Relaxing Constraints on Risk Management:

Evidence from a Natural Experiment

Sabrina T. Howell*†

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Abstract

I estimate commodity price risk pass-through in a product market, and explore how this pass-through varies across firm types. A quasi-experiment in which a state government fully insures highway-paving firms against oil price risk permits causal inference. Surprisingly, the risk shifting policy reduced procurement costs and increased competition. Private firms value insurance more than public firms, but family-owned firms are not more risk averse than their counterparts. Firms with high credit risk and low industry diversification are most risk averse. Financial constraints and distress costs appear to lead firms to value insurance, yet these and other frictions prevent firms from hedging in financial markets.
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*NYU Stern. Contact: sabrina.howell@nyu.edu. Click Here for Latest Version and Appendix.

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1 Introduction

A rich theoretical literature describes how frictions related to the cost of capital may lead firms to value risk management yet fail to insure in financial markets. Specifically, financial constraints lead firms to value risk management (Froot, Scharfstein, and Stein 1993, henceforth FSS). Despite this value, collateral requirements can make hedging in financial markets prohibitively costly for such constrained firms (Rampini and Viswanathan 2010, 2013). Instead, firms facing capital-intensive hedging may manage risk with cash and other alternatives to financial markets (Bolton, Chen, and Wang 2011). This paper integrates these points in an empirical context.

To my knowledge, this paper provides the first estimation of how commodity price risk passes through to output prices, and conducts the first comparison of the value of risk management across public, private, and family-owned firms. The empirical challenge is to find an exogenous shift in commodity price risk. To obtain causal inference, I use a quasi-experiment in which the Kansas state government began to insure highway construction firms against oil price risk. Kansas shifted oil price risk in highway procurement from the private sector to the state in 2006 because "The volatile price of the asphalt oil has led contractors to make bids that are more costly than necessary" (Shaad 2006). The state used a price index to adjust payments, such that in expectation the insurance had zero cost for both sides. Nearby Iowa has never implemented such a policy.

I assess the value to firms of relaxing constraints on risk management with a difference-in-differences (DD) design using detailed procurement auction data from Iowa and Kansas between 1998 and 2012. The unit of observation is a bid to pave asphalt ("blacktop") roads. Asphalt's primary component is bitumen, an oil product. 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 premium for holding crude oil futures should be quite small.[2] If firms can efficiently hedge in derivatives markets, Kansas' policy should have had little effect. Further, during this period oil prices increased on average between the auction and work start, so the policy should have increased procurement costs if firms were risk-neutral. Instead, I find that relative to Iowa, Kansas' policy reduced average bitumen cost by 9% and increased competition.

I modulate the DD with oil price volatility to show that fully insured bids are less sensitive to risk. 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 a litany of tests, including placebo, falsification with non-oil bid items, and

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

[2] See Section 6 for discussion.

alternative volatility metrics. The result translates to a 4.2% average cost of risk.

Private firms dominate the sample, and a majority are family-owned. These firm types are economically important; private firms account for 99.9% of U.S. firms, and family-owned firms account for over 60% of U.S. GDP and employment (Asker, Farre-Mensa, and Ljungqvist 2014, Astrachan and Shanker 2003). The firms in my data also range in size and industry diversification. I show that the policy also 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. Both approaches 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, but the difference is similar in magnitude across industry diversification and size. In particular, single-location firms have a much higher cost than multiple-location firms. The public-private difference, however, is robust to excluding high credit risk and small private 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). I do not find evidence consistent with this channel, because family-owned firms do not have a higher cost than non family-owned firms. The alternative hypotheses are that demand for risk management emerges from managerial agency and information problems (Stulz 1984, DeMarzo and Duffie 1995, Breeden and Viswanathan 1998) or from financial constraints and distress costs (FSS, Purnanandam 2008). My results are consistent with the latter.

In the absence of the 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, firms in Kansas universally chose to take the state insurance (free, albeit with basis risk). Firms' 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 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. A firm would need to collateralize its promises if it insured with an arm's length financial counterparty. Conversely, the local supplier and the state know that the firm, if it wins the auction, is certain to be paid once it builds the road. This information, plus the benefits of longstanding relationships and local market power, permit 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. When the state takes on the risk, it has informational and enforcement advantages, and is the final consumer. It benefits from eliminating the supplier's profit margin on the forward.

The policy saved Kansas around $77 million over 6.5 years. In a hypothetical calculation, I show that since the state can borrow at about 1%, its cost of hedging with oil futures is very small. 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%. In such product market relationships, it is more efficient to reassign risk to the party with the lower cost of managing it. Murfin and Njoroge (2014) make a similar point on the costs for small, constrained suppliers of providing trade credit to much larger customers.

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

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

What I measure in this paper can be interpreted in two, equally valid ways: the value of government insurance to firms, and the extent to which risk is passed through 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. My data also permit the first firm-level study of private firm risk management. This complements

[3] Mackay and Moeller (2007) find that the value of oil price risk management among oil refiners rises with firm energy intensity. Since they do not observe hedging behavior, they derive the value of hedging by estimating production functions. Acharya, Lochstoer and Ramadorai (2013) propose that end users may have limited ability to hedge because of counterparty (speculator) capital constraints, and show empirically that oil producers with high default risk use more derivatives. My findings are also consistent with a negative correlation between idiosyncratic risk and firm value (Goyal and Santa Clara 2003).

Cornaggia (2013), who at the county level finds a positive association between an insurance policy and farm yields, and contributes to the small literature on private firm financial constraints (e.g. Saunders and Steffen 2011, Howell 2015).

This paper has several additional contributions. First, most risk management studies focus on derivative use. Chen and Xiong (2014) show that derivative trading is conflated with speculation among commercial hedgers. Like the literature on liquidity and distress costs (Acharya, Almeida and Campello 2013, Acharya, Davydenko and Strebulaev 2012), I do not rely on evidence of derivative use. Also, it has been challenging to identify data sources that are not cross-sectional or survey-based. Third, the risk studied can be correlated with other determinants of firm value, especially demand. Finally, the hedging decision is often endogenous to firm value. An exception here is Pérez-González and Yun (2013), who examine electric utilities' response to the introduction of weather derivatives.

Despite its advantages along these dimensions, my setting has important limitations. In the primary analysis I do not observe hedging directly, so I cannot distinguish between hedging efficiency and risk aversion. I also do not quantify the effect of hedging on firm value. In part because I study private firms, there is no data on profitability or investment. Last, my findings are limited to an imperfectly competitive procurement auction market, and should only cautiously be applied to other settings.[4] 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. 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

In Iowa and Kansas, as in most states, the state Department of Transportation (DOT) uses auctions to procure highway construction projects.[5] Bidders submit itemized bids, including a per ton bid for bitumen. An oil product, bitumen (also called asphalt binder or

[4]Section 5.3 discusses the imperfectly competitive nature of the market at length.

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

asphalt oil) is a black, sticky material that is mixed with rock pieces to make asphalt. The bidder with the lowest vector sum of unit item bids wins the auction.[6] Paving firms face cost uncertainty when they bid - if oil prices rise between the auction and work start, the firm's bitumen cost will increase.[7]

Most auctions occur during the winter, but firms are paid when work is underway, on average about five months later. 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.

Part 1 of the Appendix contains a simple model of the firm's bidding decision that shows how a risk premium is included in the bitumen bid markup. In Adam, Dasgupta, and Titman's (2007) model, financially constrained firms are disincentivized from hedging when they can adjust output to reflect realized cost. In my setting, this is not the case as output (the quantity of road to be paved) is fixed regardless of oil prices.

The federal government has urged state DOTs to remove oil price risk from highway contractors since the early 1970s, but the policy only became widespread in the mid-2000s. To my knowledge there is no quantitative analysis of whether, in fact, private firms were charging the government excessive risk premiums, nor has there been any effort to evaluate the policies' effectiveness. Risk shifting policies are now used in most states and there seems to be consensus in the policy community that any cost to the government of bearing oil price risk is offset by lower bids (Skolnik 2011). In the only analysis thus far, Kosmopoulou and Zhou (2014) examine one state, Oklahoma. They attribute their finding that firms bid more aggressively after the policy to the winner's curse effect, and assume firms are risk-neutral. There has been no analysis of whether this policy produced cost savings for Kansas or any other state.

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

[6]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.

[7]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.

is paid his bid plus the index increase, and when prices go down, the firm receives his bid less the index decrease.[8] The policy applied universally, with no preferential treatment for certain (e.g. small) firms.

After the policy, firms in Kansas choose whether or not to take the policy when they submit their bids. All bids have opted for the policy.[9] With the policy, payments to the winner are adjusted to account for changes - both up and down - in a regional bitumen price index. Appendix Figure 7 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 index were equal, firms should choose the forward because it is a perfect hedge. However, they choose the index, which is free. Therefore the cost of the forward must exceed the cost of basis risk in the index.

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

3 Procurement Auction Data

This paper uses data from five sources. First, I have comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012.[10] Second, I use firm characteristics from Dunn & Bradstreet's (D&B) database, supplemented with information from firm websites. Third, I observe actual hedging behavior in the form of 105 forward physical contracts between paving firm Z (identity protected) and all four regional bitumen suppliers. Firm Z is among the top three firms in number of total bids, and near the mean

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

[9]There are a few exceptions, which appear to be mistakes.

[10]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.

among regular bidders in win percentage. I also conducted a survey of twenty of the top bidders in the data.[11] Fourth, I use oil price and volatility data from Bloomberg (summary statistics in Appendix Table 1).

I focus on paving projects, which are bitumen-intensive.[12] 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.[13] In practice, bitumen is purchased from local suppliers in one-off, non-public transactions. Examples of these contracts are in Figures 3 and 4. Suppliers purchase bitumen from refineries and store it. Bitumen is very costly to transport and store, so suppliers naturally form a territorial oligopoly.

Bitumen comprises 11.3% of the total bid on average for the contracts in my data, but can be up to 40%.[14] Figure 1 shows Iowa and Kansas bitumen bids (per ton bid items within the larger total project bid) over time, as well as the crude oil price and historical oil price volatility. Summary statistics of the auction data are in Table 1, with two-tailed p-tests for difference of means across states. While Iowa and Kansas are similar in their auction format, road characteristics, and firm type distribution, they are not the same. My analysis will rely on the assumption that unobservable differences across states are constant around the policy.

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

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

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

[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.

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

[14] 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.

which is the overall bid for the project.

Overall, there are more firms in Iowa (213 relative to 131 in Kansas) because it has a larger construction industry.[15] Nineteen firms bid in both states. Table 3 shows firm type summary statistics. It is challenging to obtain data on private firms. While not ideal, the characteristics I use are relevant to financial constraints and risk aversion. There are six publicly listed firms. The majority of firms are family owned (71% in Kansas, and 79% in Iowa).

My measure of diversification is whether or not the firm does construction beyond asphalt highway paving (based on 8-digit SIC codes). This is notably different across the two states: 60% of firms in Iowa are paving-only compared to 22% in Kansas. I define credit risk to be high when D&B rates the firm high or medium risk.[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 measure is whether the firm has only one location firm and is not a subsidiary of a larger business. Within the private firms, some of these characteristics proxy for each other. Panel 2 of Table 3 shows correlations among the key variables. The correlation between family ownership and high risk is -.02. All the others are positive. The highest is 0.49 between firms with a single location and small firms. Undiversified firms are also rough proxies for single location firms.

Firms select into bidding on projects, so I use extensive project controls. Notable differences are that private firms bid on projects slightly further away than public firms (94 miles on average compared to 83 miles), and public firms tend to bid in more competitive auctions. Large, multiple location, and low risk firms bid on much larger projects than their small, single location, and high risk counterparts. There are no significant differences across firm types in months to start.[18]

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

[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.

[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.

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 return, and implied volatility, which is derived from the Black-Scholes (1973) option pricing formula.[20] I use historical volatility over the past 12 weeks, and at-the-money implied volatility for options expiring in three months (these are considered directly comparable). Historical volatility is the more natural measure, as paving firms are cognizant of recent oil price trends but do not report looking at options on oil futures, much less implied volatility. I focus on results using 12-week historical volatility, but show robustness to 26-week and implied volatility.

4 Estimation Strategy

I use a difference-in-differences design to ask whether the policy affected firms in Kansas. The key identifying assumption is that nothing changed in Iowa *at the same time* as the 2006 risk shifting policy in Kansas. The DD intuition is that if two groups are ex-ante similar and one is subject to treatment in the second of two time periods, then with controls for treatment and group the estimated coefficient on the treated group should be the average difference between treatment and control, without bias from time trends and permanent differences between groups. I estimate the following regression, where the dependent variable is the price that Kansas paid after adjusting the winning bid to account for oil price changes:

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

The coefficient of interest (β_1) gives the mean difference across states ($s \in Kansas,\ Iowa$) in the actual price paid by the government after the policy, controlling for the pre-policy

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

[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 ($\sim$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).

difference.[21] Since the policy, oil prices have increased on average between the auction and work start, so the policy should have increased procurement costs if firms were risk-neutral.

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

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

The dependent variable is the log bitumen bid, $price_t^{oil}$ is the 6-month WTI crude oil futures price, and $\ln Vol_t^{oil}$ is its volatility. The coefficient of interest, β_1, represents the effect of volatility on bids in Kansas relative to Iowa after oil price risk shifted to the public sector.

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

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

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

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

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

The primary identification concern for the DD analysis (Equations 1-2) is a violation of the parallel trends assumption. First, I examine whether bidders responded to risk differently across the states prior to the policy. This is an important direct test of the validity of estimating Equation 2. Table 10 column I shows no difference. Next, I show that important observables do not exhibit major deviations across states around the policy. Appendix Figure 1 shows that Iowa and Kansas were on similar GDP growth paths before, around, and after the policy. Appendix Figures 2 and 3 show parallel trends for total highway spending (capital and maintenance outlays) and vehicle miles traveled. Appendix Figures 4 and 5 show parallel trends around the policy in the number of contracts and the total quantity of bitumen required. None of these are statistically different around the policy across states. In the 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. 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]

5 Real Effects of the Policy in Kansas

Estimates of Equation 1 are in Table 4. Column I shows that Kansas' policy yielded savings of $43 per ton, 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

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

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

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 analysis to contracts that use little bitumen. For example, a less-intensive contract might be primarily bridge building.[24] These estimates, in Appendix Table 10, find similar savings from the policy of \$49-\$54 per ton, using county and firm fixed effects. These savings are remarkable given that oil prices on average increased between the auction and the time of work

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 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 fully insuring the pavers (eliminating their need to hedge). This supports Liu and Parlour's theory that when hedges are contingent on winning - as occurs when firms must hedge themselves - bidders rather than the seller capture the benefits of hedging.

Competition

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

I find that the 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. The distribution of winning bids also changed after the policy. In Figure 7, the bar heights indicate the number of firms in each category of auction win percentage. Kurtosis and skewness both declined

[24]See note to Appendix Table 10 for details.

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.

In an interview, one CEO said that imperfect competition permits even very risk averse pavers to stay in business. Paving firms and bitumen suppliers are in oligopolistic, territorial equilibria. This illustrated in Appendix Figures 11-15, which show the location of auction wins and losses for five large bidders. Wins are concentrated in a portion of the state while losses predominate outside that territory. Unreported maps for other major bidders show a similar pattern. Spatial oligopoly is a natural result of high transportation costs; with perfect competition rents are zero on territory boundaries and positive within.

The bitumen suppliers 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 may provide a signaling mechanism, as in Friedman (1971).[26] The suppliers apparently charge the pavers a large fraction of, if not their full, cost of risk. Thus this context features imperfect competition in two layers of product markets.

Imperfect competition and financial frictions impede efficient allocation of risk, allowing firms to pass high and heterogeneous insurance premiums to the consumer. Relatedly, Scharfstein and Sunderam (2013) find that imperfect competition in mortgage lending decreases the pass-through of lower mortgage-backed security yields to mortgage rates, vitiating government policies aimed at home buyers.

6 Policy Effect on Risk Pass-Through

The Kansas risk shifting policy reduced the responsiveness of bids to oil price volatility, relative to bids in Iowa. Table 5 shows the results using the primary specification and

[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 messages."

historical volatility. The value of -0.14 for β_1 in Column I means that a one standard deviation increase in volatility, or a 14% increase, decreases bids in Kansas relative to Iowa by 2%, relative to their pre-policy difference.[27] Using the log total bid per ton bitumen as the dependent variable (column II) gives a very similar coefficient of -0.15.

Kansas firms faced zero oil price risk after the policy, so the difference between Iowa and Kansas provides an implied cost of managing oil price risk over this period. The post-policy mean of historical volatility is 30%. The average cost of bearing risk is then 4.2% (30·0.14).

Alternative fixed effects specifications are informative about the mechanism. County fixed effects permit recomposition within county (exit and entry of firms). 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 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 7 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. This confirms that the result does not reflect firms entering new areas.

Firms can manage risk with hedges, insurance, or diversification. The highway pavers in my data often fully insure by signing physical forward contracts with suppliers before the auction. If the firm wins, the contract binds. Sometimes they wait to sign later, and occasionally they don't hedge at all or, very rarely, hedge in financial markets.[28] The forward contracts are essentially a reservation price of hedging; if firms choose forwards rather than hedging in financial markets, the latter must be at least as costly.

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

[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.

[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).

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

I use the 105 Firm Z forward contracts to provide an anecdotal measure of the risk premium in the forwards relative to the index price, which also provides an upper bound on the basis risk. Specifically, the risk premium is the forward contract price less the realized index price in the week that work starts (typically, the forward contract price is dated in the winter, and work starts the following summer).[29] The individual premiums are graphed in Appendix Figure 16. The average risk premium is 24% of the forward contract price, and its standard deviation is 10%. By choosing the index over their forwards, firms avoided paying the premium but took on basis risk. Since firms use the index when it is available and forwards otherwise, we can infer that the basis risk in the index is no more than 10%, and that hedging in financial markets must be costlier than both of these options.

Why Don't Firms Hedge in Derivative Markets?

My results that firms value state-provided insurance, and in its absence charge the state about 4.2% for bearing oil price risk (generally reflecting the cost of forwards) are 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 conventional asset pricing models fail to explain returns and a number of recent studies were unable to reject a zero risk premium for long-only commodity portfolios (Basu and Miffre 2013, Erb and Harvey 2006). Oil prices are close to a random walk; Alquist and Kilian (2010) show that the no-change

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

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 6), 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).

Hedging is sometimes considered a zero-cost transaction on an expected value basis, but in practice hedging in financial markets creates exposure to cash flow risk. To illustrate, consider Southwest Airlines, whose 2014 Annual Report states: "The Company is also subject to the risk that cash collateral may be required to be posted to fuel hedge counterparties, which could have a significant impact on the Company's financial position and liquidity." Southwest paid $60 million in premiums to hedge 34% of its 2014 jet fuel consumption using option collars and swaps. Despite instruments that should minimize losses and much less hedging than usual, Southwest lost $256 million on its positions, bringing fuel hedging costs to 28% of net income.[30] Southwest's hedging instruments require payment up front and scale.

The alternative is to hedge in futures markets, which require a performance bond, or "margin," which is marked-to-market every day and changes regularly to reflect volatility.[31] A simple thought experiment can illustrate how much this costs. Suppose that an average firm in my data used oil futures to hedge its annual bitumen needs, choosing a hedge ratio to minimize basis risk. It would purchase about 16 six-month WTI crude oil futures contracts in January (auctions are usually held in the winter, and paving done in the summer). Figure 6 shows the results of this exercise for years for which I was able to gather historical margin requirement data.[32] The dots below zero are instances when oil prices go down and the margin account does not have a cushion, so the firm must wire in money or have its positions liquidated. The graphs show that the margin account requirement varies, and on average is

[30] Southwest Airlines 2014 Annual Report.

[31] 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.

[32] 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.

about $150,000.[33] This does not include margin calls from intermediate volatility increases. Even in the absence of high volatility and no margin change, a $1 drop in the price of oil requires an immediate wire of $16,000.[34]

The cost of hedging is the cost of capital in the margin account, abstracting away from employee time and transaction fees. A financially constrained firm by definition has a high cost of borrowing. Suppose the firm borrows at 5%. Then the cost of the capital dedicated to hedging in our example is about $2.26 per ton of bitumen. Note that this does not include exposure to cash flow risk during the hedge period, nor does it includes costs of learning about derivatives, basis risk, or transaction costs, all of which are essentially zero with the physical forwards. My regression results above calculated a 4.2% cost of risk. The implied cost of capital that makes this cost cheaper than hedging in futures markets is around 25%.[35]

A formal model for this cost of capital problem is Gârleanu and Pedersen's (2011) "margin CAPM." Though they do not address hedging, they show that securities with the same cash flows but different margin requirements can have different returns, and empirically demonstrate a margin premium based on the cost of capital for investors who borrow to fund their margin accounts. Hedegaard (2014) uses data on commodity futures to show that margin changes affect open interest and prices, and concludes that margins matter for liquidity. Given the relatively low margins for oil futures, the margin premium cannot fully explain the cost of risk that I observe. It does, however, confirm the relevance of funding constraints to derivative markets.

Kansas DOT officials report essentially no costs of bearing the risk; the annual cost is about $36,750.[36] Although the state does not hedge or set aside specific funds to cover oil price spikes, we can conduct a thought experiment from Section 2.2 for the state instead of the firm. To hedge state-wide annual bitumen needs, Kansas would need to deposit a $3.2 million performance bond.[37] This calculation suggests that the annual savings from the

[33] 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.

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

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

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

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

policy of about \$12 million are nearly four times the capital required to hedge in financial markets. If the state can borrow money at 1%, the cost of capital is \$21,250 per year on average, or about 46 cents per ton bitumen (relative to \$2.26 per ton for the firm).[38]

Economies of scale and basis risk are further barriers to hedging in financial markets for small firms (Mian 1996, Géczy et al. 1997, Haushalter 2000). Aggregating the risk at the state level, assuming that the state did wish to hedge, would dramatically reduce administrative cost. These challenges might raise the suggestion that a firm 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. 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 the firms may not hedge in financial markets, which is information costs or lack of sophistication.

7 Heterogeneity in the the Cost of Risk

Insurance should benefit firms with higher costs of bearing risk. I expect private firms to have a higher cost of external finance than public firms. They may also be more risk averse if their owners are less diversified than the shareholders of public companies. However, there may be no difference in effective risk aversion 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 that permit testable hypotheses of risk management theory. Size is a widely used proxy for financial constraints in the literature. Small firms usually have less collateralizable assets than large firms, so are often assumed to face more severe financing constraints (Hennessy and Whited 2007, Nance, Smith and Smithson 1993). I expect that if distress costs help explain the value of insurance, as suggested in FSS, firms with less industry diversification and higher credit risk will find the risk shifting policy particularly helpful. A natural hedge is diversification away from oil-intensive construction to projects like sewers or concrete highways. Thus industry diversification should also lead to a lower cost of oil price risk; firms that only pave asphalt roads should face a higher probability of distress from an oil price spike. Credit risk is a direct measure of the probability

[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

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 in the firm. These undiversified manager-owners may maximize personal utility and smooth income through the firm (Bertrand and Schoar 2006, Shleifer and Vishny 1986, Schulze et al. 2001). If 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. Columns IV and V of Table 4 show that after the policy, private firms are 19 percentage points more likely to win after the policy than before, relative to an average of 74%. The dependent variable is an indicator for winning, and the estimating equation is a triple differences design using bids, where the coefficient of interest is on $\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$. All six individual and single difference interactions are included. The average probabilities in each state moved in opposite directions: the probability that a private firm won in Kansas increased from 71% before the policy to 77% after, while it decreased from 91% to 81% in Iowa. Volatile oil prices in Iowa in 2008 and 2009 seem to have favored the public firms, while private firms in Kansas were protected and increased market share.

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%. In the fully-controlled regression analysis, I find that 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.

Cost of Risk

I explore heterogeneity in the cost of risk across firm types in two ways. First, I split the sample, as the specification is too complex for an additional set of interactions. Table 5 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).

[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 4).

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. Shown in Table 6, these regressions use only private firms, so that the public-private effect does not contaminate the results. 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 risk for high credit risk firms of 5.9%, compared to 3.1% for low 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. The R^2 is over .9 for all the estimates in Tables 5 and 6, indicating that Equation 3 captures over 90% of the variation in bitumen bids. The extensive project controls ensure that projects are not systematically and observably different across firm types.

I turn to an alternative risk measure in order to combine firm types in a single model and establish statistical significance of differences across coefficients. This approach calculates risk as the square root of months between auction and work start) interacted with oil price volatility (Equation 3). The results are in Tables 7 and 8.

Table 7 columns I-II show that public firms have a significantly lower cost of risk management than private firms; using the whole sample, the coefficient on the triple interaction of being public with risk (time to start times log volatility) is -.065, significant at the 5% level. When I limit the sample to low credit risk firms, the coefficient increases to -.09 and is significant at the 1% (column II). High risk firms are by definitely closer to distress and naturally have a higher cost of risk. They create noise within the public-private comparison, and for other characteristics create a concern that any effect may reflect correlation with high credit risk. Subsequent columns in Table 7 compare family and non-family owned firms. There is no effect, regardless of the sample. Here and for subsequent characteristics, I also include a specification limiting the sample to private firms.

In Table 8 I find a coefficient of .04 for paving-only firms relative to diversified firms (column I, significant at the 10% level), which increases to .06 and becomes highly significant when I limit the sample to low risk firms. Columns IV-VI look at single location firms relative to multiple location firms, and yield very similar and highly significant coefficients. Finally, I examine high vs. low credit risk in columns VII-VIII. As expected, high risk firms are more

[40]This does not reflect an overlap with family ownership; in Appendix Table 5, I show a similar result when I compare high risk, non-family-owned firms with low risk, non-family-owned firms.

[41]Again, the diversification result is not driven by family owned firms (see Appendix Table 5 column I).

risk averse than low risk firms. This effect is very strong and significant when I limit the sample to private firms.

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

Interpretation

There are three possible mechanisms explaining heterogeneity in risk premiums: effective risk aversion, cost of capital, or risk-varying bargaining power. In the FSS framework, the first two are two sides of the same coin, because high external finance costs drive risk aversion. A narrow interpretation of my results is that I identify varying costs of capital. That is, firms have homogenous risk aversion, but some have the scale or liquidity to hedge in financial markets. My interviews with executives suggest that such an interpretation would be inaccurate. They indicated that the variation reflects the willingness of some firms to forego signing a forward at the time of the auction, instead waiting and taking on risk during the period between the auction and the work. Other firms always insure, signing forwards at very high prices when oil is volatile. 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.

The third explanation is that my results reflect varying 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. As I do not directly observe all paver-supplier contracts, I cannot affirmatively identify the channel. Note, however, that the policy implications are independent of the mechanism: the cost of managing risk varies by firm type, and in this context aggregation by the state is more efficient.

The question of which party in a transaction 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 financial 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, power to withhold supply in the future, and ability to vary the forward price to reflect the firm's risk premium. 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 would help explain why the small, undiversified firms value the government insurance so much more. The information asymmetry that Rothschild and Stiglitz (1976) show has a deleterious effect on insurance contract provision – indeed, sometimes preventing anyone from buying insurance – surprisingly appears present among firms insuring against commodity price risk.

8 Robustness Tests

I conducted a rich array of robustness tests. I begin with robustness tests of the policy effect on the costs to Kansas' DOT, the main specification for which is shown in Table 4 column I. Appendix Table 6 first shows that the effect increases with a narrower bandwidth around the policy (only using years 2004-2009) to $68 per ton (column I). The effect also increases when I omit controls (Appendix Table 6 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.

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 8 columns V-VI use 10 and 20 quantiles of volatility, respectively, and finds that the triple interaction effect remains negative and highly significant.

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 V and no clusters in VI. Further alternative error assumptions are in Appendix Table 8 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.

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 7 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. Alternative fixed effects specifications also test for robustness. For example, 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 7 column IV uses firm fixed effects. Rather than the effect disappearing, there is actually a slightly larger effect than in the main specification.

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.

Appendix Table 7 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).

Despite the demonstration of parallel trends in Section 3, Kansas and Iowa are not the same, and there may be concern that the results reflect unobservable time-varying differences across the states. I therefore 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 10. 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 10 column II).

Alternative oil measures are in Appendix Table 7 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 9 shows that the main effect is not statistically significant and has a magnitude of -0.7 among these firms, which makes sense since they continue to face risk in Iowa, but are also larger and better diversified to begin with. The effect is much larger, at -0.19 and significant at the 1% level, for firms that bid in only one state.

Finally, I examine the effect of the policy and volatility within Kansas across firm types. While this model is not of great interest given the drastic changes in the economic environment after the policy, my finding that certain types of firms are more risk averse should translate to these firms being less responsive to volatility after the policy, relative to their within-Kansas counterparts. Appendix Table 11 shows the results of a regression where the coefficient of interest interacts either $\mathbf{I}_{Public_j}$ or $\mathbf{I}_{High\ Risk_j}$ with both the policy and oil volatility (see notes to table for specifics). I find that 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). This is consistent with my main findings in Section 4.3. I have much less power since there is less data for Kansas, and I do not find statistically significant effects for the other characteristics.

9 Conclusion

In a highway paving market, I find government insurance to be valuable to firms and reduce procurement costs. Since firms that are publicly listed, are diversified across industries, and have low credit risk charge lower risk premiums, financial constraints and costly distress appear most directly related to demand for risk management. The combination of financial frictions and imperfect competition, which plague many sectors, prevent product markets from exploiting efficient markets for risk.

The value of government insurance depends on the cost of hedging privately. The market failure observed here is troubling given the liquidity and complexity of derivative markets in the U.S. If credit constraints and frictions like a lack of financial sophistication prevent small firms from using derivatives, there may be demand for simple, low transaction-cost risk management markets or aggregation services.

A limitation of this analysis is its industry-specific focus on public procurement and asphalt paving. However, the firms in my sample much more adequately represent the size and ownership distribution of U.S. firms than most risk management studies, which address large, publicly listed corporations. One might ask 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.

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 (capital requirements) for their own hedging activities, they are more likely to forego fixed rate instruments. This may be costly if it forces a more risk averse customer to bear the risk.

When they support small firms, governments usually hope to foster entry, reduce price, and/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 $V = \mathbf{E}(C) - \rho\sigma$. Traditionally, government subsidizes small firms by increasing C. An alternative is a mean preserving spread that reduces 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 easily observed sector or financing risks.

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

Panel 1: Contracts (Auctions)

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

Panel 2: Bids

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

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

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

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

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

Table 3: Summary Firm Characteristics

Panel 1: Number of Firms by State and Attribute

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

Panel 2: Correlation Matrix of Key Attributes

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

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

Table 4: 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, and the number of bidders (in I,III). Standard errors clustered by firm. *** $p < .01$.

Table 5: Marginal Effect of Oil Price Volatility; Overall Results and Ownership Sample Splits

Dependent variable: Log bitumen bid (except II)

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

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

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,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 Equation 2. 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 using Alternative Risk Measure

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

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

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

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

Table 8: 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:

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

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

Table 9: Select Robustness Tests (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

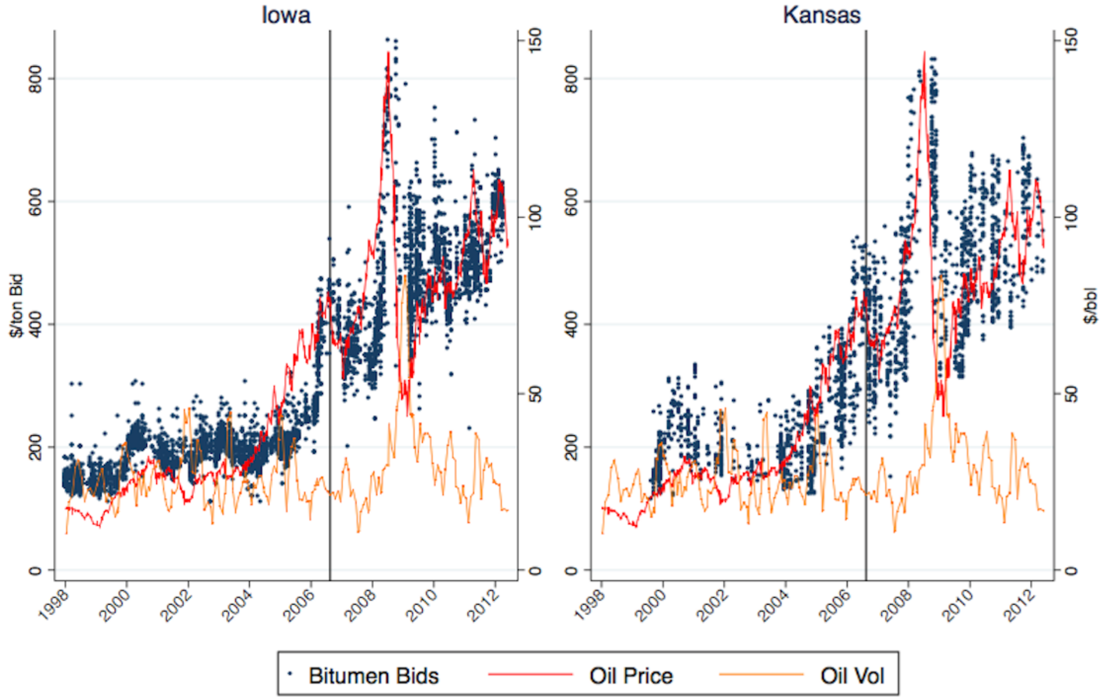
Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 2. The dependent variable is the log bitumen item bid. †Unreported controls are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

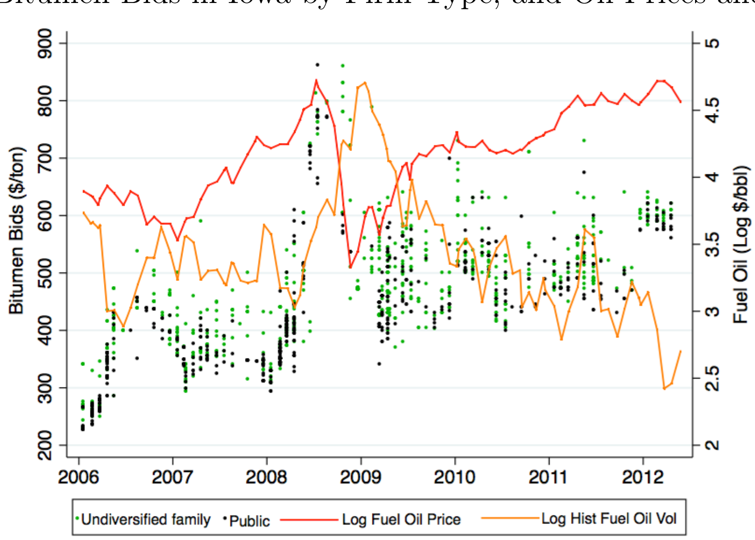
Note: This table reports regression estimates of the effect of the risk shifting policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 2. The dependent variable is the log bitumen item bid. †Unreported controls are 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: Bitumen Bids in Iowa by Firm Type, and Oil Prices and Volatility



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

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

Sales Agreement

FLINT HILLS RESOURCES

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

Page 1
Sales Agreement NO. 66870

Sold To: 227

[redacted]

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

Line No: 1

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

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

FOB Location ORIGIN

Freight Terms COLLECT

Product PG 58-28

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

Line No: 2

Product PG 64-22

1	TON	$330.00				DAVENPORT,IA

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

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

Accepted

[redacted]

Accepted

FLINT HILLS RESOURCES, LP ("Seller")

By ROBERT RIUTTA

Title

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

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

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

[redacted]

DATE: 02-24-09

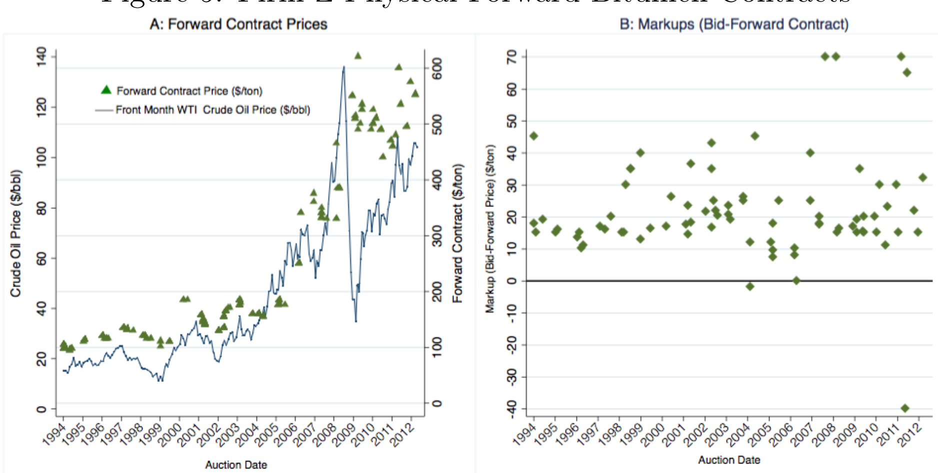
Subject to the terms and conditions on the reverse side hereof, this document constitutes a firm offer which will automatically expire without notice if not accepted by____. This offer expressly limits acceptance to the terms and conditions of this offer. Acceptance must be indicated by signing in the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

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

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

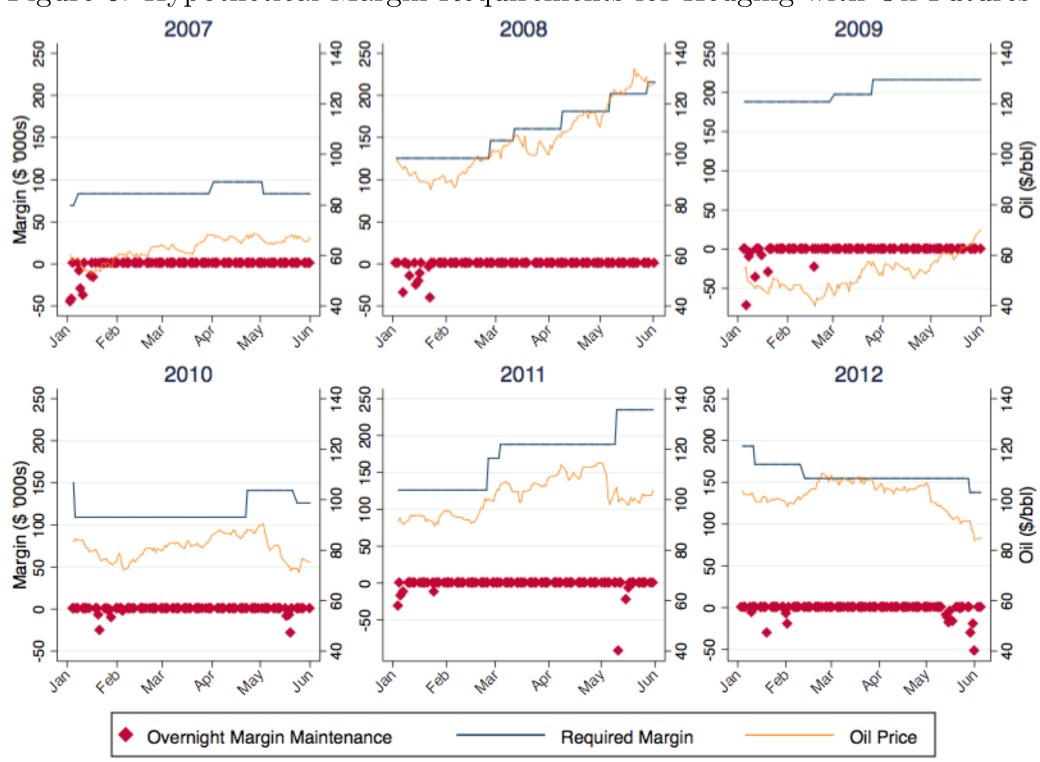
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 5: Firm Z Physical Forward Bitumen Contracts



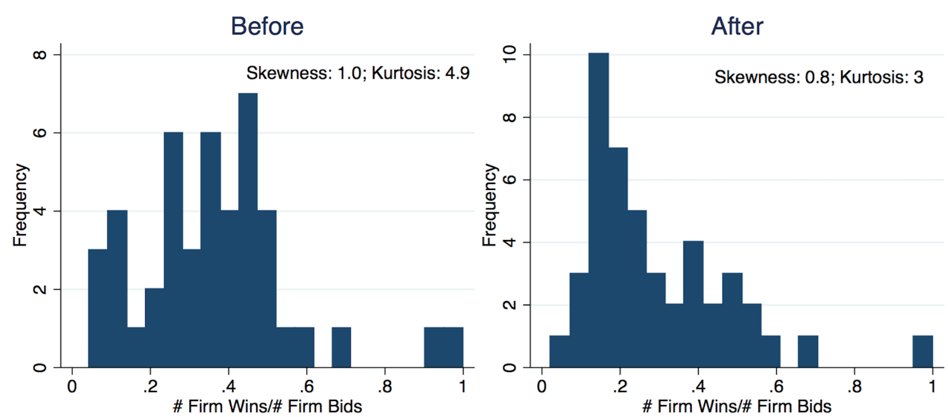
Note: This figure shows the bitumen prices in 100 forward physical contracts between one large paving firm and bitumen suppliers, as well as the spot oil price.

Figure 6: Hypothetical Margin Requirements for Hedging with Oil Futures



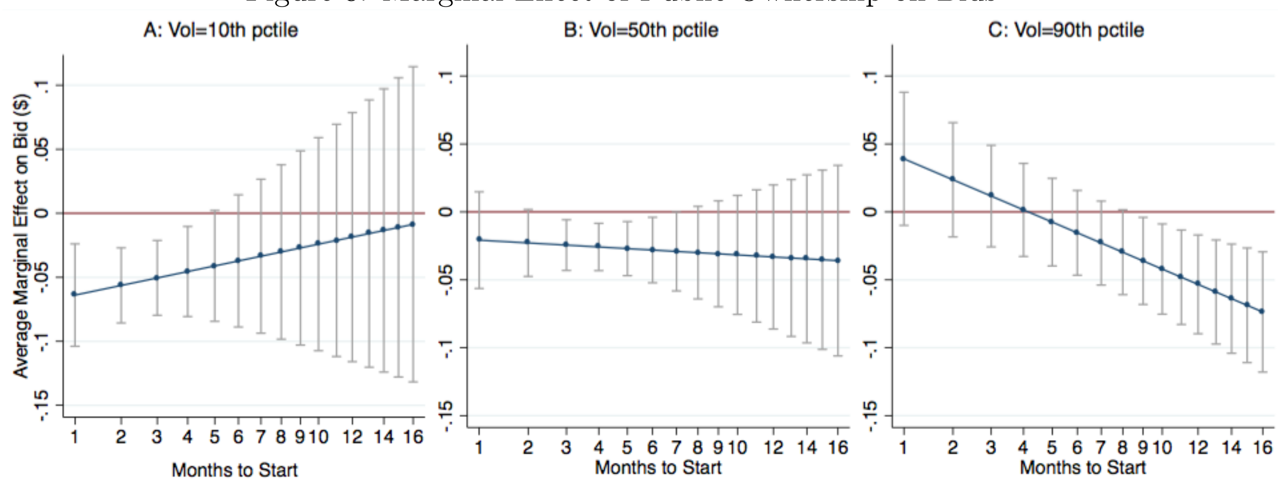
Note: This figure shows the capital an average firm needs to hedge annual bitumen (purchase 16 6 month crude oil futures contracts in Jan., as auctions are usually in winter, work in summer). Overnight maintenance is the amount the firm needs to deposit overnight to maintain its margin.

Figure 7: Kansas win distribution around risk shifting policy



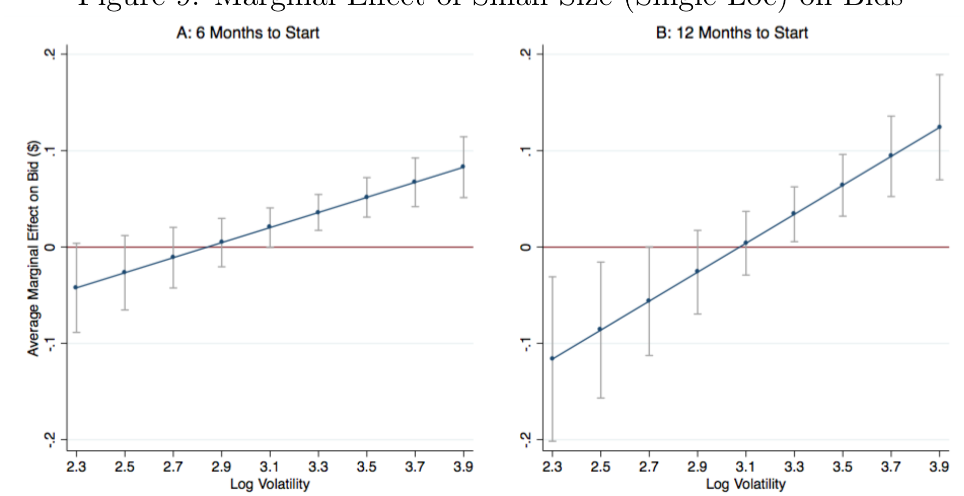
Note: These figures show the frequency of of firms by win percentage. The changing distributions indicate that after the policy wins were more evenly spread across firms.

Figure 8: Marginal Effect of Public Ownership on Bids



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

Figure 9: Marginal Effect of Small Size (Single Loc) on Bids



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