The Cost of Risk Management:

Evidence from a Quasi-Experiment

Sabrina T. Howell*

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Abstract

This paper asks whether public policy can reduce the pass-through of input cost risk to product markets. State highway procurement provides a useful setting. The Kansas government began to insure highway-paving firms against oil price risk in 2006. With a difference-in-differences design using data from 1998 to 2012, I evaluate the policy's effect in Kansas relative to Iowa, which never introduced it. The policy reduced procurement costs by 8% and increased competition by 24%. It also substantially reduced bid sensitivity to oil price volatility. Further, to my knowledge this paper offers the first firm-level comparison of the cost of risk management across public, private, and family ownership. I find the most pass-through of risk among private firms with high credit risk and low industry diversification, and no pass-through at all for public firms.

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*NYU Stern, 44 West 4th St, NY NY 10012. Phone: 212-998-0913. Email: sabrina.howell@nyu.edu.
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1 Introduction

Public procurement constitutes about 10% of U.S. GDP, and 15% of worldwide GDP (Cernat & Kutlina 2015). Many procured products expose private contractors to commodity or currency risk, such as ships, food, and roads. This paper evaluates a government policy seeking to mitigate financial frictions in hedging. It also offers the first firm-level evidence of risk management among privately owned firms, and the first comparison of risk management behavior across public, private, and family-owned firms.

Large, sophisticated firms should use capital markets to efficiently manage the price risk of inputs such as steel, corn, and oil. Yet we know little about how small, privately owned firms manage risk. Whether they do so efficiently is economically important, as they are responsible for about half of U.S. GDP (Kobe 2012). Small businesses are also relevant to procurement; in 2015, the U.S. federal government procured goods and services from small businesses worth more than $352 billion.[1]

I estimate the pass-through of risk to product market prices in highway procurement auctions.[2] Bitumen, a petroleum product, is the primary component of asphalt roads. I analyze firm bids in Iowa and Kansas auctions for paving asphalt ("blacktop") roads. In 2006, the Kansas state government shifted oil price risk in highway procurement contracts from the private sector to the state. The government offered an optional payment adjustment to reflect changes in oil prices between the auction date and the time of work. Kansas did not charge firms for this insurance. I assess the effect of the insurance policy in a difference-in-differences design using data from Kansas and Iowa for 1998-2012.

A nearby state with similar highway characteristics and spending trends, Iowa has never had the policy. Kansas and Iowa are useful states to study because Kansas adopted the policy for idiosyncratic reasons: one exceptionally high bid, and interest in oil prices on the part of one official. I demonstrate parallel trends across the two states in highway demand and other relevant observables. To address concern that changing oil prices or

[1] Small businesses are private firms with revenue and/or employment below SBA sector thresholds (mostly well under 500 employees). See https://www.fpds.gov.

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

macroeconomic factors confound the analysis, I demonstrate that the main results are robust to restricting the sample to two years around the policy event, placebo tests, falsification tests using non-oil bid items, including firm fixed effects, alternative volatility metrics, and alternative time periods, such as excluding the American Recovery and Reinvestment Act (ARRA) period.

The risk premium for holding crude oil futures should be quite small (see Section 6). Therefore, while I expect free insurance to reduce costs, the policy would have had little effect on total costs to the government if firms efficiently hedged in derivative markets. Instead, the policy reduced procurement cost for Kansas by about 8% (relative to Iowa), saving the government around $77 million over 6.5 years. I find a similar result in within-Kansas analysis comparing bitumen-intensive and non bitumen-intensive contracts.

The policy also increased competition, measured as the number of bidders per auction, by 24%. Construction procurement has been plagued by collusion and monopoly power, so increasing competition is especially important in this sector (Porter & Zona 1993, Pesendorfer 2000, Bajari & Ye 2003). The industry is quite static, so it is not surprising that I find no effect of the policy on firm entry or exit.

To estimate how bid sensitivity to risk changed after the policy, I modulate the difference-in-differences design with oil price volatility. I show that for a 100% increase in historical volatility after implementation of the policy, bitumen bids in Kansas were 14% lower than in Iowa, relative to the pre-policy difference. This translates to a 4.2% average cost of bearing oil price risk.

How much did the policy cost Kansas? Administrative costs have been less than 1% of the estimated savings. The Kansas government has not hedged, but the cost of doing so with oil futures would be small because the state borrows at about 1%.[3] In contrast, for the average paving firm, the implied cost of risk from the pass-through analysis suggests that the cost of capital to hedge with financial futures must be roughly 25%. This difference highlights the desirability of assigning risk in a product market relationship to the party with

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

the lower cost of managing it. The state has informational and enforcement advantages, and is the final consumer. In assuming the risk, it benefits from eliminating the profit and risk premium on physical forwards from suppliers.

This paper provides the first rigorous assessment of an oil product price insurance policy in highway procurement. Most U.S. states now have a similar policy (Skolnik 2011). Since the procurement auction process and industry composition vary little across states, there is no reason to believe that the effects I find in Kansas would not apply elsewhere.

To my knowledge, there is no firm-level study of risk management that compares public to private firms, or examines family ownership, industry diversification, or credit risk within private firms. My context is well suited to comparing firm types. While highway paving is essentially a commodity, construction firms are diverse.[4] The theoretical literature justifying hedging among public firms begins by proposing that financial constraints and distress costs can lead firms to value risk management (Froot, Scharfstein & Stein). We expect these frictions to be larger among private firms, and perhaps compounded by greater risk aversion.

I show that the insurance policy increased the probability of winning for private firms, particularly undiversified ones, at the expense of public firms. I use two methods to address heterogeneity in risk pass-through. One is to split the sample in the volatility-modulated difference-in-differences design. The other is to measure risk as the time between the auction and work start interacted with oil price volatility, excluding post-policy Kansas. Both approaches reveal that private firm bids are much more sensitive to risk than public firm bids. Within private firms, high credit risk and undiversified firm bids are much more sensitive to risk than their respective counterparts.

Private firms may be more risk averse because poorly diversified owners smooth personal income through the firm. Manager-owners of family firms are known to smooth consumption through the firm, rather than maximize firm value (Bertrand & Schoar 2006). If concentrated ownership contributes to the risk premium, as Faccio et al. (2011) suggest,

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

I expect family firms to have a higher cost of bearing oil price risk. In fact, I find that that family-owned firms' cost of risk is indistinguishable from non family-owned firms.

Alternatively, some firms might have greater managerial agency and information problems. These should be more severe among larger private firms, where monitoring is more difficult. While I find that single-location firm bids are somewhat more sensitive to risk, I do not find strong effects of firm size. Finally, as Manova (2013) describes in the context of international trade, some firms may face higher costs of capital and distress, which they pass through to product markets. Consistent with this mechanism, firms with high credit risk and low industry diversification are most responsive to the policy.

In the absence of government-provided insurance, asphalt paving firms usually purchase physical forward (fixed-price) contracts from local bitumen suppliers at the time of the auction, thereby fully insuring with no cash up front. Such fixed-price contracts with distributors are also common among farmers, electric utilities, and airlines. After the policy, asphalt paving firms in Kansas universally elected to use the state-provided insurance, which is free to them albeit with basis risk. Their revealed preference suggests that the state-provided insurance is cheaper than physical forwards, which in turn are cheaper than hedging in financial markets. End users may perceive financial derivatives as costly because of capital requirements, basis risk, economies of scale, daily marking to market, and a lack of financial sophistication.

Rampini & Viswanathan (2010) show that costly capital can preclude firms from insuring in financial markets because of an inability to meet collateral requirements. Bolton, Chen & Wang (2011) point out that high capital costs may lead firms to manage risk with alternatives to financial derivatives, such as cash and fixed-price contracts. If the cost of these alternatives above the cost of hedging in financial markets is passed on to the product market, an opportunity for a public hedging program to improve efficiency arises.

In addition to evaluating a hitherto under-studied policy, this paper contributes to the literature on risk management. An important related paper is Cornaggia (2013), who finds a positive association between an insurance policy and farm yields at the county level. In contrast, my data is at the firm level. Cornaggia examines whether yields increase when farmers can purchase crop insurance policies from the government. The Kansas insurance policy is free to firms, permitting to my knowledge the first study of the price impacts of eliminating a risk, rather than simply reducing the cost of managing it. Cornaggia's results focus on variation in the moral hazard incentives of group policies relative to individual policies. In contrast, I study variation focused on firm ownership, size, industry diversification, and credit rating.

This paper also complements Pérez-González & Yun (2013), who examine how publicly traded electric utilities respond to the introduction of weather derivatives. They show that utilities benefit from access to weather derivatives, but do not explore whether part of the cost reduction is passed to electricity prices. I build on Pérez-González and Yun by studying private firms and by demonstrating the pass-through of input cost risk to the consumer.

Other related work addresses financial constraints and hedging in the public firm context (Acharya, Almeida & Campello 2007; Campello et al. 2011; Lin & Paravisini 2013; Rampini, Sufi & Viswanathan 2014). While much of the financial economics literature has focused on the relationship between hedging and firm value, this paper studies the pass through of risk to product markets and, in particular, the deleterious effect of inefficient risk management on the consumer (here, the government).

This paper also contributes to procurement auction analysis. For example, Athey & Levin (2001) find evidence of bidder risk aversion in timber auctions, and Esö & White (2004) examine ex-post risk in auctions. Other work includes Ewerhart & Fieseler (2003), Jofre-Bonet & Pesendorfer (2003), and Krasnokutskaya & Seim (2011). Finally, this paper relates to pass-through analysis, including of costs and taxes (Campa & Goldberg 2005; Weyl & Fabinger 2013). To my knowledge, there is no causal estimate of risk pass-through.

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

2 Highway Procurement and the Kansas Insurance Policy

The study of risk management has faced a number of challenges, including the potential correlation of risk with other determinants of firm value; hedging decisions that are endogenous to firm value; conflation of speculation with hedging; and cross-sectional or survey-based data sources.[5] Highway procurement is a useful setting because it does not face these challenges.

Like in other U.S. states, the Iowa and Kansas Departments of Transportation (DOTs) use auctions to procure highway construction projects. DOTs initially prepare a public proposal for a project detailing the location and type of work, which includes estimated quantities of materials needed and the expected start date. For example, the proposal might include an estimated five miles of guardrail. Firms submit unit bids for each item, such as $10 per foot of guardrail. The bidder with the lowest vector sum of unit item bids times estimated quantities wins the auction.[6]

In asphalt paving, one of the construction materials (and unit items in contracts) is bitumen, a petroleum product. Also called "asphalt binder" or "asphalt oil", bitumen is a black, sticky material that is mixed with rock pieces to make asphalt. Paving firms face cost uncertainty when they bid on a highway construction project. If oil prices rise between the auction and the start date of the project, the firm's bitumen cost will increase.[7] Auctions are mostly held in the winter, while work is done in warmer months. Paving firms are typically paid when work is underway, on average about six months after the auction. As a result, they are often cash flow constrained at precisely the time of year when they are most exposed

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

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

[7]I present a simple model of the firm's bidding decision in Section 1 of the Appendix. It shows how a risk premium is included in the bitumen bid markup. I do not address the risk of losing an auction. Interviews I conducted with paving firm executives suggest that paving firms are risk-averse towards input costs but risk-neutral towards an individual auction. Paving firms participate in many auctions and treat them as a portfolio. While the risk of losing any given auction is idiosyncratic, oil price risk for the upcoming construction season is highly correlated across projects.

to oil price risk.[8]

In the early 2000s, state DOTs began to shift oil price risk from highway paving firms to the government, believing that any cost to the government of bearing oil price risk would be offset by lower bids (Skolnik 2011). The policies were motivated by the belief that "The volatile price of the asphalt oil has led contractors to make bids that are more costly than necessary" (Shaad 2006). They reflected longstanding suggestions from the U.S. Federal DOT that such risk shifting might lower bids ([9] The Kansas DOT implemented its bitumen insurance policy (called a "price adjustment policy") in August 2006. One official had a personal interest in oil prices and had become interested in price adjustment policies following a federal DOT report on them. The precipitating event, according to Kansas DOT officials, was a contractor bidding an outrageously high price for a contract in which he was the only bidder, claiming that he could not get a firm bitumen price from suppliers. Most states have implemented such an insurance policy for petroleum products. Yet there is no public evidence that firms charge excessive oil price risk premiums, nor has there been any public evaluation of these policies' effects on procurement costs, to my knowledge.[10]

Iowa, which is northeast of Kansas, has not pursued an insurance policy as of the fall of 2016. Iowa DOT officials told me that despite experiencing similar cost escalation, they were not interested in the policy. My interviews with both states' DOTs indicate that neither industry lobbying nor local economic or demographic factors played a role in Kansas' decision to adopt the policy and Iowa's decision not to.[11] Other than the circumstantial preference of

[8] Adam et al. (2007)theorize that financially constrained firms are disincentivized from hedging when they can adjust output to reflect realized cost. In my setting, this cannot occur as output (road construction) is fixed.

[9] A 1980 U.S. DOT Technical Advisory began with the following statement: "Price volatility of construction materials and supplies such as asphalt, fuel, cement and steel can result in significant problems for contractors in preparing realistic bids. In many cases, prospective bidders cannot obtain firm price quotes from material suppliers for the duration of the project. This leads to price speculation and inflated bid prices to protest against possible price increases. This Technical Advisory will provide contracting authorities with information for development and application of price adjustment provisions to respond to this price volatility by transferring a portion of the risk to the contracting agency, resulting in lower bids" (USDOT 1980).

[10] In the only analysis thus far, Kosmopoulou & Zhou (2014) examine one state, Oklahoma. They find that firms bid more aggressively after the policy, which they ascribe to the winner's curse effect. They assume firms are risk-neutral.

[11] Interviews in person, on the phone, or over email were conducted in 2012 with Steven Belzung, Roger

middle-management DOT officials following the bidding incident described above, there was no industry or government motivation for the insurance policy in Kansas. Iowa and Kansas were on similar economic growth paths before, around, and after the insurance policy was implemented in Kansas; they had parallel trends in highway spending, basic transportation statistics, and ARRA funding (see Section 4 for details).

The insurance policy operates as follows. The Kansas DOT purchases a regional bitumen price index from a private data firm. It then adjusts payments to the paving firm if the bitumen price index changes between the auction and the time the project begins. When bitumen prices rise, the paving firm is paid the amount of the bid plus the bitumen price index increase, and when prices go down, the paving firm receives the bid less the bitumen price index decrease.[12] In auctions in Kansas, paving firms choose whether or not to use the insurance policy when they submit their bids. There is no preferential treatment for certain types of firms. All bidders have opted for the policy (a few exceptions appear to be mistakes). Appendix Figure 1 shows the ex-post contract price adjustments over time.

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

Bierbaum, LouAnn Hughes, Kevin Martin, Abe Rezayazdi, Greg Sheiber, and Sandy Tommer.

[12]Specifically, each month the Kansas DOT publishes an Asphalt Material Index (AMI), which they purchase from Poten & Partners. Paving firms incorporate the current month's AMI into their bid for asphalt. The AMI for the month of the letting is the Starting Asphalt Index (SAI) for the contract. DOT technicians take samples from the mix being placed to monitor quality and to obtain a percentage bitumen content to adjust payment based on the change in the AMI. The difference between the SAI and the AMI to the nearest dollar becomes the adjustment factor, applied to work completed during that month. The adjustment only occurs when the AMI differs from the SAI by $10 or more. The Kansas bitumen price index is almost identical to the Argus Media spot price index I use elsewhere in the paper. Both are created from surveys of recent bilateral transactions.

3 Procurement Auction Data

I employ comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012.[13] I focus on road paving projects, which are bitumen-intensive.[14] One outcome variable in the analysis is the unit item bitumen bid, which is the per ton bitumen bid within the larger total project bid. A secondary outcome variable is the total bid for the paving project per ton of required bitumen, which accounts for the possibility that different strategies for allocating profit among items could distort the true effect of volatility on the metric that matters to DOT (the overall bid for the project). Bitumen comprises 11.3% of the total bid amount on average for the contracts in my data, but can be up to 40%.[15] Figure 1 shows Iowa and Kansas bitumen bids over time, as well as the crude oil price and historical oil price volatility. Although its price is correlated with crude oil (0.8 in my data), there are no liquid spot or futures markets for bitumen in the U.S.[16] In practice, bitumen is purchased from local suppliers in one-off, non-public transactions. Suppliers purchase bitumen from refineries and store it. Bitumen is costly to transport and store, so suppliers naturally form a territorial oligopoly (Appendix Figure 2).

Auction data summary statistics are in Table 1. In both Iowa and Kansas the average number of bidders in an auction is 3.4. The time between an auction and the start of a paving project varies from less than a month to 16 months; on average, it is 4.6 months in Iowa and 5.7 months in Kansas (this difference is not statistically significant). Iowa and Kansas are similar in their auction format, road characteristics, weather patterns, and firm type distribution. Iowa has more paving firms because its highway construction industry is larger. Firms select the projects they bid on, so I use extensive project controls in the analysis.[17]

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

[14]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.

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

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

[17]Appendix Tables 1 and 2 show selection across the firm characteristics for key control variables: bitumen

I also employ data from four other sources. First, data on firm characteristics is from Dunn & Bradstreet (D&B), supplemented with manually collected information from firm websites. Second, I observe actual hedging in 105 forward physical contracts between paving firm Z (identity protected) and all four regional bitumen suppliers. Firm Z, based in Iowa, is among the top three firms in number of total bids in the Iowa, and near the mean among regular Iowa bidders in win percentage. Third, I conduct a survey of 20 of the top bidders across both states.[18] Finally, I use oil price and volatility data from Bloomberg (summary statistics in Appendix Table 3).

As shown in Table 2 Panel 1, there are six publicly listed firms in my sample. A majority of private firms is family owned (71% in Kansas and 79% in Iowa). I identify a firm as diversified if its activities are not limited to asphalt highway paving, based on 8-digit SIC codes. Note that 60% of firms in Iowa are paving-only firms compared to just 22% in Kansas. I define credit risk to be high when D&B rates the firm as high or medium risk. Credit risk is also different across the states: 34% of asphalt paving firms in Iowa are rated as high risk, compared to 13% of Kansas firms. I use two measures of size. The first is based on the number of employees and revenue in the cross-sectional D&B data.[19] The second is whether the paving firm has only one location and is not a subsidiary. Unfortunately, variables like investment and profitability are not available for privately held firms. The correlations among characteristics are shown in Table 2 Panel 2. All correlations are positive except for the one between family ownership and high risk, which is -.02. The highest is 0.49 between firms with a single location and small firms. Undiversified firms are also rough proxies for single location firms.

I use six-month WTI oil futures as a measure of the expected oil price.[20] The measures of risk are historical volatility, which is an annualized standard deviation of daily returns, and

quantity, miles between the firm and the project, number of bidders in the auction, and months between the auction and work start.

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

[19]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.

[20]This follows convention. The average time to work start is five months.

implied volatility, which is derived from the Black & Scholes (1973) option pricing formula. In the analysis, I primarily use 12-week historical oil price volatility, but show robustness to 26-week and at-the-money implied volatility for oil futures options expiring in three months.

4 Estimation Strategy

This section describes the three empirical approaches in the paper: the policy evaluation, the estimation of risk pass-through to bids, and heterogeneity across firm types in risk pass-through. First, I employ a difference-in-differences (DiD) design to ask whether the insurance policy affected the ex-post cost of bitumen for the government of Kansas. Oil prices increased on average between the auction and the project start date in post-policy Kansas.[21] This means that if firms were risk-neutral, Kansas should have experienced an increase in costs after implementation of the insurance policy in 2006.

I use equation 1, where i indicates bidders, j indicates projects (same as the specific auction/contract), and t indicates the day of the auction. The dependent variable ($Cost_j$) is the price paid by the state, including any Kansas adjustments. I also examine the effect on bids and on the number of bidders (the latter proxies for the competitiveness of the auction). $\mathbf{I}_{post\ policy_t}$ is an indicator for whether the auction took place after August 2006. $\mathbf{I}_{Kansas_j}$ is an indicator for whether the auction took place in Kansas.

$$\begin{aligned} Cost_j = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} + \beta_2 \mathbf{I}_{post\ policy_t} + \beta_3 \mathbf{I}_{Kansas_j} \\ + \gamma' \cdot controls_j + \delta_1 \mathbf{I}_{county_j} \cdot year_j + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{jt}. \end{aligned} \tag{1}$$

The coefficient of interest (β_1) gives the mean difference across states in the actual price paid by the government after implementation of the insurance policy, controlling for the pre-policy difference. In some specifications I limit the sample to years immediately around the policy, but in the main model I include all auctions in Iowa and Kansas between 1998

[21] The average increase was \$7.5 per ton, with a standard deviation of \$16 (across 1,444 contracts).

and 2012. Auction-level controls are the number of bidders and project size.[22]

County-year fixed effects control for unobserved economic shocks, and the twelve month-of-year fixed effects account for changing capacity constraints over the construction season. 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. I cluster standard errors by firm.

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

$$\begin{aligned}\ln bid_{ijt} = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{Kansas_j} + \beta_4 \mathbf{I}_{post\ policy_t} \\ + \beta_5 \mathbf{I}_{post\ policy_t} \cdot \ln Vol_t^{oil} + \beta_6 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} + \beta_7 \mathbf{I}_{\text{Kansas}_j} \cdot \ln Vol_t^{oil} + \beta_8 \ln price_t^{oil} \\ + \gamma' \cdot controls_j + \delta_1 \mathbf{I}_{county_j} \cdot year_j + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{ijt}. \quad (2)\end{aligned}$$

Here, $price_t^{oil}$ is the oil futures price, and Vol_t^{oil} is its volatility. The coefficient of interest, β_1, is the effect of volatility on bids in Kansas relative to Iowa after oil price risk shifted to the public sector. I also use firm fixed effects to test whether the main result reflects differences in sophistication, and county fixed effects to test whether the result is due to recomposition (firm exit and entry) within a county. A larger result with county fixed effects would suggest the policy allowed firms to enter counties where they did not previously bid. In the main specification, state and time fixed effects subsume any average changes in the competitive equilibrium in Kansas among paving firms and between paving firms and suppliers after the policy.

Finally, I examine cross-sectional heterogeneity in two ways. First, I split the volatility modulated DiD (equation 2) by firm type. Second, I measure risk as the forward market interacted with oil price volatility (equation 3 below). That is, I evaluate how oil price volatility affects bids in auctions with varying distances in time from the work start date, so that the measure of risk is $\sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}}$.[23] When the project starts the month after

[22] The log bitumen tons proposed multiplied by average total bid (the latter includes non-bitumen items).
[23] I use the square root of $Wait_j$ because volatility moves at the square root of time.

the auction, there is little risk regardless of recent volatility. I then interact this with a firm type indicator; the case in equation 3 is $\mathbf{I}_{public_j}$, which is 1 if the firm is publicly owned, and 0 if privately owned. The estimating equation is:

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

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

Parallel Trends

The key identifying assumption is that, after the rich controls and county-year fixed effects, nothing relevant to oil price risk for highway contractors changed in Iowa or Kansas around the same time as the 2006 policy implementation. In other words, the primary identification concern in the DiD analysis is a violation of the parallel trends assumption. I address this by demonstrating parallel trends for relevant observables, and through robustness tests.

Figures 2 and 3 show that Iowa and Kansas had similar GDP and vehicle miles traveled growth paths around the 2006 policy, using Bureau of Economic Analysis and Federal Highway Administration (FHWA) data, respectively. Figures 4 and 5 show that for the overall construction industry and for the highway construction industry in particular, the number of employees, establishments, and total annual payroll also exhibit parallel trends. These graphs use U.S. Census County Business Patterns data. Figures 6 shows parallel trends for total highway spending (capital and maintenance outlays) across the two states, also using FHWA data.

Figures 7 and 8 use data from the Iowa and Kansas DOTs to show the number of asphalt paving procurement contracts in each state, and the total annual tons of bitumen used in these contracts. These last graphs exhibit the least correlation across the two states. In particular, Iowa experienced a larger jump as a result of the ARRA in 2009. To ensure that this jump for Iowa does not bias the results, in robustness tests I exclude 2009. Overall, Iowa and Kansas received similar amounts of ARRA funding ($4.7 and $4.4 billion, respectively, relative to a national per-state average of $10 billion and standard deviation of $11 billion).[24]

I also test statistically for parallel trends by asking explicitly whether bidders in Iowa and Kansas responded to risk differently prior to the insurance policy. The results, in Table 7 column 1, show that when the sample is limited to pre-policy years, there is no difference.

5 Real Effects of the Insurance Policy

In Table 3, I show average bids, ultimate project costs, and number of bidders in Iowa and Kansas around implementation of the insurance policy. Bitumen bids in Kansas were higher before the insurance policy than those in Iowa. This is because Iowa has more road paving projects (Table 1), and the per-ton cost decreases with scale. The difference narrowed around implementation of the policy. Bids in Kansas were $28 per ton higher before the policy and $15 higher after. Before the policy, Kansas' bitumen costs were $36 more per ton than Iowa's. After the policy, Kansas paid $28 less; this amount reflects the lowest bid and any price adjustment from the policy.

Table 4 shows estimates of equation 1, where the dependent variable is the bitumen cost to the state in dollars per ton. It reflects both the bids and any adjustments from the insurance policy. Kansas' insurance policy yielded savings of $39 per ton of bitumen, or 8% of the average per-ton cost (column 1). Note that if realized bitumen prices after implementation of the policy were systematically lower than market expectations, the price paid could be lower for Kansas than Iowa without any risk premium change. However, as explained above, oil prices on average increased between the auction and the work start date after the policy.

The main specification implies that Kansas saved around $77 million in the 6.5 years after implementation of the policy, relative to total bitumen expenditure of about $820 million. The Kansas DOT did not hedge its oil price risk between 2006 and the end of my

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

sample in 2012. Administrative annual costs of the policy are negligible, at around \$36,750.[25]

Narrower bandwidths of two and three years around the policy (columns 2-3) yield larger effects, of \$76 and \$68, respectively. Two-way error clustering by firm-month and state-month in columns 4 and 5 has little effect on the standard errors. Appendix Table 4 columns 3 and 4 show robustness to alternative error assumptions. Omitting the controls increases the estimated effect (column 6). Omitting fixed effects in column 7 has little effect. Finally, the result is also quite similar with firm fixed effects (column 8).

Despite the demonstration of parallel trends in Section 4, there may be concern that the results reflect unobservable time-varying differences across Kansas and Iowa. I estimate a within-Kansas DD comparing the bitumen-intensive contracts in the main analysis to contracts that include little bitumen (e.g., a contract for mainly bridge building). These estimates, in Appendix Table 4 columns 1 and 2, show savings from the policy of \$49-\$54 per ton of bitumen, quite similar to the main specification.

The result confirms the theoretical result in Liu & Parlour (2009). They examine the value of hedging in a winner-take-all auction setting where firms face a common risk. When firms invest in a hedging portfolio that is not contingent on the auction outcome, losing firms are over-hedged, and firms compete away the benefits of hedging. Hedging leads to a loss in social welfare borne by the seller. In highway paving, the forward bitumen contracts are contingent on winning the auction, allowing firms to hedge without competing away rents. Liu and Parlour conclude that "it is to the seller's advantage to...reduce the bid-to-award period or to hedge the common value of the project himself." Kansas (the seller) pursued precisely the latter strategy in 2006, and benefited from eliminating firms' need to hedge.

Policy Effect on Competition

I next consider the policy's effect on competition. Like many industries, highway construction is characterized by imperfect competition. Inelastic demand, high barriers to entry, information asymmetry, easy defection detection, and a static market environment are all conducive to

[25] Interviews led to the following estimates. The insurance policy requires a \$5,295 per year subscription to Poten & Partner's bitumen price index, and about one hour of employee time per project. There were 166 projects post-policy. I assume employee time is valued at \$30/hr in real terms between 2006 and 2012.

collusion and are features of highway procurement (Porter 2005). The average bid decreased after the policy by 7.6% (Table 5 column 1), suggesting an increase in competition from the insurance policy. This is confirmed in Table 5 column 2, where I use the number of bidders in the auction as the dependent variable. The insurance policy increased the number of bidders in auctions by 0.8, relative to an average of 3.4. In Appendix Table 5, I omit fixed effects, and find similar results.

The distribution of winning bids also changed after the policy. In Figure 9, the bar heights indicate the win percentages by number of firms in each category of auction. Kurtosis and skewness both declined significantly after the insurance policy; the former from 4.9 to 3.0. This means that firm "winningness" was more evenly distributed across firms after the policy. The distributional changes are consistent with a more competitive market. There was little firm entry or exit.

Paving firms and bitumen suppliers are in oligopolistic, territorial equilibria. Appendix Figures 3-7 show the location of auction wins and losses for five large bidders. Wins are concentrated in a portion of the state while losses predominate outside that territory. Other major bidders exhibit similar patterns. Spatial oligopoly is a natural result of high transportation costs; even with perfect competition rents would be zero on territory boundaries and positive within. In an interview, a CEO said that imperfect competition permits even very risk averse pavers to stay in business.

The bitumen suppliers form a second layer of imperfect competition. Like the paving firms, suppliers enjoy markups within their territories at least as large as the differential transportation cost for the next-closest supplier. Suppliers provide quotes to paving firms before each auction, and itemized bids are published immediately afterwards. In interviews, the suppliers suggested that recent auctions might serve as a signaling mechanism, as in Friedman (1971).[26] The suppliers apparently charge the pavers a large fraction of, if not their full, cost of risk.

[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."

Thus this context features imperfect competition in two layers of product markets. It seems likely that imperfect competition compounds financial frictions to impede efficient risk allocation, allowing firms to pass high and heterogeneous insurance premiums to the consumer. Relatedly, Scharfstein & 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 Insurance Policy Effect on Risk Pass-Through

The Kansas insurance policy reduced bid sensitivity to oil price volatility. Table 6 shows estimates of equation 2. The value of -0.14 for β_1 in column 1 means that a one standard deviation increase in volatility, or a 14% increase, decreases bids in Kansas relative to Iowa by 2%, relative to their pre-policy difference. Since paving firms in Kansas faced zero oil price risk after implementation of the policy, the difference between Iowa and Kansas is the pass through of risk management costs. The implied average cost to firms in my data of bearing oil price risk is therefore 4.2% (the post-policy mean of historical volatility, 30%, times the .14 estimate).

Using the log total bid per ton of bitumen as the dependent variable (column 2) gives a similar coefficient of -0.15. The effect declines by a bit less than half when I use a narrow bandwidth of two years around the policy, but remains significant at the 5% level (column 3). There is no independent effect of being in Kansas after the policy, as Table 6 column 4 shows. When I limit the sample to periods of high volatility (column 2), the coefficient becomes -0.1, significant at the 1% level. This confirms the main result that volatility drives the triple difference coefficient.

Despite the demonstration of parallel trends in Section 4, there may be concern that this result reflects unobservable time-varying differences across Kansas and Iowa. Two tests suggest that this is not the case. First, I conduct a within-Kansas modulated DD design comparing bitumen to non-bitumen items. If the policy reduced risk pass-through, the effect of volatility on bitumen items relative to non-bitumen items should be smaller after the policy than before. 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 6. The effect of volatility on the bitumen relative to non-bitumen items after relative to before the policy is -.44 (column 1). 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 (column 2).

Second, I test whether the effect of the policy is as strong for the 19 firms who bid in both states. The main effect is not statistically significant and has a magnitude of -0.7 among these firms. They continue to face risk in Iowa, but are also larger and better diversified to begin with. The effect is much larger, at -0.19 and significant at the 1% level, for firms that bid in only one state (Appendix Table 6 columns 3-4).

To shed light on the mechanism, I vary fixed effects. With firm instead of county fixed effects, the coefficient of interest on the triple interaction is slightly larger, at -.18 (Appendix Table 7 column 4). This suggests that static forces at the firm level, such as average risk aversion or financial sophistication, do not explain the results. Firm fixed effects also obviate concern that firm selection into auctions may explain the result. While the policy changed the competitive landscape, firm selection does not explain the average risk pass-through result. The result also does not reflect firms expanding into new markets, as the specifications in Appendix Table 7 omitting county effects demonstrate. Instead, the policy lowers costs among incumbent firms in their existing markets.

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 show in Table 6 column 6 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 7 omits the county-year fixed effects. The result is essentially unchanged at -0.17.

Clustering standard errors by state-month, in Table 6 column 8, doubles the standard error of the triple interaction, but it remains significant at the 10% level. If there are unobserved firm-specific exposures, clustering by firm should render the main effect less significant. Firm-month clusters in column 8, and other alternative error assumptions in are in Appendix Table 8 columns 1-3 continue to find robust results.

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 7 column 2 shows that the effect is -0.13 excluding 2009. Column 3 shows robustness to excluding years after 2009. Placebo tests are in columns 4 and 5, 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.

Appendix Tables 7 and 8 contain additional robustness checks. Individual effects are in Appendix Table 7 columns 1 and 2. I conduct a falsification test in column 3. Here, 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.

There is concern that time-varying state highway spending or state-level construction activity could bias the results. Appendix Table 7 columns 6 and 7 show robustness to state-year and state-month fixed effects, respectively. Column 8 uses quarter fixed effects.

Alternative oil measures are in Appendix Table 7 columns 9-11. 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 11 uses 5-month futures instead of 6-month, and finds a very similar coefficient of -0.13.

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 use dummies for quantiles. Appendix Table 8 columns 5 and 6 use 10 and 20 quantiles of volatility, respectively, and finds that the triple interaction effect remains negative and highly significant.

How Firms Manage Risk in Practice

The large effect of the policy on risk pass-through raises the question of how this industry manages risk in the absence of state-provided insurance. In general, firms can manage risk with hedges, insurance, diversification, or cash holdings. Paving firms typically fully insure by signing physical forward contracts with suppliers before the auction.[27] Sometimes paving firms wait, and sign sometime between the auction and the time work begins. Occasionally, they buy bitumen at the time work begins with no prior fixed price. Very rarely, if ever, do paving firms hedge in financial markets. Interviewees suggested that public firm subsidiaries more often wait to sign physical forwards. They likely are able to draw liquidity from their corporate parents if an oil price shock occurs. While the parent may trade derivatives at a global level, interviews indicated that the subsidiary is not involved in that trading. The physical forward contracts represent a reservation price of hedging; if firms choose forward contracts rather than hedging in financial markets, the latter must be at least as costly.

The counterparties in the forward contracts are suppliers. They buy and store bitumen year-round, so at the time of an auction, they are partially physically hedged against the short positions they are taking in their contracts with paving firms. Nonetheless, in the supplier-paver relationship, the supplier generally has downside risk while the paving firm has upside risk. If the supplier has total bargaining power, the forward price could include both sides' risk premiums. Volatility helps explain why the price in the 2009 contract in Figure 11 is so much higher than the 2008 contract in Figure 10, even though oil prices fell across the two dates. Volatility was quite low in early 2008 but peaked at over 70% in early 2009 (see Figure 1).

I use the 105 Firm Z forward contracts to estimate the risk premium in the forwards

[27] The paving firm typically signs a contract with one supplier committing to purchase the bitumen at the quoted price at the time of work start should he win the project. The price is good only for the DOT project specified in the contract, but the bitumen can be taken typically any time during the construction season. The supplier must have sufficient bitumen stored to cover all contracted supply. Suppliers buy bitumen from oil refineries, which produce it year-round as a byproduct.

relative to the bitumen index price that Kansas used to implement its policy.[28] This also gives an upper bound on the basis risk from using the index. Specifically, the risk premium is the forward contract price less the realized index price in the week that work starts (typically, the forward contract price is dated in the winter, and work starts the following spring or summer). These risk premiums are graphed in Appendix Figure 8. The average risk premium is 24% of the forward contract price, and its standard deviation is 10%. By choosing the index over their forward contracts, paving firms avoid paying the premium but take on basis risk. Since paving firms use the index when it is available and forward contracts otherwise, the basis risk in the index can be inferred to be no more than 10%. Paving firms must perceive hedging in financial markets as costlier than both of these options.

The Cost of Hedging with Oil Futures and the Implied Cost of Capital

I showed above that paving firms place significant value on state-provided insurance. This is incongruous with two facts: (a) oil has notably liquid derivative markets; and (b) evidence indicates that excess returns to holding oil futures (the simplest hedge) should be quite small. There is no general consensus on the oil price risk premium, but researchers have been unable to reject a zero risk premium for long-only commodity portfolios (Erb & Harvey 2006; Basu & Miffre 2013). Oil prices are close to a random walk; Alquist & Kilian (2010) and Kellogg (2014) show that the no-change forecast is much more accurate than forecasts based on oil futures or oil futures spreads. Ahn & Kogan (2012) report an oil equity beta of 0.01 between 1971 and 2010. One-factor betas change sign over time, and are rarely more than 0.5 (see Appendix Figure 9), implying a premium of at most 1.5%. Note that correlation between macroeconomic growth and oil prices may depend on the source of the shock. Economic growth may induce a positive demand shock, increasing prices, while a positive supply shock may decrease prices, having a positive effect on growth (Anderson et al. 2014).

[28] Firm Z's per ton contract prices for bitumen are graphed in panel A of Figure 12. The contracts are tied to a specific Iowa DOT paving project, so I observe the bid item markup over the contract price. The markup is stable at around $22 per ton regardless of oil prices or volatility (Figure 12, panel B). Interviewees indicate that this fixed markup reflects transportation costs, and profit margins are usually loaded on bid items for labor and overhead. Although not central to my analysis, this suggests that the cost of risk is embedded in the forward contract.

The simplest hedging strategy is to purchase oil futures.[29] This requires a performance bond, or "margin," which is marked-to-market every day and changes with volatility.[30] A thought experiment supposing that an average firm in my data used oil futures to hedge its annual bitumen needs illustrates how much this might cost. Figure 13, using historical margin requirement data from CME, shows the results of this exercise.[31] The margin account averages about \$150,000. The dots below zero are instances when oil prices declined and the account has no cushion. The firm must wire in money within 24 hours or have its positions liquidated. In the absence of a volatility-driven percentage change in margin, a \$1 drop in the price of oil requires an immediate wire of \$16,000.

The cost of hedging is the cost of capital in the margin account. A financially constrained firm by definition has a high cost of borrowing. The implied cost of capital that equates the average cost of risk (4.2% from Table 5) with the cost of hedging in futures markets is around 25%.[32] This reflects hidden costs of trading in derivative markets, including the need for financial sophistication, exposure to cash flow risk during the hedge period, employee time to manage the account, basis risk, and transaction fees. Also, economies of scale are barriers to hedging in financial markets for small firms (Géczy et al. 1997; Haushalter (2000)). These implicit costs of hedging in financial markets are essentially zero with physical forward contracts. The role of financial sophistication, or information acquisition costs, deserves future research. In interviews, executives often described hedging in financial markets as complicated and expensive gambling.

If a firm were able to borrow at 5% (likely a low assumption), the cost of capital dedicated to hedging in our example is about \$2.26 per ton of bitumen. As mentioned above, the Kansas government did not hedge after the policy. I repeat the futures hedging thought experiment for the state instead of the firm. To hedge average annual statewide

[29]The more complex strategy is to purchase call options on futures. Although the firm loses at most the cost of the options and has upside potential, this is on average a more costly and complex strategy.

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

[31]Contact the author for details.

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

bitumen needs, Kansas would initially need \$3.2 million in its margin account each year.[33] Note that this amount is about one-fourth the annual savings from the insurance policy of \$12 million). If the state can borrow at 1%, the cost of capital would \$21,250 per year on average, or about 46 cents per ton of bitumen.[34] This calculation demonstrates the simple fact that all else equal, risk should be allocated to the party in a transaction with a lower cost of bearing it.

7 Heterogeneity in Risk Pass-Through

Thus far, we have seen that the insurance policy reduced costs for Kansas, increased competition, and substantially reduced bid sensitivity to oil price volatility. Next, I explore which types of firms especially benefited from the policy, providing the first firm-level comparison of the cost of risk management across public and private firms, and family-owned and non-family-owned firms.

Predictions from Theory

State-provided insurance should be most useful to paving firms with higher costs of bearing risk, but it is not obvious which firms should derive the most benefit. On one hand, I expect private firms to have a higher cost of external finance than public firms and to be more risk averse because they have less diversified owners.[35] On the other hand, there may be no difference if public firms have risk-averse managers and agency problems (Stulz 1996), or if firms hedge for informational reasons, such as to reduce noise in their accounting statements (DeMarzo & Duffie 1995; Breeden & Viswanathan 1998).

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

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

[35] For theory, see Fama & Jensen (1983) and Schulze et al. (2001); for evidence, see Tufano (1996) and Panousi & Papanikolaou (2012).

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

Predictions from theory are clearer for other firm dimensions. First, small firms usually have fewer collateralizable assets than large firms, so they face more severe financing constraints (Nance et al. 1993; Hennessy & Whited 2007). Second, I expect that if distress costs are related to the value of insurance, as in Rampini & Viswanathan (2013), and Purnanandam (2008), firms with higher credit risk or less industry diversification will most benefit from the insurance policy.

Probability of Winning an Auction

First, I estimate the effect of the policy on the probability that a certain type of firm won the auction. Private firms were 19 percentage points more likely to win after implementation of the insurance policy than before, relative to a mean of 74% (Table 5 column 3). Similarly, the policy increased the probability of winning for paving-only firms by 20 percentage points relative to diversified firms. Logit models produce larger effects with smaller standard errors.[36] Appendix Table 5 columns 3 and 4, I omit fixed effects, and find similar results, except that the private vs. public interaction becomes insignificant. I do not find statistically significant differences in the probability of winning across other observable characteristics.

Effect of Volatility by Firm Type: Sample Splits

I explore heterogeneity in the implied cost of risk across firm types first through sample splits. (Equation 2 is too complex for an additional set of interactions, so I cannot test whether

[36]Logit models produce larger and more significant results because they drop groups (e.g., county-months) with no "successes" (e.g., paving-only firm wins). With a logit specification, the odds ratios for the coefficients on private versus public and paving-only versus diversified are 2.8 and 4, respectively, significant at the 1% level.

these differences are statistically significant.) First, I split the sample by ownership type in Table 8. The insurance policy's effect is -0.14 among private firms (column 1), and -0.08 among public firms (column 2). The difference across family-owned and non-family-owned firms is much smaller, at -.12 and -.1 (columns 3 and 4).

Next, Table 9 limits the sample to private firms and examines characteristics associated with financial constraints. The insurance policy's effect is -.24 for high credit risk firms, while it is only -.12 for low credit risk firms (columns 1 and 2). This implies a 5.9% cost of oil price risk for high credit risk firms, compared to 3.1% for low credit risk firms.[37] The coefficient among single-location, non-subsidiary firms is -0.18, relative to an insignificant -0.0031 for other firms (columns 3 and 4).

Similarly, the coefficient is -0.19, significant at the 1% level, for paving-only firms and an insignificant -0.084 for diversified firms (Table 6 columns 5 and 6). MacKay & Moeller (2007) and Faccio et al. (2011) also find that well-diversified firms are less risk-averse.[38] Finally, when I use the secondary size metric (based on revenue and employment), there is less variation; -.15 for small firms and -.091 for large firms (columns 7 and 8). Extensive project controls ensure that projects are not systematically and observably different across firm types (see also Appendix Tables 2 and 3).

My main heterogeneity findings should translate to certain Kansas firms being relatively less sensitive to volatility after the policy. I therefore examine within-Kansas effects across firm types. Appendix Table 9 shows estimates in which the coefficient of interest interacts either $\mathbf{I}_{Public_j}$ or $\mathbf{I}_{High\ Risk_j}$ with the policy and volatility. As expected, public firms submitted relatively higher bids after relative to before the policy in response to additional volatility (columns 1 and 2), and high risk firms submitted relatively lower bids (columns 3 and 4). I do not find significant effects for the other characteristics, possibly due to lack of power.

[37]This does not reflect an overlap with family ownership; in Appendix Table 10, I show a similar result when I compare high risk, non-family-owned firms with low risk, non-family-owned firms.

[38]Again, the diversification result is not driven by family owned firms (see Appendix Table 10 column 1).

Alternative Risk Measure

To combine firm types in a single model and test for statistical significance across types, I turn to the alternative risk measure proposed in Equation 3, where a firm characteristic is interacted with risk measured as $\sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}}$. Again, I find that public firms have a significantly lower cost of risk management than private firms; the coefficient on the triple interaction is -.065, significant at the 5% level (Table 10 column 1). In the public-private case, credit risk creates noise within the private sample. When I limit the sample to low credit risk firms, the coefficient increases to -.09, significant at the 1% level (column 2).

As in the split sample approach, I find no difference between family and non-family owned firms (Table 10 columns 3-5). Instead, industry diversification and credit risk continue to be the sharpest dividers. In Table 11, I find a coefficient of .04 for paving-only firms relative to diversified firms (column 1, significant at the 10% level), which increases to .06 and becomes highly significant when I limit the sample to low credit risk firms. I examine single location firms relative to multiple location firms, and find similar results in columns 4-6. Finally, I examine high versus low credit risk. As expected, the former have a much higher cost of risk, particularly when measured within private firms, as the results in columns 7 and 8 show.

Discussion

Three mechanisms could drive heterogeneity in risk premiums: cost of capital, effective risk aversion, and risk-varying bargaining power. In the Froot et al. (1993) framework, the first two are sides of the same coin, because high external finance costs drive risk aversion. The third mechanism requires bargaining power to vary with risk, because the modulated DiD isolates the effect of risk. I find a much weaker effect of firm size on the cost of risk than other characteristics, making it unlikely that bargaining power alone explains the main results. However, I cannot rule out that the mechanism is narrowly related to a certain product market equilibrium.

My results could reflect varying costs of capital if firms have homogenous risk aversion.

Some paving firms may have the scale or liquidity to hedge more cheaply in financial markets. The interviews with executives contradicted this hypothesis. They said that the variation reflects some firms' willingness to forego signing a forward contract at the time of the auction. By waiting to sign these contracts, they take on risk between the auction and the start of work. Other firms always insure, signing regardless of the price. In combination with my empirical results, the interview evidence suggests that while capital costs may help explain the absence of financial derivative use, costly distress is most responsible for the within-sample heterogeneity.

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

8 Conclusion

In a highway procurement setting, I show that government-provided insurance against oil price risk significantly reduces procurement costs as well as the pass-through of risk to product market prices. Financial constraints and costly distress best explain why some firms find value in relaxing constraints on risk management. My results are relevant to settings where there is a question of which party in a transaction should bear risk. For example, a related policy question is capital requirements for banks hedging interest rate risk, currently under consideration by the Basil Committee on Banking Supervision (BIS 2015). Banks can issue fixed rate instruments (like mortgages) and hedge the risk in derivative markets. If they face surcharges in the form of capital requirements for their own hedging activities, they may forego fixed rate instruments. This may be costly if it forces a more risk averse customer to bear the risk.

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

When they support small firms, governments usually hope to foster entry, reduce price, or promote innovation. Kansas' insurance policy has a positive effect on the first two of these goals. Insurance, therefore, may be an alternative to possibly more costly and distortionary subsidies. Consider the standard mean-variance utility framework, where utility is average consumption (C) less the cost of its standard deviation (σ): $V = \mathbf{E}(C) - \frac{1}{2}\rho\sigma^2$. Small firm subsidies traditionally increase C. An alternative is a mean preserving spread to reduce σ^2 (Rothschild & Stiglitz 1976). A promising area for future research is whether governments could exploit their risk neutrality and low cost of capital to transition some small business support to nearly costless risk management products. For example, firms could be insured against currency risk or weather disasters. Innovative startups with high-risk, high-return projects – a frequent target of government support – could be insured against observable sector or financing risks.

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

	Iowa		Kansas		Diff	All	
Panel 1: Contracts (Auctions)							
	Mean (sd)	N	Mean (sd)	N	Iowa-Kansas†	Mean (sd)	N
Number of bidders	3.4 (2.0)	1,363	3.4 (1.6)	433	-0.08	3.4 (2.0)	1796
Months from auction to work start	4.6 (2.8)	1,363	5.7 (9.7)	433	-1.1	4.7 (2.8)	1796
Money on the table††	0.06 (0.07)	1187	0.04 (0.09)	433	0.02***	0.06 (0.08)	1796
Panel 2: Bids							
	Iowa		Kansas		Diff	All	
	Mean (sd)	N	Mean (sd)	N	Iowa-Kansas†	Mean (sd)	N
Total bid ($ millions)	2.3 (3.3)	4,669	2.6 (4.5)	2,215	-0.3***	2.4 (3.9)	6,884
Bitumen bid item ($ bid per ton)	304 (150)	4,669	347 (164)	2,215	-43***	318 (156)	6,884
Bitumen fraction of total bid $\left(\frac{\text{tons*bid item}}{\text{total bid}}\right)$	.14 (.11)	4,669	.16 (.13)	2,394	-.02***	0.15 (0.11)	6,884
Total bid per ton bitumen ($ thousands)	10 (29)	4,669	17 (82)	2,394	-7***	12 (53)	6,884
Miles to project	75 (57)	4,669	111 (182)	2,394	-36***	87 (117)	6,884

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

Table 2: Summary Firm Characteristics

Panel 1: Number of Firms by State and Attribute

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

Panel 2: Correlation Matrix of Key Attributes

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

Note: This table summarizes firm characteristics used in the heterogeneity analysis. Panel 1 shows the number of firms in various categories (except for the bottom row, which summarizes firm age). Panel 2 shows the correlation of these characteristics across firms (each firm is one observation). †Public firms purchased private firms during span of data. ‡ Based on 8-digit SIC codes. ††Heavily concentrated in Kansas. ‡‡Credit risk is high when D&B rates the firm high or medium risk, or Kansas assigns the firm a max bidding cap <25th pctile. Low is a D&B "Low Risk" rating. †††Size is small if the firm is below the median number of employees/sales (75 employees, $31 million in sales), and large if above the 75th percentile.

Table 3: Average Differences Across States Before and After Price Adjustment Policy

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

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

Table 4: Risk Shifting Policy Effect on Cost to Kansas Government

Dependent variable: \$/ton to DOT

				Errors clustered by			Fixed effects	
		2005-2008 only	2004-2009 only	Firm-month	State-month	No controls	None	Firm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	-39***	-76***	-68***	-39***	-39***	-57***	-41***	-37**
	(12)	(21)	(18)	(14)	(11)	(12)	(14)	(16)
$\mathbf{I}_{Kansas_j}$	46***	120***	211***	46***	46***	288***	278***	-
	(8.8)	(18)	(10)	(8.2)	(11)	(7)	(7.9)	
$\mathbf{I}_{post\ policy_t}$	271***	180***	95***	271***	271***	30***	41***	272***
	(6.9)	(9.6)	(18)	(5.8)	(5.2)	(8.4)	(8.5)	(9.3)
Controls†	Y	Y	Y	Y	Y	N	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	N	Y
County·year f.e.	Y	Y	Y	Y	Y	Y	N	Y
N	1637	645	785	1637	1637	1637	1637	1637
R^2	0.804	0.654	0.685	0.804	0.804	0.791	0.776	0.819

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 with data between 1998 and 2012, except where noted. Each observation is an auction. †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. Standard errors clustered by firm, except in 3 and 4. *** $p < .01$.

Table 5: Risk Shifting Policy Effect on Competition

Dependent variable:	Log bid	# bidders	Prob. of winning across firm types	
			Private vs. public	Paving-only vs. diversified
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	-.076***	.8***	-.12	-.083
	(.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)
$\mathbf{I}_{Kansas_j}$	.15***	-.35	.21*	.14***
	(.018)	(.22)	(.12)	(.046)
$\mathbf{I}_{post\ policy_t}$	.83***	-.54***	.017	.014
	(.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
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
N	6111	1794	6324	5921
R^2	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 2, and bids elsewhere. The dependent variable in 4 and 5 is 1 if the firm won the auction, and each column interacts the policy effect with a firm type. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, oil price. The number of bidders is also included in 2. Standard errors clustered by firm. *** $p < .01$.

Table 6: Marginal Effect of Oil Price Volatility

Dependent variable: Log bitumen bid (except 2)

								Errors clustered by	
		Total bid‡	2005-2008 only		Vol>75th pctile*	Controls		State-month	Firm-month
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-.14***	-.15**	-.077**			-.19***	-.17***	-.14*	-.14***
	(.035)	(.072)	(.037)			(.035)	(.037)	(.073)	(.035)
$\mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	.75***	.33***	.81***			.57***	.77***	.75***	.75***
	(.042)	(.089)	(.051)			(.036)	(.041)	(.11)	(.041)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	.44***	.44*	.18	-.017	-.097***	.58***	.54***	.44*	.44***
	(.12)	(.24)	(.13)	(.016)	(.027)	(.12)	(.12)	(.24)	(.12)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.038	.17**	-.059*			.066**	.037	.034	.034
	(.029)	(.068)	(.035)			(.031)	(.03)	(.054)	(.03)
Vol_t^{oil}	.00068	.0056	.046***	.052***	.013	-.026***	.0062	.00031	.00031
	(.0092)	(.01)	(.016)	(.013)	(.04)	(.0089)	(.0097)	(.023)	(.0091)
$\mathbf{I}_{Kansas_j}$	-.017	2.1***	.34***	.12***	.12***	-.097	.0037	.0033	.0033
	(.096)	(.23)	(.11)	(.012)	(.022)	(.099)	(.099)	(.17)	(.097)
$\mathbf{I}_{post\ policy_t}$	-2.3***	-.93***	-2.4***	.11***	.69***	-1.7***	-2.3***	-2.2***	-2.2***
	(.13)	(.25)	(.16)	(.032)	(.061)	(.12)	(.13)	(.34)	(.13)
$\ln price_t^{\text{oil}}$	.27***	.14***	.34***	.055*	.24***		.27***	.27***	.27***
	(.032)	(.042)	(.051)	(.03)	(.038)		(.033)	(.059)	(.032)
Controls†	Y	Y	Y	Y	Y	N	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y	Y	Y	N	Y	Y
N	6111	4542	3714	6111	1780	6111	6111	6111	6111
R^2	0.922	.97	0.895	0.912	0.937	0.917	0.914	0.922	0.922

Note: This table reports regression estimates of Equation 2: 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. ‡The dependent variable is the log total bid divided by the tons of bitumen used. * Sample restricted to periods of top quartile volatility, relative to the sample average. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 7: Marginal Effect of Oil Price Volatility; Robustness tests using time frame

Dependent variable: Log bitumen bid	Time Frame			Placebo policy in year:	
	Parallel trends (before policy)	Excluding 2009	Excluding post-2009	2002	2008
	(1)	(2)	(3)	(4)	(5)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$		-.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. *** $p < .01$.

Table 8: Marginal Effect of Oil Price Volatility; Sample Split by Ownership Type

Dependent variable: Log bitumen bid

	Privately owned	Public (listed)	Family-owned	Non family-owned
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-.14***	-.079**	-.12**	-.097**
	(.049)	(.026)	(.059)	(.049)
$\mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	.71***	.84***	.76***	.74***
	(.037)	(.17)	(.037)	(.076)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	.43***	.17*	.37*	.29*
	(.16)	(.095)	(.2)	(.16)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.04	-.073	.011	-.0081
	(.04)	(.045)	(.043)	(.045)
Vol_t^{oil}	-.009	.047	-.0075	.0048
	(.0077)	(.041)	(.0071)	(.021)
$\mathbf{I}_{Kansas_j}$	-.011	.42**	.07	.16
	(.13)	(.14)	(.13)	(.15)
$\mathbf{I}_{post\ policy_t}$	-2.1***	-2.5***	-2.3***	-2.2***
	(.12)	(.48)	(.13)	(.23)
$\ln price_t^{\text{oil}}$	.24***	.29**	.27***	.26***
	(.032)	(.12)	(.041)	(.061)
Controls†	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
N	4991	894	3609	2254
R^2	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 Equation 2. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. In III, V, and VI, $\mathbf{I}_{SmallFirm_i}$ is also a control. Standard errors clustered by firm. *** $p < .01$.

Table 9: Marginal Effect of Oil Price Volatility; Sample Splits within Private Firms

Dependent variable: Log bitumen bid

	Credit Risk		Single location, non-subsidiary		Paving only (not diversified)		Size	
	High	Low	Yes	No	Yes	No	Small	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-.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. 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 1-6, $\mathbf{I}_{SmallFirm_i}$ is also a control. Standard errors clustered by firm. *** $p < .01$.

Table 10: Ownership Effects with Alternative Risk Measure

Dependent variable: Log bitumen bid

$X_j =$	Public firm		Family firm		
Sample:	All	Low risk	All	Private	Low risk
	(1)	(2)	(3)	(4)	(5)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	-.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 Equation 3. Sample limited to certain types of firms (e.g. low credit risk firms in 2). †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. *** $p < .01$.

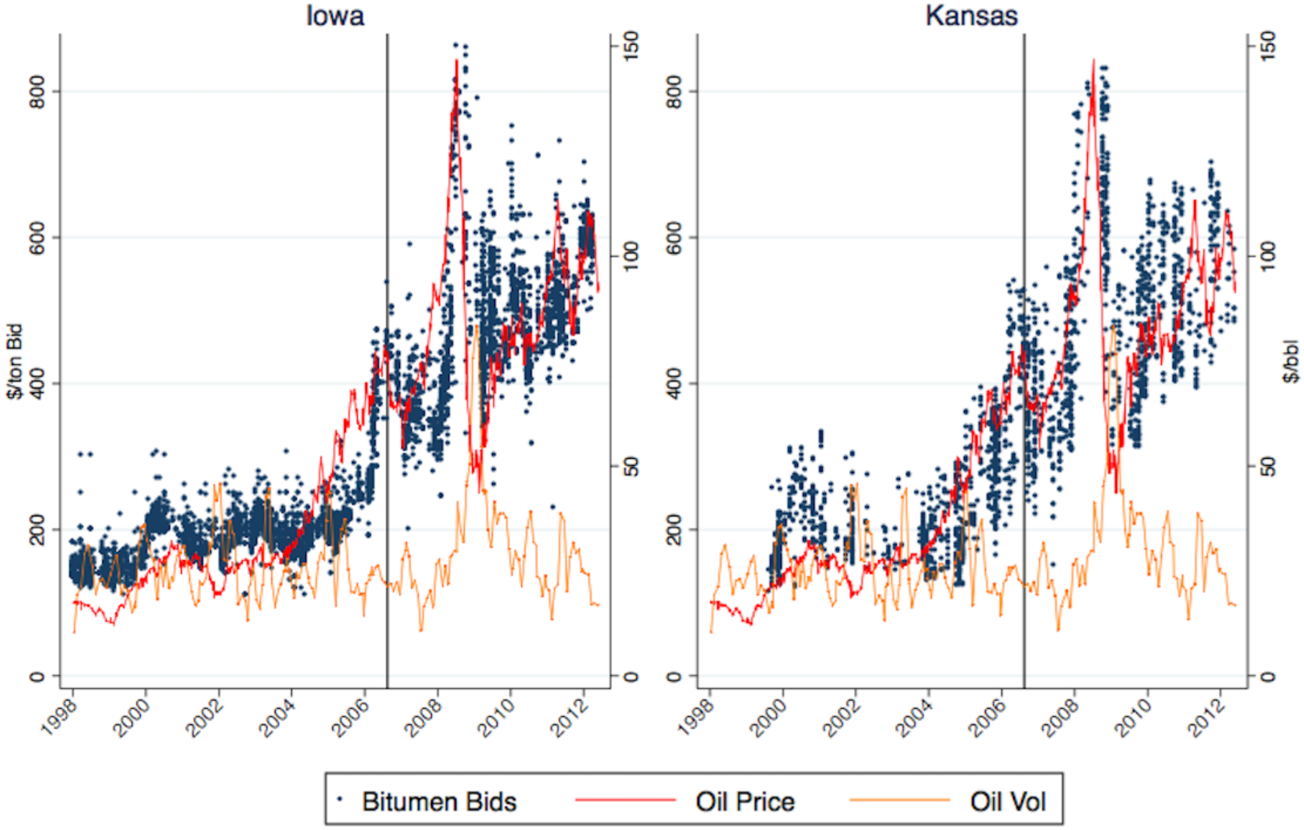
Table 11: Diversification, Size, and Risk Effects in Alternative Risk Measure

Dependent variable: Log bitumen bid

$X_j =$	Paving only (vs. diversified)			Single location			High risk	
Sample:	All	Private	Low risk	All	Private	Low risk	All	Private
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	.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

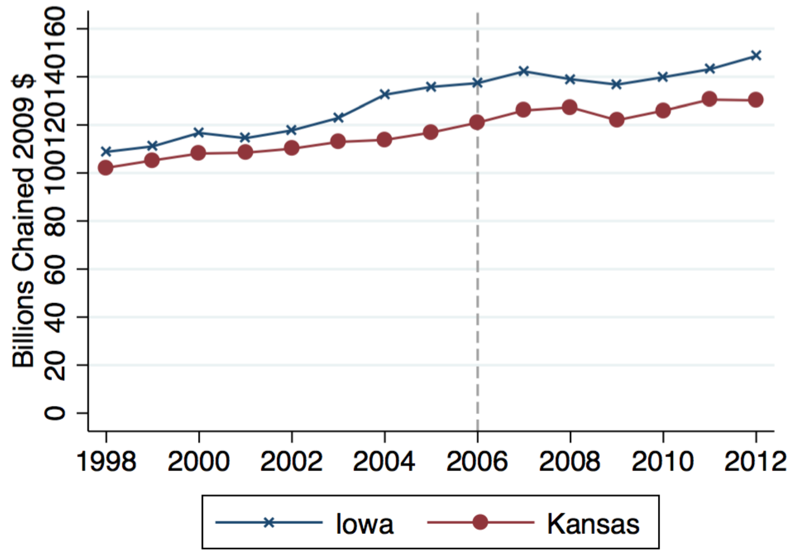
Note: This table reports estimates of the effect of the risk by firm type, where risk is measured as volatility interacted with the time between the auction and work start, using variations on Equation 3. Sample limited to certain types of firms (e.g. private firms in 2). †Unreported controls are log 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



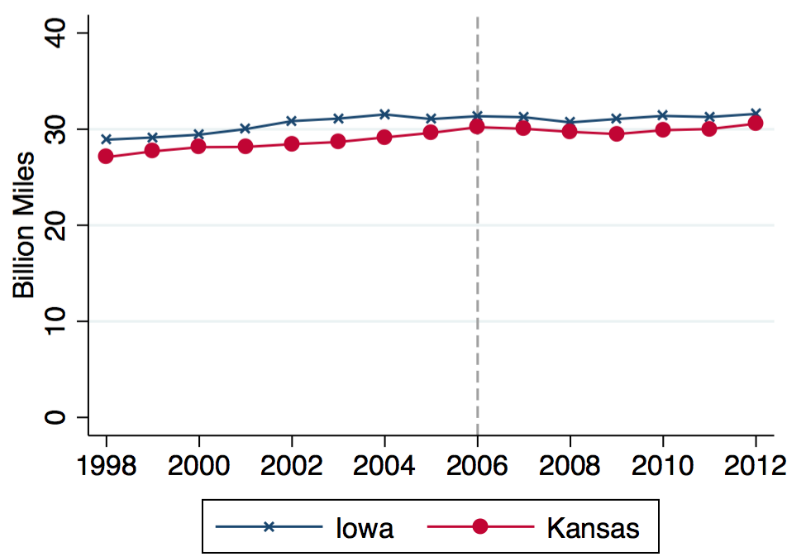
Note: This figure shows all bitumen bids in Iowa and Kansas between 1998 and 2012.

Figure 2: Iowa and Kansas State GDP (Real 2009 $ Billions)



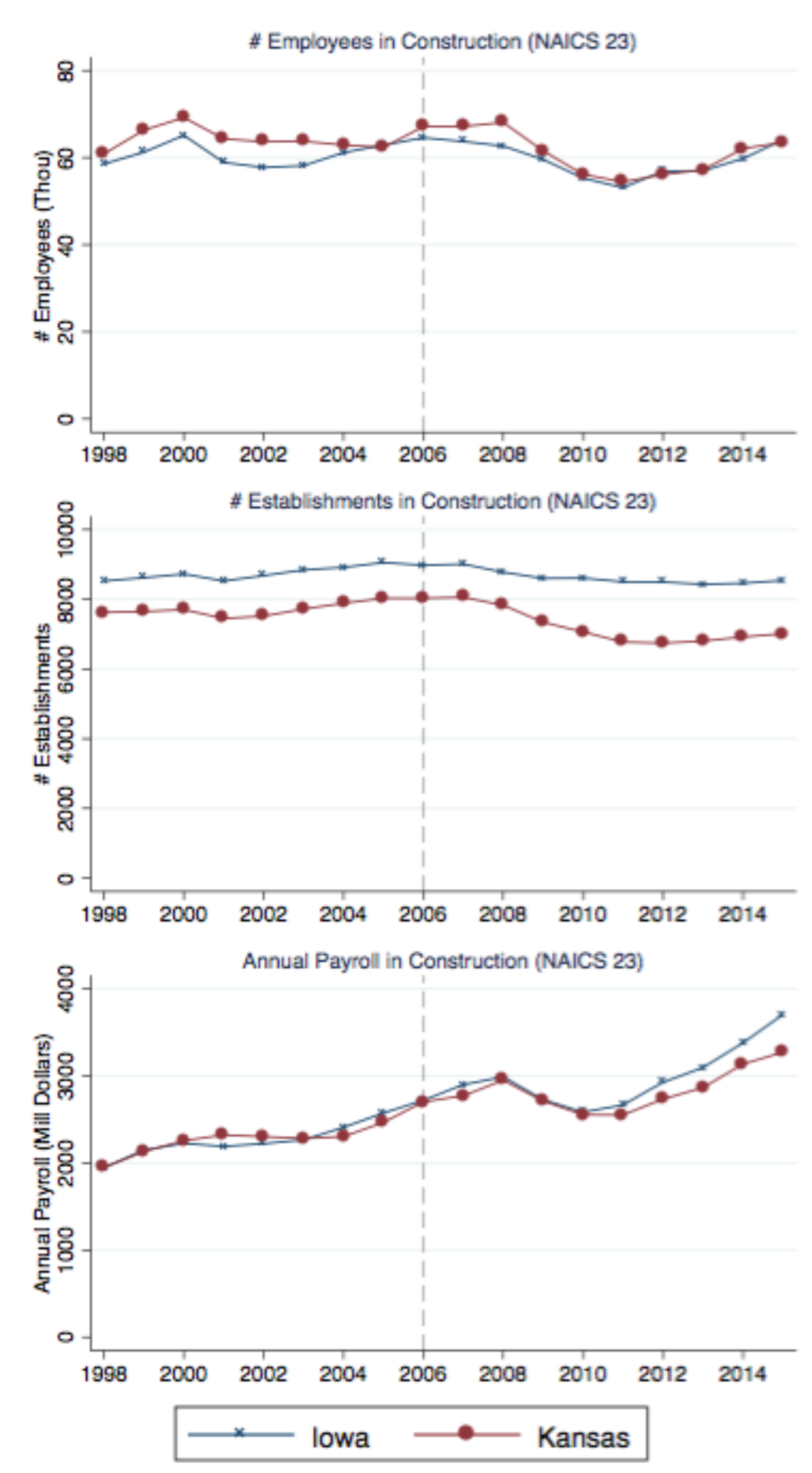
Note: This figure shows state-level GDP for Iowa and Kansas. Source: BEA Regional Data, available at http://www.bea.gov/regional/index.htm.

Figure 3: Iowa and Kansas Vehicle Miles Traveled



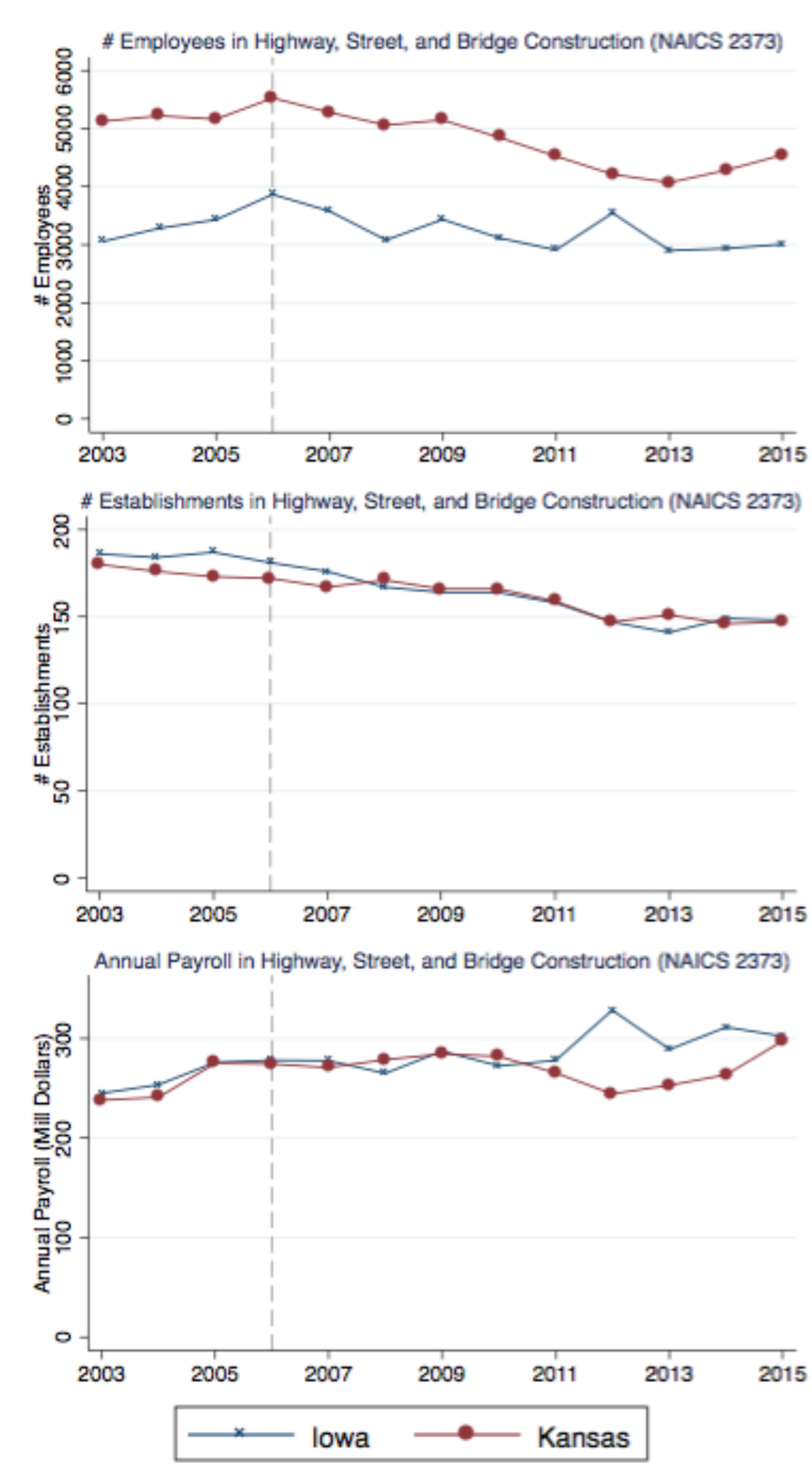
Note: This figure shows state-level vehicle miles traveled on public roads in Iowa and Kansas. Source: Federal Highway Administration, Office of Highway Policy Information, available at http://www.fhwa.dot.gov/policyinformation/index.cfm.

Figure 4: Construction Industry Trends in Iowa and Kansas



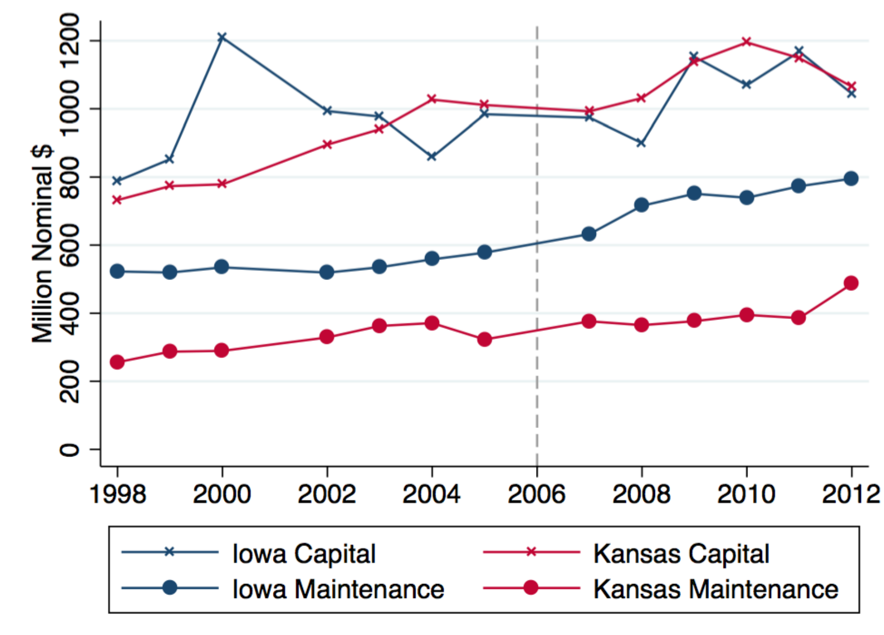
Note: This figure shows state-level construction industry data for Iowa and Kansas. Source: U.S. Census County Business Patterns, available at https://www.census.gov/programs-surveys/cbp/data/tables.html

Figure 5: Highway Construction Industry Trends in Iowa and Kansas



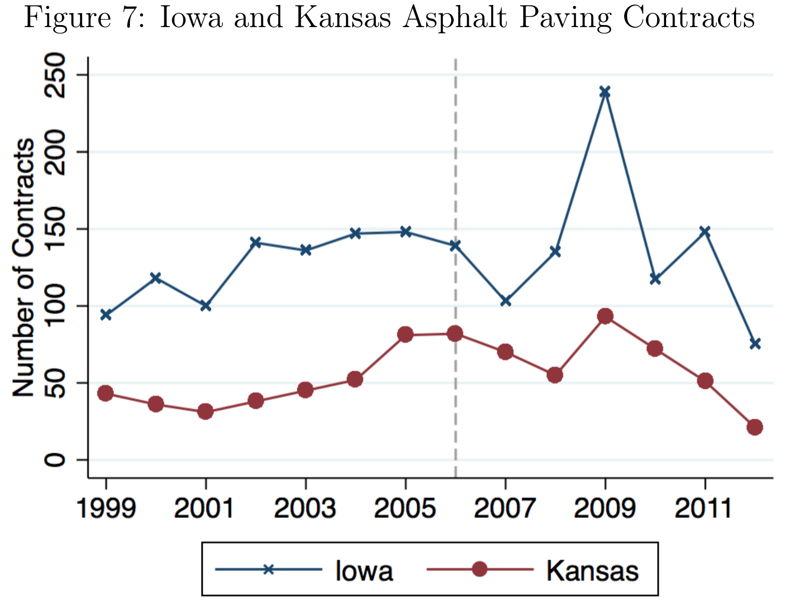
Note: This figure shows state-level highway, street, and bridge construction industry data for Iowa and Kansas (not available prior to 2003). Source: U.S. Census County Business Patterns, available at https://www.census.gov/programs-surveys/cbp/data/tables.html

Figure 6: Iowa and Kansas State Highway Spending (Capital and Maintenance Outlays)



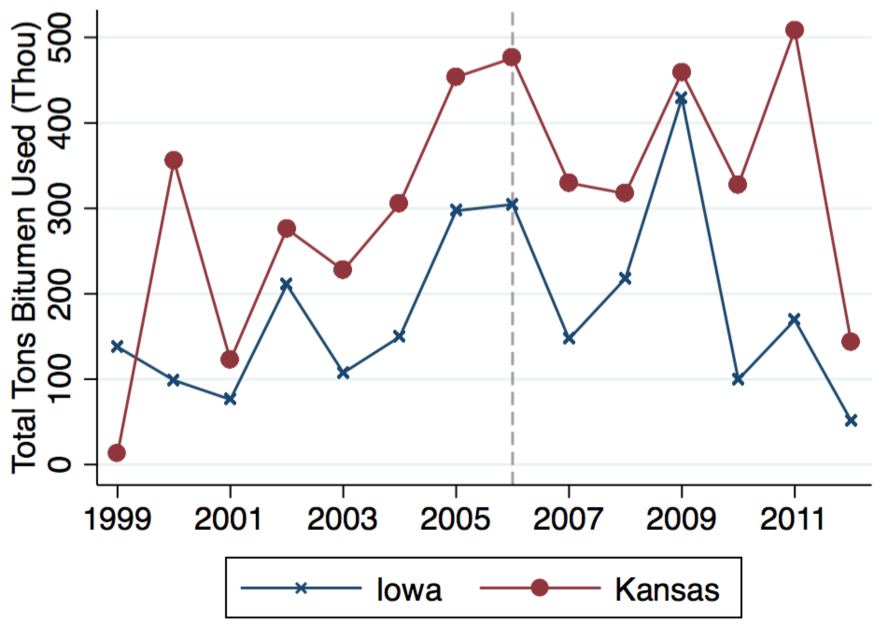
Note: This figure shows state and federal highway spending for Iowa and Kansas (2001 and 2006 missing). Federal Highway Administration, Office of Highway Policy Information, available at http://www.fhwa.dot.gov/policyinformation/index.cfm.

Figure 7: Iowa and Kansas Asphalt Paving Contracts



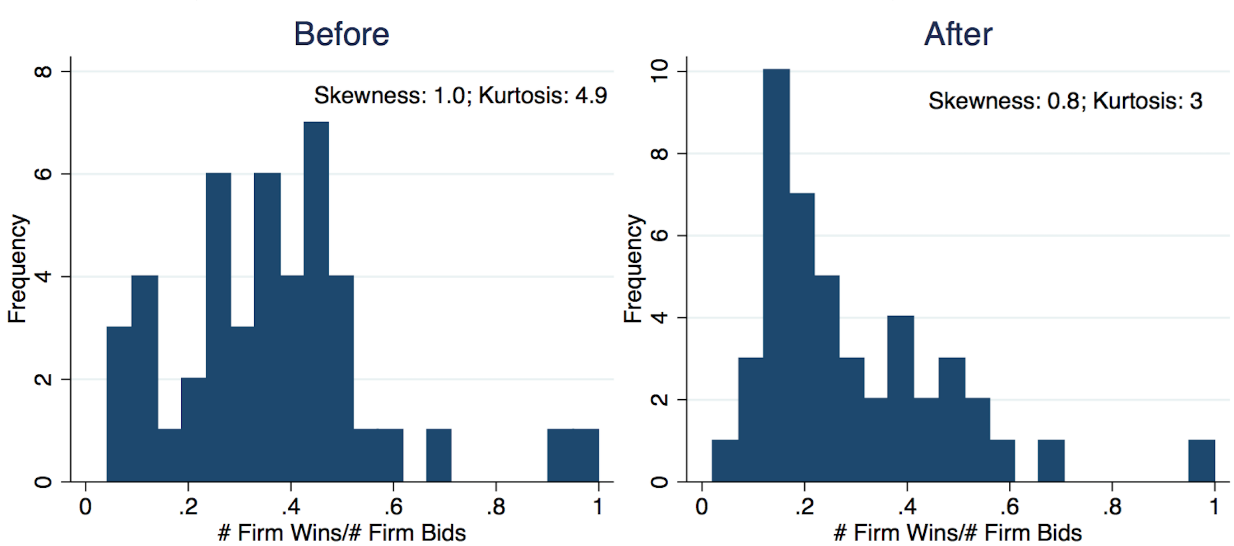
Note: This figure shows the total number of asphalt paving contracts auctioned by each state.

Figure 8: Iowa and Kansas Asphalt Paving Contracts Tons Bitumen Used



Note: This figure shows the total tons of bitumen required in asphalt paving contracts auctioned by each state.

Figure 9: 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 10: 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 11: 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.

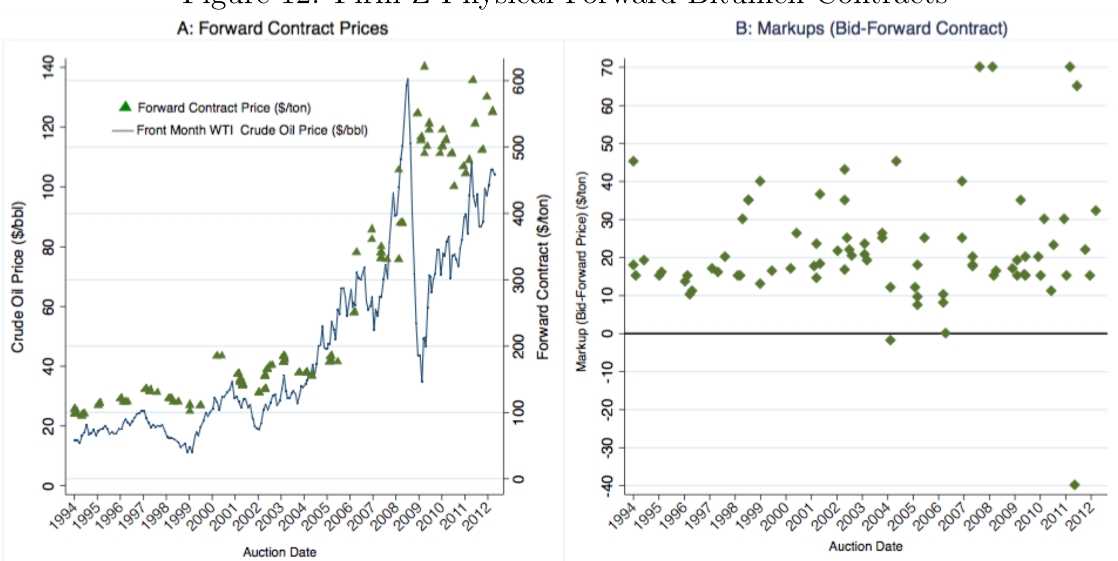
DELIVERY PERIOD	Construction Season 2009			
PROJECT NO.	Jasper County HSIPX-163-2(54)--3L-50			
SPECIFICATIONS	Iowa Department of Transportation			
PRODUCT		Asphalt Cement PG 58-28	Emulsion Prime & Tack	Cutback Prime & Tack
QUANTITIES:	MAXIMUM Approx.	1,849 - Tons		
	MINIMUM			
PRICE TRUCK	F.O.B. Tama	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

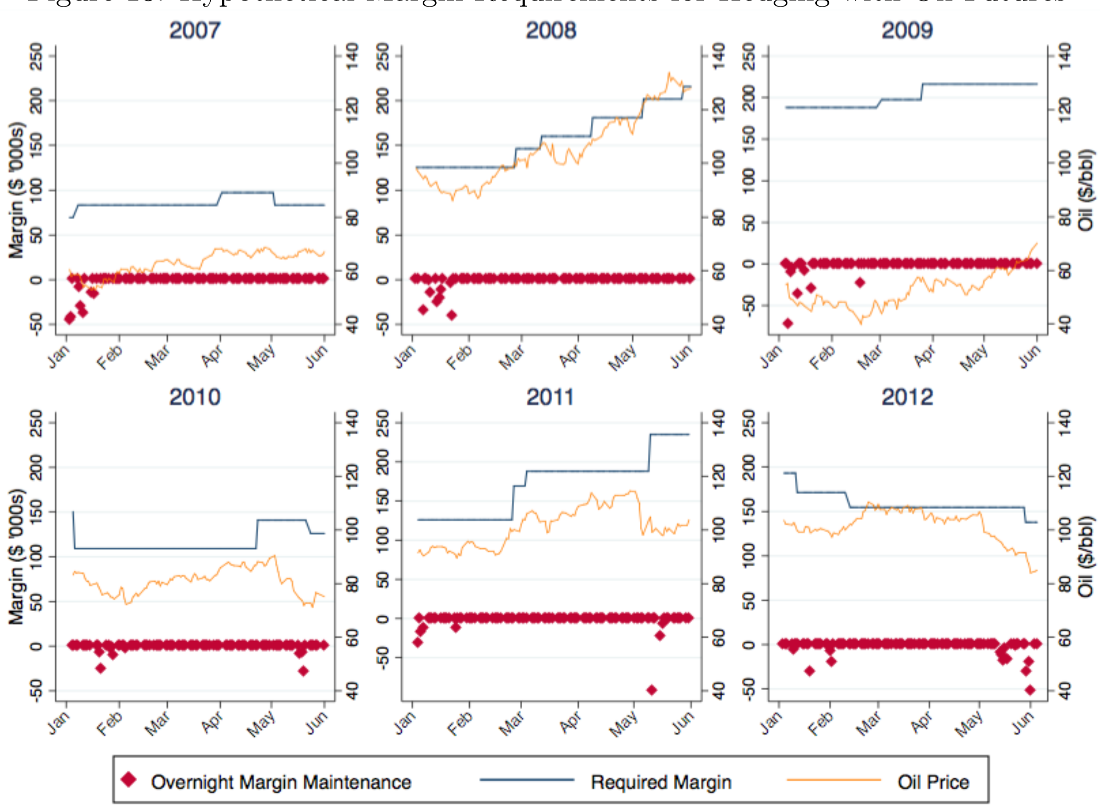
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 12: 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 13: 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.