiring in three months.

4 Estimation Strategy

A difference-in-differences (DD) design estimates the policy's effect. The DD intuition is that if two groups are ex-ante similar and one is subject to treatment in the second of two time periods, then with controls for treatment and group the estimated coefficient on the treated group should be the average difference between treatment and control, without bias

[18]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.

[19]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.

[20]This is: $V_t^H = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}\left(O_t - E(O_t)\right)^2} \cdot \sqrt{T}$ where T is the number of trading days in the year (∼252) and N is the period over which volatility is measured. O_t are returns, or daily percent changes in the price: $O_t = 100 \cdot \ln\left(\frac{p_t}{p_{t-1}}\right)$ where p_t is the daily futures contract price. "Model-free" option-implied volatility metrics have been developed to deal with perceived issues with Black-Scholes, but these are beyond the scope of this paper (see Bollerslev et al. 2011).

from time trends and permanent differences between groups. The key identifying assumption is that nothing changed in Iowa *at the same time* as the 2006 risk shifting policy in Kansas.

First, I estimate the policy's effect on cost using Equation 1, where i indexes bidders, j indexes projects (same as the specific auction/contract), and t indexes the day of the auction. The dependent variable is the price paid by the state, including any Kansas adjustments.

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

The coefficient of interest (β_1) gives the mean difference across states in the actual price paid by the government after the policy, controlling for the pre-policy difference.[21] After the policy, oil prices increased on average between the auction and work start, so the policy should have increased procurement costs if firms were risk-neutral.

I estimate the effect of risk on bids by modulating the DD framework with oil price volatility. The competitive equilibrium in Kansas among pavers and between pavers and suppliers may have changed after the policy. However, changes unrelated to oil price risk should be controlled for by state and time fixed effects. The regression, where the dependent variable is now the log bitumen bid, is:

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

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

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.

I examine cross-sectional heterogeneity in two ways. First, I split the volatility modulated DD by firm type. The data does not permit adding a fourth interaction and the additional three- and two-way control interactions. This limits my ability to interpret differences in effects across sample splits. The second approach measures risk as the forward market interacted with oil price volatility. Specifically, I exclude post-policy Kansas (where there was no risk) and evaluate how oil price volatility affects bids 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 equation is:

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

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

$Controls_{ij}$ are as follows. At the auction level I control for project size using the log average total bid and log bitumen tons proposed. I also control for the number of bidders in the auction, county times year, and month-of-year fixed effects. Controlling for the month of the year is important because of capacity constraints that firms face as the construction season progresses. At the firm level, I control for the firm's log total non-bitumen bid and the log Vicenty distance from the firm to the project, using latitude and longitude data provided with the auction data. Following Bertrand et al. (2004), I cluster standard errors by firm in my primary specification. Except where otherwise noted, the analysis includes all auctions between 1998 and 2012.

The primary identification concern in the DD 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 states around the policy. Appendix Figure 3 shows that Iowa and Kansas were on similar GDP growth paths before, around, and after 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 responded to risk differently across the states prior to the policy. Table 10 column I shows no difference. Third, in robustness tests I exclude certain years to ensure that the results are not explained by the financial crisis, the Stimulus Act, or other macroeconomic shocks subsequent to the policy (see Section 8). Iowa and Kansas received similar amounts of Stimulus funding ($4.7 and $4.4 billion, respectively, relative to a national average of $10 billion and standard deviation of $11 billion).[22]

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

5 Real Effects of the Risk Shifting Policy

Before presenting regression results, I show raw average bids, ultimate project cost, and number of bidders across states and around the policy in Table 3. Before the policy, Kansas paid $36 more per ton of bitumen than Iowa. After the policy, Kansas paid $28 less. This amount paid reflects the lowest bid and any price adjustment from the policy. Examining all bids, we find a narrowing difference around the policy. Bids in Kansas were $28 per ton higher before the policy and $15 higher after. Iowa has more 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 policy than those in Iowa.

Estimates of Equation 1, in Table 4, use outcome variables that are important from an economic standpoint; in particular, the ex-post actual price paid and measures of competition. The ex-post price reflects both the bids and any adjustments from the policy. It should be noted that if realized bitumen prices after the policy were systematically lower than market expectations, the price paid could be lower for Kansas than Iowa without any risk premium change. However, oil prices on average increased between the auction and the time of work after the policy. Further, there is evidence that the current spot price is the best forecast of future oil prices (Kellogg 2010, Alquist and Kilian 2010).

Column I shows that Kansas' policy yielded savings of $43 per ton, or 9% of the average per-ton cost. The estimate implies that Kansas saved around $77 million in the 6.5 years after the policy, relative to total bitumen expenditure of about $820 million.[23] The average bid also decreased after the policy; column II replaces the dependent variable in Equation 1 with all bids, and shows that the policy decreased the average bid by 7.6%. I also estimate a within-Kansas DD comparing the bitumen-intensive contracts in the main

[23]Kansas used 1.79 million tons of bitumen across all post-policy projects.

analysis to contracts that use little bitumen. For example, a less-intensive contract might be primarily bridge building.[24] These estimates, in Appendix Table 4, find similar savings from the policy of $49-$54 per ton.

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.

Competition

Like 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, and Porter and Zona (1993), Ishii (2008), Gupta (2002), and Pesendorfer (2000) demonstrate collusive bidding in highway procurement specifically.

The risk shifting policy increased competition in Kansas relative to Iowa. Using the number of bidders in the auction as the dependent variable, column III of Table 4 shows that the policy increased the number of bidders in auctions by 0.8, relative to an average

[24] See note to Appendix Table 4 for details.

of 3.4. The distribution of winning bids also changed after the policy. In Figure 4, the bar heights indicate the number of firms in each category of auction win percentage. Kurtosis and skewness both declined significantly; the former from 4.9 to 3.[25] 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).[26] The suppliers apparently charge the pavers a large fraction of, if not

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

[26]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

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.

6 Policy Effect on Risk Pass-Through

The Kansas risk shifting 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 I means that a one standard deviation increase in volatility, or a 14% increase, decreases bids in Kansas relative to Iowa by 2%, relative to their pre-policy difference.[27] Using the log total bid per ton bitumen as the dependent variable (column II) gives a similar coefficient of -0.15. Firms in Kansas faced zero oil price risk after the policy, so the difference between Iowa and Kansas provides an implied cost of managing oil price risk over this period. Since the post-policy mean of historical volatility is 30%, the average cost of bearing risk is 4.2% (30·0.14).

Varying fixed effects sheds light on the mechanism. County fixed effects permit re-composition - exit and entry of firms - within county. A larger result with county effects would imply that the policy allowed new and more efficient firms to enter. This is similar to the effect of arm's length banking relationships on small firm innovation in Hombert and

messages."

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

Matray (2015). Conversely, a larger result with firm effects would suggest that the policy creates value for existing firms. I find the latter; Appendix Table 5 column IV uses firm fixed effects, and finds a larger effect of -.18, relative to -.14 with county effects. Table 9 column IV omits county effects and finds a similar result of -.17. Thus the main result does not reflect firms entering new areas.

To understand this result, we need to know how risk is managed in this industry in the absence of the policy. In general, firms can manage risk with hedges, insurance, diversification, or cash holdings. Highway paving firms typically fully insure by signing physical forward contracts with suppliers before the auction.[28] If the firm wins, the contract binds. Sometimes firms wait to sign later, and occasionally they buy spot at the time of work. Very rarely, if ever, do firms hedge in financial markets. In interviews, executives suggested that public firm subsidiaries more often wait to sign as they can depend on the liquidity of the corporate parent in the event of a shock. While the parent may trade derivatives at a global level, the subsidiary is not involved in that trading.

The forward contracts are a reservation price of hedging; if firms choose forwards rather than hedging in financial markets, the latter must be at least as costly. The counterparties in the forwards are suppliers. They buy and store bitumen year-round, so at the time of the auction they are partially physically hedged against the short positions they are taking in their contracts with paving firms. Nonetheless, in the supplier-paver relationship

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

the supplier generally has downside risk while the paver has upside risk. If the supplier has total bargaining power, the forward price could include *both* sides' risk premiums.

To illustrate how this might work, consider the following examples of actual forward contracts between Firm Z and two local suppliers. Figure 2 shows a February 2008 contract for delivery in summer 2008 priced at $330 per ton. Figure 3 shows a February 2009 contract for delivery in summer 2009 is $515 per ton. The price of oil fell from around $100 per barrel in February 2008 to $43 in February 2009. Volatility helps explain why the 2009 contract is so much more expensive than the 2008 contract; volatility was quite low in early 2008 but rose to an all-time peak of over 70% in early 2009 (Figure 1).

Firm Z's per ton contract prices are graphed in Figure 5 panel A. The contracts are tied to a specific Iowa DOT paving project, so I observe the 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). Interviews indicate that this fixed markup reflects transportation costs, and profit margins are usually loaded on bid items for labor and overhead. Though not central to my analysis, this suggests that the cost of risk is embedded in the forward contract.

I use the 105 Firm Z forward contracts to estimate the risk premium in the forwards relative to the index price. This also gives an upper bound on the basis risk. Specifically, the risk premium is the forward contract price less the realized index price in the week that work starts (typically, the forward contract price is dated in the winter, and work starts the following summer).[29] The individual premiums are graphed in Appendix Figure 13. The average risk premium is 24% of the forward contract price, and its standard deviation is

[29]This analysis is anecdotal, as it is limited to a single firm. Unfortunately these forward contracts are considered trade secrets and are impossible to acquire for other firms. For the index price, I use the Argus Media Iowa index price, which exists for the entire period for which I have Firm Z contracts. It is almost identical to the Poten & Partners Kansas index used in Kansas after the policy. Firm Z is in Iowa, and never faces the policy.

10%. By choosing the index over their forwards, firms avoided paying the premium but took on basis risk. Since firms use the index when it is available and forwards otherwise, we can infer that the basis risk in the index is no more than 10%, and that hedging in financial markets is costlier than both of these options.

Why Don't Firms Hedge in Derivative Markets?

My result that firms place a high value on risk management is incongruous with two facts: (a) oil has notably liquid derivative markets; and (b) the balance of evidence indicates that excess returns to holding oil futures (the simplest hedge) should be quite small.

There is no consensus on the oil price risk premium, but recent studies are unable to reject a zero risk premium for long-only commodity portfolios (Basu and Miffre 2013, Erb and Harvey 2006). 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 between 1971 and 2010 at 0.01. 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 macroeconomic growth can correlate with oil prices moving up or down, depending on the source of the shock. Growth may cause a positive demand shock, increasing prices, while a positive supply shock decreases prices, which has a positive effect on growth (Anderson, Kellogg, and Salant 2014).

Given this literature, hedging using derivatives should be quite cheap. One reason firms may not do so is that in practice hedging in financial markets creates exposure to cash flow risk. To illustrate, consider Southwest Airlines, whose 2014 Annual Report states:

> "The Company is also subject to the risk that cash collateral may be required to be posted to fuel hedge counterparties, which could have a significant impact on the Company's financial position and liquidity."

Southwest paid $60 million in premiums to hedge 34% of its 2014 jet fuel consumption using option collars and swaps. Despite instruments that should minimize losses and less hedging than usual, Southwest lost $256 million on its positions, bringing fuel hedging costs to 28% of net income.[30] Southwest's OTC tools require payment up front and scale, making them inaccessible to small, private firms.

The simplest alternative is to purchase oil futures.[31] This requires a performance bond, or "margin," which is marked-to-market every day and changes with volatility.[32] A thought experiment illustrates how much this might cost. Suppose that an average firm in my data used oil futures to hedge its annual bitumen needs. It would purchase about 16 six-month WTI crude oil futures contracts in January (auctions are usually held in the winter, and paving done in the summer). Figure 6 shows the results of this exercise for years for which I was able to gather historical margin requirement data.[33] The margin account

[30] Southwest Airlines 2014 Annual Report.

[31] 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 strategy (and more complex). The firm must purchase more options than the underlying oil quantity to achieve a 1-to-1 hedge, navigating the declining delta of the option as it moves out of the money. 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.

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

[33] Sixteen contracts (where contracts are denominated in 1,000 barrels) is the rough oil equivalent of 2970 tons of bitumen, which is the average project amount (928 tons) times the number of projects the average firm wins (3.2). (For conversion rates, see EIA). The margin account requirement is the CME spec amount for 5-10 month CL6 contracts. The firm should choose a hedge ratio to minimize basis risk, but I abstract

averages about $150,000.[34] The dots below zero are instances when oil prices fall and the 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 margin percent change, 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. Suppose the firm borrows at 5%. Then 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." Though they do not address hedging, they show that securities with the same cash flows but different margin requirements can have different returns, and empirically demonstrate a margin premium based on the cost of capital for investors who borrow to fund their margin accounts. Hedegaard (2014) uses data on commodity futures to show that margin changes affect open interest and prices, and concludes that margins matter for liquidity. Given the relatively low margins for oil futures, the margin premium cannot fully explain the cost of risk that I observe. It does, however, confirm the relevance of funding constraints to derivative markets.

My regression results above calculated a 4.2% average cost of risk. The implied cost of capital that makes this cheaper than hedging in futures markets is around 25%.[35] While this seems large, it implicitly includes other costs of hedging in financial markets that are essentially zero with physical forwards: exposure to cash flow risk during the hedge period, employee time to manage the account, basis risk, and transaction fees. Economies of scale

from that here.

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

[35] 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 $\left(\frac{1}{12.7} \cdot \frac{150{,}000}{2{,}970}\right)$.

have been shown in the literature to be further barriers to hedging in financial markets for small firms (Mian 1996, Géczy et al. 1997, Haushalter 2000). In interviews, executives of firms in my data consistently viewed hedging in financial markets as complicated and expensive gambling. This brings up a final reason firms may not hedge in financial markets: information costs or lack of sophistication.

Since implementing the risk-shifting policy, the Kansas DOT has not hedged its oil price risk. Officials report very low annual costs of the policy, which I calculate to be no more than $36,750.[36] We can, however, repeat the 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 policy of $12 million).[37] If the state can borrow at 1%, the cost of capital is $21,250 per year on average, or about 46 cents per ton bitumen.[38] This compares with $2.26 per ton for the firm if it borrows at 5%. This calculation demonstrates the simple fact that hedging is cheap when money is cheap.

7 Heterogeneity in the Cost of Risk

Insurance should disproportionately benefit firms with higher costs of bearing risk. 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,

[36]Interviews with official yielded the following estimates. The policy requires a $5,295 per year subscription 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.

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

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

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).

I consider several other characteristics relevant to hypotheses from the risk management literature. First, small firms usually have less collateralizable assets than large firms, so are widely assumed to face more severe financing constraints (Hennessy and Whited 2007, Nance, Smith, and Smithson 1993). Second, I expect that if distress costs help explain the value of insurance, as FSS suggest, firms with less industry diversification and higher credit risk will most benefit from the policy. A natural hedge is diversification away from oil-intensive construction to projects like sewers or concrete highways. Firms that only pave asphalt roads should face a higher probability of distress from an oil price spike. Credit risk is a direct measure of the probability of distress.

Family ownership permits 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 undiversified manager-owners may maximize personal utility and smooth income through the firm (Bertrand and Schoar 2006, Shleifer and Vishny 1986, Schulze et al. 2001). If the undiversified owners explain the risk premium, I expect family firms to charge a higher risk premium.

Real Effects

The policy seems to have increased competition by leveling the playing field. 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. Table 4 columns IV and V show that private firms are 19 percentage points more likely to win after the policy than before, relative to an average of 74%. Similarly, the policy increased the probability of winning for paving-only firms by 20 percentage points relative to diversified firms.[39] I do not find statistically significant differences in the probability of winning across the other characteristics.

The raw probabilities moved in opposite directions in Kansas and Iowa. The probability that a private firm won in Kansas increased from 71% before the policy to 77% after, while it decreased from 91% to 81% in Iowa. On average, Kansas paving-only firms' probability of winning increased from 33% to 60%, while this chance decreased for Iowa paving-only firms from 45% to 26%. Volatile oil prices in Iowa in 2008 and 2009 seem to have favored the public and diversified firms, while private firms in Kansas were protected and increased market share.

Cost of Risk

I explore heterogeneity in the cost of risk across firm types in two ways. First, I split the sample. Table 5 column III shows that the policy's effect is -0.14 among private firms, and column IV shows that it is -0.079 among public firms (significant at the 1% and 5% levels, respectively). Columns V and VI show that the difference across family ownership is much smaller, at -.12 and -.097.

There are sharper differences for the characteristics that proxy for financial constraints and distress probability. These regressions use only private firms, so that the public-private effect does not contaminate the results. Table 6 columns I and II show that the effect for high credit risk firms is -.24, and -.12 for low credit risk firms. This implies a cost of oil price

[39] Logit specifications produce similar results, but they are magnified because logit drops groups (e.g. county-months) with no "successes" (e.g. paving-only firm wins). The odds ratios for private vs. public and paving-only vs. diversified are 2.8 and 4, respectively (Appendix Table 6).

risk for high credit risk firms of 5.9%, compared to 3.1% for low credit risk firms.[40] The coefficient among single-location, non-subsidiary firms is -0.18, relative to an insignificant -0.0031 for other firms (Table 6 columns III and IV).

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 V and VI). Mackay and Moeller (2007) and Faccio, Marchica and Mura (2011) also find that well-diversified firms are less risk averse.[41] Finally, columns VII-VIII use the secondary size metric (based on revenue and employment), which yields less variation; -.15 for small firms and -.091 for large firms. 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 I). High risk firms are by definition closer to distress, so including them may swamp the effect of other characteristics. 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 II).

Subsequent columns in Table 7 find no difference between family and non-family

[40]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.

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

owned firms, regardless of the sample. Here and for subsequent characteristics, I also include a specification limiting the sample to private firms. In Table 8 I find a coefficient of .04 for paving-only firms relative to diversified firms (column I, significant at the 10% level), which increases to .06 and becomes highly significant when I limit the sample to low risk firms. Columns IV-VI examine single location firms relative to multiple location firms, and yield very similar and highly significant coefficients. Finally, columns VII-VIII examine high versus low credit risk. As expected, the former have a much higher cost of risk, particularly when measured within private firms.

Mechanisms

Three mechanisms could explain heterogeneity in risk premiums: cost of capital, effective risk aversion, and risk-varying bargaining power. In the FSS framework, the first two are sides of the same coin, because high external finance costs drive risk aversion. The third explanation is that my results reflect bargaining power with suppliers. This interpretation requires bargaining power to vary with risk, because the modulated DD 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 results. However, I cannot rule out that the mechanism is narrowly related to a certain product market equilibrium.

If firms have homogenous risk aversion, my results may reflect only varying costs of capital. Some firms have the scale or liquidity to hedge more cheaply in financial markets. Interviews with executives contradicted this hypothesis. They said that the variation reflects some firms' willingness to forego signing a forward at the time of the auction. By waiting to sign, they take on risk between the auction and the work. Other firms always insure, signing regardless of the price. In combination with my empirical results, this interview evidence suggests that while capital costs may explain why *no firms* in this market insure with financial derivatives, costly distress explains the within-sample heterogeneity. Note that the policy implication is independent of the channel. In this context, it is more efficient for the state to aggregate risk.

In a product market relationship, which party should provide insurance is related to the ability to enforce payment. The pecking order of enforcement ability in this market is state, local supplier, and finally derivative counterparty. Hedging is expensive is because of 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.

In the absence of the policy, the local supplier has an advantage through its longstanding relationship with the firm and power to withhold supply in the future. For these reasons, the supplier does not require cash up front. More nefariously, the supplier could have information about the firm's cost of risk and vary the forward price accordingly. This helps explain why the small, undiversified firms value the government insurance so much more. This could be a case of the information asymmetry that Rothschild and Stiglitz (1976) show has a deleterious effect on insurance contract provision.

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 insurance 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. Although the setting's specificity limits the external validity of this analysis, a benefit is that my sample much more adequately represents the size and ownership distribution of U.S. firms than most risk management studies, which address large, publicly listed corporations.

The reader may wonder why public or private equity firms do not acquire the small firms. 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.

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 had a positive effect on the first two goals. This suggests that insurance is an intriguing 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). Government could exploit its 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.

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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)

			Sample Split by Ownership Type			
	I: Full Sample	II. Dep Var=Log total bid per ton bitumen	III. Private	IV. Public	V. Family	VI. Non-Family
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	-.14***	-.15**	-.14***	-.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:

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

Sample limited to certain types of firms (e.g. 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. *** $p < .01$.

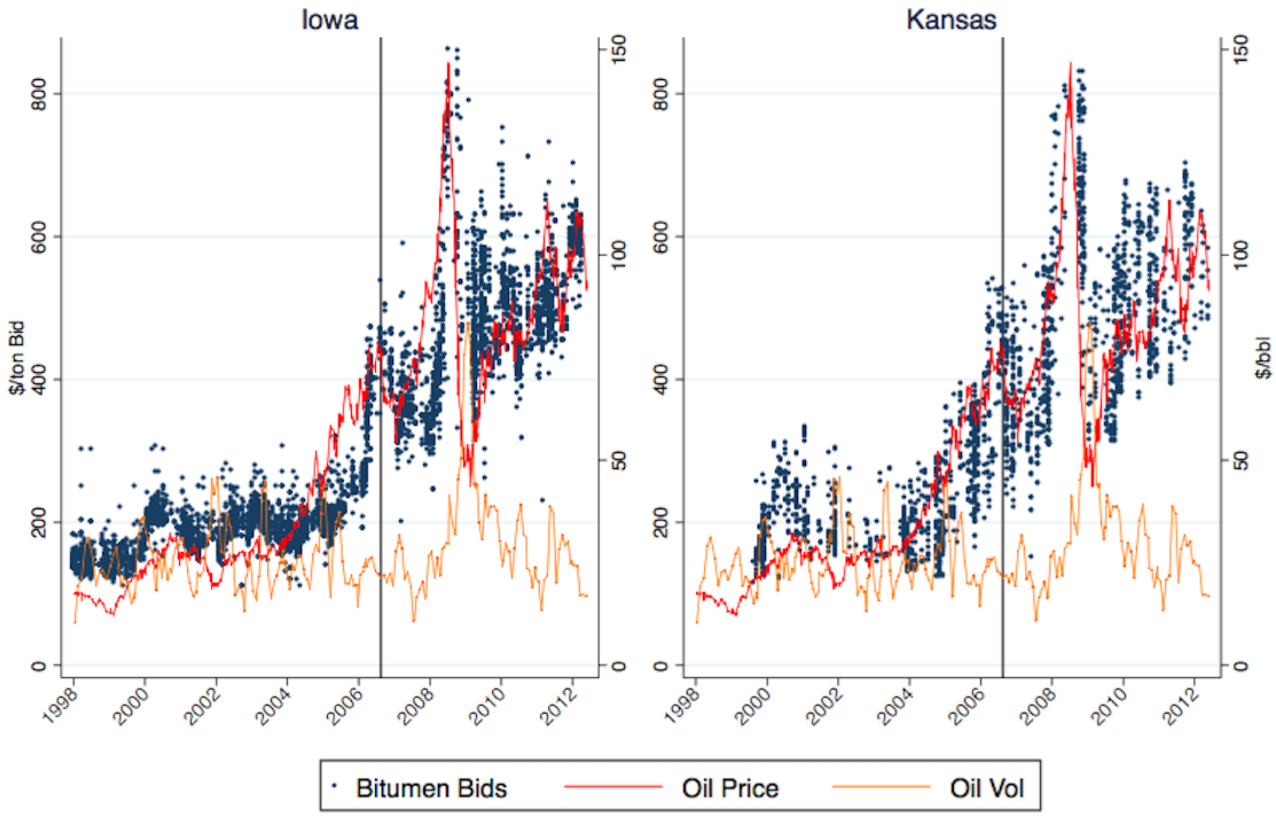
Table 10: Select Robustness Tests (Part 2)

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

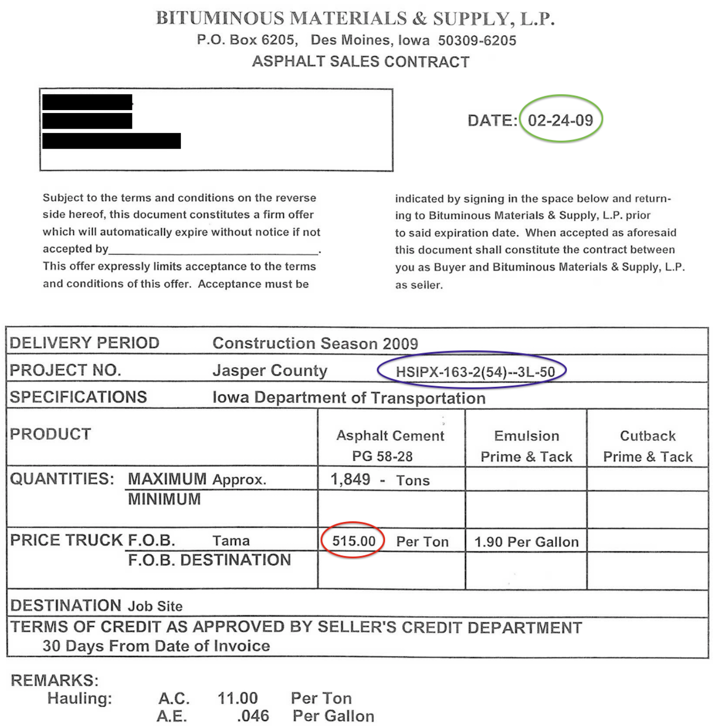
FLINT HILLS RESOURCES, LP ("Seller")

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

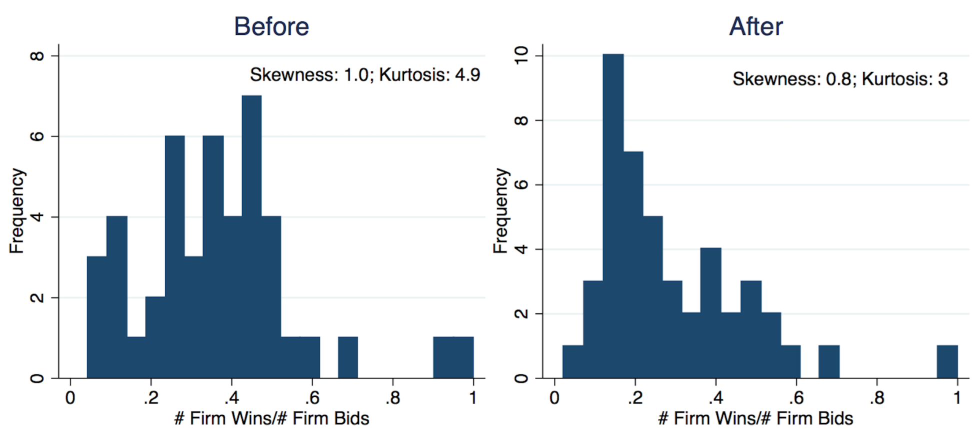
Subject to the terms and conditions on the reverse side hereof, this document constitutes a firm offer which will automatically expire without notice if not accepted by____________________. This offer expressly limits acceptance to the terms and conditions of this offer. Acceptance must be indicated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

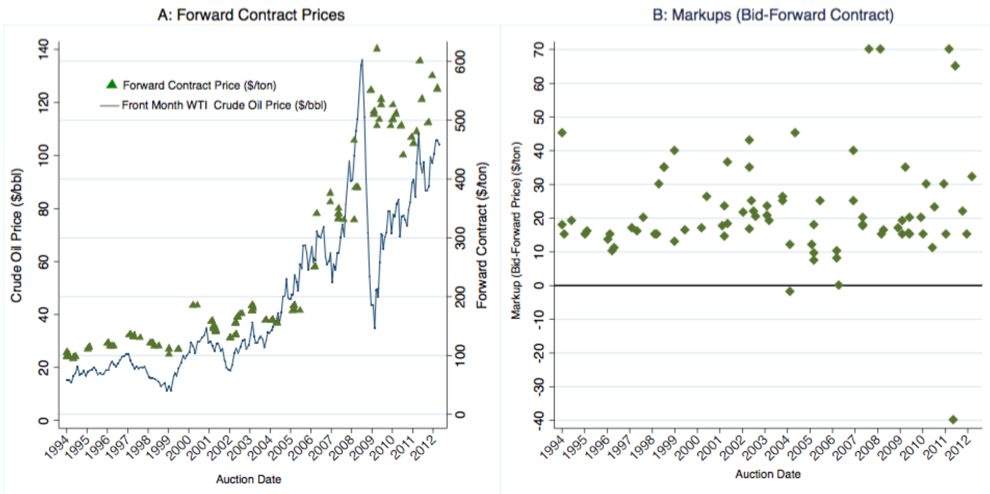
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 4: Kansas win distribution around risk shifting policy



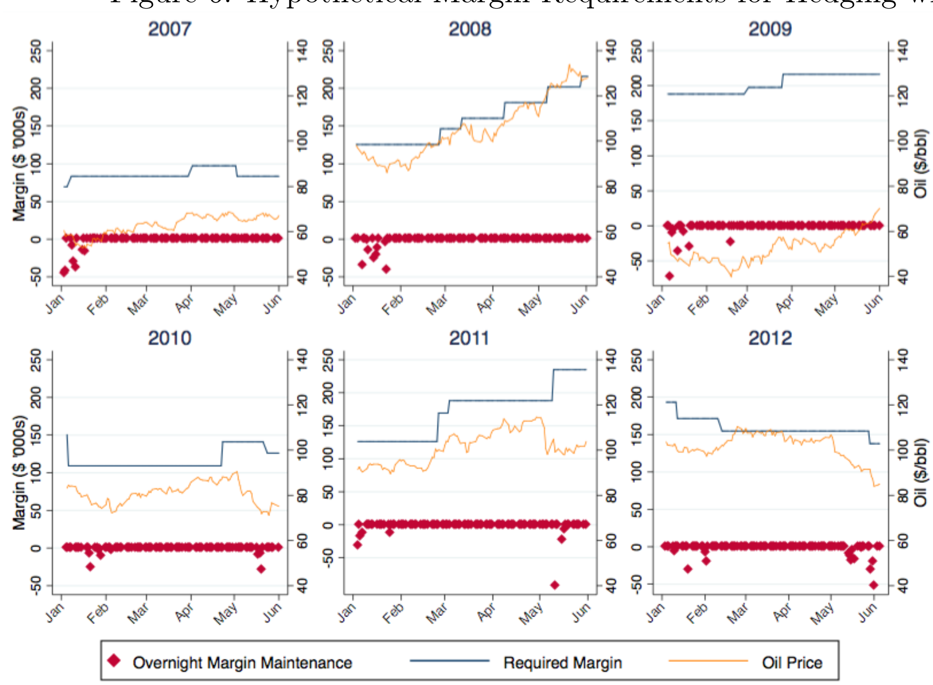
Note: These figures show the frequency of of firms by win percentage. The changing distributions indicate that after the policy wins were more evenly spread across firms.

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.