Firm Type Variation in the Cost of Risk Management

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Abstract

This paper explores how the cost of risk management varies with firm characteristics, offering the first comparison between private, public, and family-owned firms. It exploits a natural experiment in highway procurement, which features diverse firms with common exposure to commodity risk. The Kansas government began to insure highway paving firms against oil price risk in 2006. The analysis compares Kansas to Iowa, which has an otherwise similar highway procurement system but never introduced such a policy. Using data from 1998 to 2012, I show that the policy reduced average bid sensitivity to oil price volatility. Private firms with high credit risk and low industry diversification exhibit the most risk pass-through, while public firms exhibit no pass-through. Family-owned firms do not have a higher than average cost of risk. Financial constraints and distress costs appear to best explain the cost of risk management, rather than risk aversion, information, or agency problems.

Keywords: Risk management, Private firms, Family firms, Insurance, Procurement

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1 Introduction

In theory, firms can use capital markets to efficiently manage the price risk of inputs such as steel, corn, and oil. There is evidence that large, sophisticated firms make use of these markets (Campello et al. 2011, Rampini, Sufi & Viswanathan 2014, Gilje & Taillard 2017). Yet we know little about how small, privately owned firms manage input price risk. Whether small, private firms manage risk efficiently is important, as they are responsible for about half of U.S. GDP (Kobe 2012). This paper offers the first firm-level study of risk management among privately owned firms, and the first comparison of the cost of risk management across firm types, including variation in firm ownership (public, private, family), size, industry diversification, and credit rating. The results shed light on the degree to which information, collateral, and other frictions affect the cost of risk management among small businesses.

Highway procurement offers several important advantages as a laboratory to study corporate risk management. One challenge for existing research has been that risks are often correlated with demand. In contrast, state demand for highways is plausibly exogenous to firm-specific factors. A second challenge has been that hedging decisions are typically endogenous to firm value. This paper focuses not on firm value, but on the effect of risk on prices and cost to the state. Third, it is often difficult to separate speculation from hedging (Cheng & Xiong 2014). This paper does not use data on derivatives, making it much less likely that speculation contaminates the estimated cost of risk. Finally, the setting offers a natural experiment in which oil price risk was eliminated for some firms but not others. In 2006, the Kansas state government shifted oil price risk in highway procurement contracts from the private sector to the state, offering a payment adjustment to reflect changes in oil prices between the auction date and the time of work. Kansas adopted the policy for idiosyncratic reasons and did not charge firms for this insurance.

The analysis compares Kansas with nearby Iowa, which never implemented the policy. It is the closest state that does not have such a policy but does have similar highway characteristics, procurement system, spending trends, and construction industry market structure. I use auction data from 1998 to 2012 and focus on a specific product, asphalt ("blacktop") roads. This is a commodity that is essentially the same across the two states. The main analysis is a triple differences design in which one variable is continuous, so it can also be called a modulated difference-in-differences. The first difference is Kansas relative to Iowa, and the second difference is after relative to before the policy change. This is modulated by oil price volatility as a third interaction. The primary outcome of interest is the "unit price bid" for bitumen, a petroleum product that is the primary component of asphalt roads. (The unit price bid is a subcomponent of the overall bid, which also includes items such as labor and guardrail.) To evaluate heterogeneity in risk pass-through, I use two methods. One splits the sample in the triple differences design. The other measures risk as the time between the auction and work start interacted with oil price volatility, excluding post-policy Kansas. This risk measure is then interacted with an indicator for firm type.

The risk premium for holding crude oil futures should be quite small because highly liquid derivative markets are available. Therefore, while free insurance should reduce costs, it should not have a large effect if firms are efficiently hedging in derivative markets. Instead, the results show that a one standard deviation increase of 14% in volatility increases bids by 2%. This translates to a 4.2% average cost of bearing oil price risk. A roughly 25% cost of capital is required to justify this cost if a firm is hedging in oil futures markets (that is, to meet margin requirements).

The main results of the paper show how this cost varies across firms. While highway paving is essentially a commodity, construction firms are diverse.[1] One reason public firms may value risk management is if they face financial constraints and distress costs (Froot, Scharfstein & Stein 1993). These frictions should be larger among private firms, which may also be more risk averse. Indeed, private firm bids are much more sensitive to risk than public firm bids. Within private firms, high credit risk and undiversified firm bids are more sensitive to risk. The insurance policy also increased the probability of winning for private firms, particularly undiversified ones, at the expense of public firms.

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, family firms should have a higher cost of bearing oil price risk. In fact, family-owned firms' cost of risk is indistinguishable from non family-owned firms, so this mechanism does not appear to be at play. Alternatively, some firms might have greater managerial agency and information problems, as in Kumar & Rabinovitch (2013). These should be more severe

[1] 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.

among larger private firms, for which monitoring is more difficult. While single-location firms are somewhat more sensitive to risk, there are no strong effects of firm size. Instead, firms with high credit risk and low industry diversification are most responsive to the policy.

Overall, the results are most consistent with financial constraints and distress explaining the cost of risk management, consistent with Rampini & Viswanathan (2010)'s theory that costly capital can prevent firms from insuring in financial markets because of an inability to meet collateral requirements. While highway procurement has features that are not found in most markets, such as auctions and government monopsony, there is no reason to believe that firm heterogeneity would be different in other imperfectly competitive industries.

The primary empirical concern is that other contemporaneous changes made Kansan firms less sensitive to risk, or Iowan firms more so. However, there are parallel trends across the two states in GDP, vehicle miles traveled, construction employment and establishments, and highway demand, among other relevant variables. 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 period. These tests address concerns that changing oil prices or macroeconomic factors could confound the analysis. Last, the results are not driven by firms selecting into projects or planning how to respond to the policy.

A conservative back-of-the-envelope calculation finds that the cost of capital dedicated to hedging is at least \$2.26 per ton of bitumen, while it would likely be no more than 46 cents per ton if the state were to hedge in financial markets. Hedging in financial markets is costly for firms firstly because it requires significant margin capital, but also because it involves information frictions, transaction costs, and basis risk. 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 highlights the advantage of allocating risk in a product market transaction to the party with the lowest cost of bearing the risk.

In the absence of government-provided insurance, asphalt paving firms rarely hedge in financial markets. Instead, they usually purchase physical forward (fixed-price) contracts from local bitumen suppliers at the time of the auction. This allows them to fully insure with no cash up front. Such fixed-price contracts with distributors are also common among farmers, electric utilities, and airlines. The revealed preference of firms in Kansas suggests that the state-provided insurance is cheaper than physical forwards, which in turn are cheaper than hedging in financial markets. This is because after the policy, they universally elected to use the state-provided insurance, which is free to them, albeit with basis risk. 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 these increase costs to consumers, a public hedging program could potentially improve efficiency.

The results are also important to understanding risk in public procurement, which constitutes about 10% of U.S. GDP, and 15% of worldwide GDP (Cernat & Kutlina 2015). Many procured products, including ships, food, and roads, expose private contractors to commodity or currency risk. Private and small businesses are relevant to procurement; for example, in 2015, the U.S. federal government procured more than more than $352 billion worth of goods and services from small businesses.[2] This paper also helps inform policy by providing the first rigorous assessment of state oil price insurance. The policy reduced procurement cost for Kansas by about 8%, saving the government around $77 million over 6.5 years. 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).

One related paper is Cornaggia (2013), who uses county level data on farm insurance to examine variation in the moral hazard incentives of group policies relative to individual policies. Another related paper is 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 their paper, and other work on risk management among public firms, including Kim, Mathur & Nam (2006) Acharya et al. (2007), Purnanandam (2008), Lin & Paravisini (2013), and Chen & King (2014), by studying variation in the cost of risk by firm type.

There is work comparing public and private firms on other dimensions, such as sources of financing (Brav 2009), cash holdings (Gao et al. 2013), dividends (Michaely & Roberts

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

2012), and innovation (Acharya & Xu 2017), but not in terms of the cost of risk management. Other work on insurance addresses determinants such as property rights protection in Lin, Lin & Zou (2012). Finally, existing work has studied the pass-through of costs and taxes to the consumer, but not risk (Campa & Goldberg 2005, Weyl & Fabinger 2013).

The paper proceeds as follows. Section 2 introduces the setting and the insurance policy. Data are described in Section 3. The estimation strategy and identifying assumptions are in in Section 4. The effect of the policy on average risk pass-through is in Section 5, and the heterogeneity results are in Section 6. Section 7 documents real effects. Section 8 concludes.

2 Institutional Context

This section first explains how highway procurement auctions operate (2.1), and then describes the insurance policy in Kansas that is used for identification (2.2).

2.1 Highway procurement

Like other U.S. states, the Iowa and Kansas Departments of Transportation (DOTs) use auctions to procure highway construction projects. While in general there are significant differences across U.S. states in, for example, the role of government (Cumming & Li 2013) an advantage of my setting is that Iowa and Kansas have similar highway procurement systems. In both cases, 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.[3]

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). In asphalt paving, one of the construction materials (and unit items in contracts) is bitumen, a

[3] Specifically, DOTs use simultaneous sealed-bid first-price auctions. DOTs also estimate the cost of each item, but these estimates are not public. 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.

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.[4] 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 to oil price risk.[5]

2.2 The Kansas Insurance Policy

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, and in general were not related to particular economic conditions in the states.[6]

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

[4] 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.

[5] 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.

[6] 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).

that he could not get a firm bitumen price from suppliers. The policy was not necessarily a surprise, which is not necessary for my identification strategy. What is important is that the Kansas DOT did not consult firms about implementing the policy, and the decision was not related to economic conditions in Kansas. My interviews with Kansas DOT officials indicate that neither industry lobbying nor local economic or demographic factors played a role in Kansas' decision to adopt the policy.[7] Other than the circumstantial preference of middle-management DOT officials following the bidding incident described above, there was no industry or government motivation for the insurance policy in Kansas.

Iowa, which is immediately northeast of Kansas, did not pursue an insurance policy during the sample period. In interviews, Iowa DOT officials told me that despite experiencing similar cost escalation, they were not interested in the policy. Neither industry lobbying nor local economic or demographic factors played a role in Iowa's decision not to adopt the policy.[8] 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.[9] 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.

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

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

[9] 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.

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. Today, most states use a similar 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]

3 Data

This paper primarily relies on comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012. These novel data were provided by the two DOTs and are proprietary. As the data must be in substantial part hand-coded and relies on particular relationships with the DOTs, it is not feasible to collect data from additional states or for a different time period. The sample is restricted to asphalt road paving projects, which are bitumen-intensive.[11] 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%.[12] Figure 1 shows Iowa and Kansas bitumen bids over time, as well as the crude oil price and historical oil price volatility. Although the price of bitumen and crude oil are related – the correlation

[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]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.

[12]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.

coefficient is 0.8 in my data – there are no liquid spot or futures markets for bitumen in the U.S.[13] 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.[14]

Data on firm characteristics are in Table 2. These data are cross-sectional as of 2012, the last year of the auction data. Firm ownership type was obtained by manually searching firm websites and third party sources (such as Bloomberg and Wikipedia). As shown in Panel 1, there are six publicly listed firms in my sample. Note that some firms operate in both Iowa and Kansas. Most of the private firms are family owned, with similar shares in Kansas – 71% – and in Iowa – 79%. Firm industry comes from 8-digit SIC codes in the auction data. I identify a firm as diversified if its activities are not limited to asphalt highway paving, based on 8-digit SIC codes. Data on credit risk and firm size come from Dunn & Bradstreet (D&B). To the degree these characteristics change over time, this may introduce noise in my estimation but should not introduce any systematic bias. Credit risk is high when D&B rates the firm as high or medium risk. The first size measure is based on the number of employees and revenue in the cross-sectional D&B data. 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.

Table 3 shows 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

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

[14] Appendix Tables 1 and 2 show selection across the firm characteristics for key control variables: bitumen quantity, miles between the firm and the project, number of bidders in the auction, and months between the auction and work start.

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.

A final firm-level dataset used in this paper is, to my knowledge, new to the literature. I observe actual hedging in 105 forward physical contracts between paving firm Z (identity protected) and all four regional bitumen suppliers. Examples are in Figures 2 and 3. 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. To gather further institutional details, I conducted a survey of 20 of the top bidders across both states.[15]

Finally, oil price and volatility data are from Bloomberg (summary statistics in Appendix Table 3). I use six-month WTI oil futures as a measure of expected oil prices, because the average time to work start is five months and the six-month contract is standard and highly liquid. Risk is measured using historical oil price volatility, which is an annualized standard deviation of daily returns, and implied volatility, which is derived from the Black & Scholes (1973) option pricing formula. In the analysis, I primarily use 12-week historical oil price volatility, but show robustness to 26-week and at-the-money implied volatility for oil futures options expiring in three months. In unreported tests, I found similar results using 52-week futures for both historical and implied volatility.

4 Estimation Approach

This section first presents the estimation strategy (4.1). It then discusses potential concerns; specifically, whether Iowa and Kansas were on similar paths before the policy, and whether selection into projects or the fact that the policy was not necessarily a surprise might bias the results (4.2).

[15]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).

4.1 Estimation strategy

To estimate the effect of risk on bids, I use the following triple differences specification, where i indicates a bidding firm, j indicates projects (same as the specific auction/contract), and t indicates the day of the auction.

$$\ln bid_{ijt} = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot \ln Vol_t^{\text{oil}} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{Kansas_j} + \beta_4 \mathbf{I}_{post\ policy_t}$$
$$+ \beta_5 \mathbf{I}_{post\ policy_t} \cdot \ln Vol_t^{oil} + \beta_6 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} + \beta_7 \mathbf{I}_{\text{Kansas}_j} \cdot \ln Vol_t^{oil} + \beta_8 \ln price_t^{oil}$$
$$+ \gamma' \cdot controls_{ij} + \delta_1 \mathbf{I}_{county_j \cdot year_j} + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{ijt}. \quad (1)$$

The log bitumen bid ($\ln bid_{ijt}$) is the dependent variable, $\mathbf{I}_{post\ policy_t}$ 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, $price_t^{oil}$ 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. 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-project level, controls include 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. At the project level, controls include log bitumen tons proposed, average total bid in the auction, and the number of bidders.

In alternative specifications, firm fixed effects test whether the main result reflects differences in sophistication, and county fixed effects 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. Standard errors are clustered by firm, though the results are robust to clustering by project.

The key analysis of the paper assesses cross-sectional heterogeneity. This is accomplished using two approaches that rely on different measures of risk. If they yield similar results, it is evidence that the differences across firm types are not a spurious artifact of some aspect of the data or estimation. First, the sample in Equation 3 is split by firm type. Second, in Equation 2 below, risk is measured as the forward market interacted with oil price volatility: $\sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}}$, where $Wait_j$ is the number of months between the auction and the work start date (summary statistics in Table 1 Panel 1). The square root of $Wait_j$ is appropriate because volatility moves at the square root of time. This assesses how oil price volatility affects bids in auctions with varying distances in time from the work start date. When the project starts the month after the auction, there is little risk regardless of recent volatility. This risk measure is interacted with a firm type indicator; the case in Equation 2 is $\mathbf{I}_{public_j}$, which is 1 if the firm is publicly owned, and 0 if privately owned. The estimating equation is:

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

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

4.2 Identifying Assumptions

The identifying assumption is that the two states would have experienced parallel trends if Kansas had not implemented the policy. Although the controls and county-year fixed effects in Equations 1 and 2 address some potential confounders, it is important to establish that nothing especially relevant to oil price risk for highway contractors changed in Iowa or Kansas around the same time as the 2006 policy implementation. Figures 4 and 5 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 6 and 7 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. Figure 8 shows parallel trends for total highway spending (capital and maintenance outlays) across the two states, also using FHWA data. While there are some changes during the financial crisis, such as to payroll, these move in parallel in the two states.

Figures 9 and 10 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, 2009 is excluded in a robustness test. 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).[16] 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 5 column 1, show that when the sample is limited to pre-policy years, there is no difference.

A second potential concern may be around firm selection into projects. The estimation of the relationship between oil price volatility and bids is conditional on a firm having decided to bid on a project, and conditional on the competitive equilibrium in the market. This implies that the analysis assesses the cost of risk among projects the firm deems NPV positive. There may also be concern that firms in Iowa choose lower risk or smaller projects because their cost of oil price risk has increased. However, scale is not an issue because the object used in estimation is the unit price bid for a ton of bitumen, not the bid for the whole project, and there is a control for tons of bitumen used. Therefore, I will observe the relationship between oil price volatility and bitumen bids among firms that are bidding on any projects. There are also controls for important project characteristics, including size and date, which further address a selection concern. Another concern is that firms may illegally shift costs across items within the overall bid to transfer the cost of oil price risk to the now less risky other items. This does not seem common, but if it exists it should bias my estimated effect of oil price risk down.

A third concern is that the policy was not strictly a surprise. My interviews suggest that the policy was initiated shortly after the very high bid in mid-2006, which prompted internal discussion. More generally, time passed between the policy's announcement and firm bids on subsequent projects, permitting them to adjust. I do not measure the short-term consequences when a firm's cost of risk changes. Instead, the analysis focuses on how firm bids were affected in the new, post-policy competitive equilibrium. That is, changes to the cost of risk may have affected the competitive equilibrium. In Section 8, I assess how the policy affected competition, including firm entry and exit.

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

5 Insurance Policy Effect on Risk Pass-Through

The effect of the insurance policy on average risk pass-through is in Table 4, which shows estimates of Equation 1. 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 0.14 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 with 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 column 4 shows. When the sample is restricted to periods of volatility above the 75th percentile, the coefficient becomes -0.097, significant at the 1% level (column 5). This confirms the main result that volatility drives the triple difference coefficient.[17]

To shed light on the mechanism, it is helpful to vary fixed effects. With firm instead of county fixed effects, the coefficient of interest on the triple interaction is slightly larger, at -0.18 (Appendix Table 5 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 concerns 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 5 omitting county effects demonstrate (columns 4-8). Instead, the policy seems to have lowered the cost of risk among incumbent firms in their existing markets.

A number of robustness tests address potential concerns with the result. First, when auction and bidder controls are omitted, the coefficient increases to -0.19 (Table 4 column 6). Therefore, these controls do not independently determine the result. Column 7 omits the

[17] I also checked whether the effect of the policy is as strong for the 19 firms bidding 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 4 columns 3-4).

county-year fixed effects. The result is essentially unchanged at -0.17. Clustering standard errors by state-month, in 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 9, and other alternative error assumptions in Appendix Table 6 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 oil price 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 5 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. In both cases, the true pre(post) period is still in at least part of the placebo pre(post) period. Nonetheless, the effect decreases to around -0.07 in both specifications, and is significant only at the 10% level.

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. The first is 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 4. The effect of volatility on the bitumen relative to non-bitumen items after relative to before the policy is -0.44 (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, Appendix Table 5 columns 6 and 7 show that the main results are robust to state-year and state-month fixed effects, respectively. Column 8 uses quarter fixed effects. These alleviate concern that time-varying state highway spending or state-level construction activity may bias the results.

Appendix Tables 5 and 6 contain additional robustness checks. Individual effects are in Appendix Table 5 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 0.058, likely reflecting oil intensity (e.g. in diesel fuel) throughout the project. Alternative oil measures are in Appendix Table 5 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. Quantile dummies ensure that neither non-linearity nor outliers explain the effect. Appendix Table 6 columns 5 and 6 use 10 and 20 quantiles of volatility, respectively, and finds that the triple interaction effect remains negative and highly significant.

6 Heterogeneity in Risk Pass-Through

This section contains the paper's main agenda, which is to assess heterogeneity across firm types in the cost of risk management. Section 6.1 presents predictions from the theoretical literature. The first empirical approach uses sample splits (6.2). The second uses the alternative risk measure to compare types of firms within a single regression (6.3). Mechanisms are discussed in Section 6.4.

6.1 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, private firms are thought to have a higher cost of external finance than public firms and to be more risk averse because they have less diversified owners (Fama & Jensen 1983). 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).

Family-owned firms permit a 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.

6.2 Sample Splits

In Table 6, panel 1, Equation 1 is estimated separately for public and family owned firms. The insurance policy's effect is -0.14 among private firms (column 2), which is the same as the main estimate. The effect is -0.079 among public firms (column 1), suggesting that removing oil price risk benefited private firms more than public firms. There is only a small difference between family-owned firms and other firms, at -0.12 and -0.097 (columns 3 and 4). Table 6, panel 2, limits the sample to private firms and examines characteristics associated with financial constraints. The insurance policy's effect is -0.24 for high credit risk firms, meaning that a one standard deviation increase in oil price volatility decreases bids in Kansas relative to Iowa by 3.4%, and implies a 5.9% cost of oil price risk for high credit risk firms (column 5). The effect is half the size among low credit firms (column 6). The coefficient among single-location, non-subsidiary firms is -0.18, relative to an insignificant -0.003 for other firms (columns 7 and 8).

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 9 and 10). MacKay & Moeller (2007) and Faccio et al. (2011) also find that well-diversified firms are less risk-averse.[18] Finally, when I use the secondary size metric (based on revenue and employment), there is less variation; -0.15 for small firms and -0.091 for large firms (columns 11 and 12). Extensive project controls ensure that projects are not systematically and observably different across firm types.

The main heterogeneity findings should translate to certain Kansas firms being relatively less sensitive to volatility after the policy. I therefore examine within-Kansas

[18] Again, the diversification result is not driven by family owned firms (see Appendix Table 7 column 1).

effects across firm types. Appendix Table 8 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.

6.3 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 2, where a firm characteristic is interacted with risk measured as $\sqrt{Wait_j} \cdot \ln Vol_t^{\text{oil}}$. The results are reported in Table 7. Public firms have a significantly lower cost of risk management than private firms; the coefficient on the triple interaction is -0.065, significant at the 5% level (column 1). When the sample is restricted to low credit risk firms, the difference between public and private firms is actually slightly larger (column 2), suggesting that credit risk creates noise within the private sample. There is no difference between family and non-family owned firms (columns 3-5).

Instead, industry diversification and credit risk continue to be the sharpest dividers. Table 8 shows a coefficient of 0.041 for paving-only firms relative to diversified firms (column 1, significant at the 0.1 level), which increases to 0.061 and becomes highly significant within the sample to low credit risk firms. Single location firms have similar effects as multiple location firms (columns 4-6). Last, columns 7 and 8 consider high versus low credit risk. They show that high credit risk, private firms have a much higher cost of risk (column 8).

6.4 Mechanisms Driving Heterogeneity

Two mechanisms appear to drive heterogeneity in risk premiums: cost of capital and effective risk aversion. In the Froot et al. (1993) framework, these are two sides of the same coin, because high external finance costs drive risk aversion. To understand how these mechanisms operate, it is useful to consider how this industry manages risk in the absence of state-provided insurance, based largely on interviews (see Section 3 for details). In general, firms can manage risk with hedges, insurance, diversification, or cash holdings. In practice, paving firms very rarely hedge in financial markets. Similar to practices among farmers, electric utilities, and airlines, paving firms typically fully insure by signing physical forward contracts with suppliers before the auction.[19] Sometimes they 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.

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

This explanation of the market structure raises the possibility of an alternative mechanism to explain heterogeneity: risk-varying bargaining power between pavers and their suppliers. Note that a bargaining power story requires that bargaining power varies with risk, because the triple difference isolates the effect of risk. There is 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.

Interviewees suggested that public firm subsidiaries more often wait to sign physical forwards. They 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 105 Firm Z forward contracts can be used to estimate the risk premium in the forwards relative to the bitumen index price that Kansas used to implement its policy. Firm Z's per ton contract prices for bitumen are graphed in panel A of Figure 11. The contracts are

[19]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.

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 11, panel B). Interviewees indicate that this fixed markup reflects transportation costs, and profit margins are usually loaded on bid items for labor and overhead. 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 3. 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 to be costlier than both of these options.

In interviews, executives reported that the variation in the cost of risk primarily 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.

The large cost of risk management revealed by the results 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. Specifically, researchers have been unable to reject a zero risk premium for long-only commodity portfolios and (Erb & Harvey 2006, Basu & Miffre 2013), measure very low oil equity betas (Ahn & Kogan 2012), and have found that oil prices behave close to a random walk (Alquist & Kilian 2010, Kellogg 2014). The remainder of this section will use back-of-the-envelope calculations to consider how despite these facts, hedging in financial may be relatively costly to the firm.

The simplest hedging strategy is to purchase oil futures.[20] This requires a performance bond, or "margin," which is marked-to-market every day and changes with volatility.[21] 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 12, using historical margin requirement data from CME, shows the results of this exercise.[22] 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 4) with the cost of hedging in futures markets is around 25%.[23] 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 bitumen needs, Kansas would initially need $3.2 million in its margin account each year.[24]

[20] 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.

[21] 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.

[22] Contact the author for details.

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

[24] 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.

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.[25] This calculation highlights the simple fact that all else equal, risk should be allocated to the party in a transaction with a lower cost of bearing it: in this case, Kansas at \$0.46 per ton rather than the firms at \$2.26 per ton.

7 Real Effects of the Insurance Policy

The final analysis in this paper assesses the policy's effect on Kansas' bitumen procurement. This serves two purposes. First, if the policy did not affect project costs, it likely did not reduce firms' cost of risk management (abstracting from any costs to Kansas of administering it). Therefore, this exercise helps to confirm the plausibility of the main results. Second, it is relevant to policymakers to understand whether the policy was effective. The section first presents an empirical strategy (7.1), then assesses the effects on cost and competition, which is crucial to efficient government procurement (7.2).

7.1 Empirical Approach

A difference-in-differences design (Equation 1 without the volatility modulation) measures the insurance policy's effect on 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.[26] This means that if firms were risk-neutral, Kansas should have experienced an increase in costs after implementation of the insurance policy in 2006.

In Equation 3, 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 (other outcomes are bids and the number of bidders, which 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

[25]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.

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

took place in Kansas.

$$Cost_j = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} + \beta_2 \mathbf{I}_{post\ policy_t} + \beta_3 \mathbf{I}_{Kansas_j} + \gamma' \cdot controls_j + \delta_1 \mathbf{I}_{county_j} \cdot year_j + \delta_2 \mathbf{I}_{month_j} + \varepsilon_{jt}. \quad (3)$$

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

7.2 Effect of the Policy on Costs

Table 9 shows estimates of Equation 3, 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 sample in 2012. Administrative annual costs of the policy are negligible, at around $36,750.[27]

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 9 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).

There may be concern that the results reflect unobservable time-varying differences

[27]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.

across Kansas and Iowa. To address this, I estimate a within-Kansas differences-in-differences design that compares 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 9 columns 1 and 2, show savings from the policy of $49-$54 per ton of bitumen, quite similar to the main specification.

7.3 Policy 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 collusion and are features of highway procurement (Porter 2005). There was an increase in competition after the insurance policy, shown in Table 10 column 2. The insurance policy increased the number of bidders in auctions by 0.800, relative to an average of 3.4. Appendix Table 10 reports models without fixed effects, with similar results.

The policy benefited private and undiversified firms. 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 10 column 3). Similarly, the policy increased the probability of winning for paving-only firms by 20 percentage points relative to diversified firms. In unreported tests, there are larger effects with logit models.[28] There are no statistically significant differences in the probability of winning across other observable characteristics.

The distribution of winning bids also changed after the policy. In Figure 13, 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 4-8 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

[28] 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.

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).[29] The suppliers apparently charge the pavers a large fraction of, if not their full, cost of risk.

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

8 Conclusion

In a highway procurement setting, this paper shows 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. The results are relevant to settings where there is a question of risk allocation among parties in a transaction. 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

[29] 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."

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

Panel 1: Contracts (Auctions)

	Iowa			Kansas			Diff	All		
	Mean	SD	N	Mean	SD	N	IA - KS	Mean	SD	N
Number of bidders	3.40	2.00	1,363	3.40	1.60	433	-0.08	3.40	2.00	1,796
Months from auction to work start	4.60	2.80	1,363	5.70	9.70	433	-1.10	4.70	2.80	1,796
Money on the table	0.06	0.07	1,187	0.04	0.09	433	0.02***	0.06	0.08	1,796

Panel 2: Bids

	Iowa			Kansas			Diff	All		
	Mean	SD	N	Mean	SD	N	IA - KS	Mean	SD	N
Total bid ($ millions)	2.30	3.30	4,669	2.60	4.50	2,215	-0.30***	2.40	3.90	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 $\left(\frac{\text{tons*bid item}}{\text{total bid}}\right)$	0.14	0.11	4,669	0.16	0.13	2,394	-0.02***	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. Money on the table is defined as the % 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. Primary business is based on 8-digit SIC codes. ‡Heavily concentrated in Kansas. Credit risk is high when D&B rates the firm high or medium risk. Low is a D&B "Low Risk" rating. A firm 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

	Panel 1: Before Policy						
	Iowa			Kansas			IA - KS
	Mean	SD	N	Mean	SD	N	
Bitumen bid ($ per ton)	196	44	2,824	224	73	1,166	-28***
$/ton paid ex-post	195	46	736	231	80	188	-36***
Number of Bidders	3.60	2.20	736	3.40	1.60	188	0.20

	Panel 2: After Policy						
	Iowa			Kansas			IA - KS
	Mean	SD	N	Mean	SD	N	
Bitumen bid ($ per ton)	469	95	1,845	484	125	1,049	-15***
$/ton paid ex-post	487	97	563	458	103	150	28***
KS Price Adjustment				0.30	75	52	
Number of Bidders	3.00	1.800	563	3.50	1.60	150	-0.48***

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

Table 4: Marginal Effect of Oil Price Volatility on Bids

Dependent variable: Log bitumen bid (except Column 2)

								Errors clustered by	
		Total bid	2005-2008		High Vol	Controls		State-month	Firm-month
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-0.140***	-0.150**	-0.077**			-0.190***	-0.170***	-0.140*	-0.140***
	(0.035)	(0.072)	(0.037)			(0.035)	(0.037)	(0.073)	(0.035)
$\mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	0.750***	0.330***	0.810***			0.570***	0.770***	0.750***	0.750***
	(0.042)	(0.089)	(0.051)			(0.036)	(0.041)	(0.110)	(0.041)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	0.440***	0.440*	0.180	-0.017	-0.097***	0.580***	0.540***	0.440*	0.440***
	(0.120)	(0.240)	(0.130)	(0.016)	(0.027)	(0.120)	(0.120)	(0.240)	(0.120)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	0.038	0.170**	-0.059*			0.066**	0.037	0.034	0.034
	(0.029)	(0.068)	(0.035)			(0.031)	(0.030)	(0.054)	(0.030)
Vol_t^{oil}	0.001	0.006	0.046***	0.052***	0.013	-0.026***	0.006	0.000	0.000
	(0.009)	(0.010)	(0.016)	(0.013)	(0.040)	(0.009)	(0.010)	(0.023)	(0.009)
$\mathbf{I}_{Kansas_j}$	-0.017	2.100***	0.340***	0.120***	0.120***	-0.097	0.004	0.003	0.003
	(0.096)	(0.230)	(0.110)	(0.012)	(0.022)	(0.099)	(0.099)	(0.170)	(0.097)
$\mathbf{I}_{post\ policy_t}$	-2.300***	-0.930***	-2.400***	0.110***	0.690***	-1.700***	-2.300***	-2.200***	-2.200***
	(0.130)	(0.250)	(0.160)	(0.032)	(0.061)	(0.120)	(0.130)	(0.340)	(0.130)
$\ln price_t^{\text{oil}}$	0.270***	0.140***	0.340***	0.055*	0.240***		0.270***	0.270***	0.270***
	(0.032)	(0.042)	(0.051)	(0.030)	(0.038)		(0.033)	(0.059)	(0.032)
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	6,111	4,542	3,714	6,111	1,780	6,111	6,111	6,111	6,111
R^2	0.922	0.970	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. In Column 2, the dependent variable is the log total bid divided by the tons of bitumen used. In Column 5, the sample is 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 5: Robustness Tests of Marginal Effect of Oil Price Volatility on Bids

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)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$		-0.130***	-0.150***	-0.069*	-0.071*
		(0.050)	(0.037)	(0.039)	(0.041)
$\mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$		0.830***	0.780***	-0.031	0.210***
		(0.060)	(0.047)	(0.025)	(0.032)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$		0.420**	0.450***	0.230*	0.220
		(0.160)	(0.130)	(0.130)	(0.140)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	-0.013	0.068**	0.009	0.086**	0.054*
	(0.032)	(0.029)	(0.032)	(0.035)	(0.027)
Vol_t^{oil}	0.023***	0.004	0.034**	0.070***	-0.014*
	(0.009)	(0.009)	(0.014)	(0.018)	(0.008)
$\mathbf{I}_{Kansas_j}$	0.160	-0.110	0.081	-0.170	-0.060
	(0.110)	(0.097)	(0.100)	(0.110)	(0.088)
$\mathbf{I}_{post\ policy_t}$		-2.500***	-2.300***	0.100***	0.110***
		(0.180)	(0.150)	(0.032)	(0.031)
$\ln price_t^{\text{oil}}$	0.360***	0.350***	0.290***	0.058*	0.130***
	(0.011)	(0.034)	(0.035)	(0.032)	(0.029)
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	3,532	5,554	5,111	6,111	6,111
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 6: Marginal Effect of Oil Price Volatility on Bids by Firm Type

Panel 1: Sample splits by ownership type

Dependent variable: Log bitumen bid

	Publicly traded		Family-owned	
	Yes	No	Yes	No
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-0.079**	-0.140***	-0.120**	-0.097**
	(0.026)	(0.049)	(0.059)	(0.049)
Controls†	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
N	894	4,991	3,609	2,254
R^2	0.896	0.930	0.939	0.906

Panel 2: 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
	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot Vol_t^{\text{oil}}$	-0.240*	-0.120**	-0.180***	-0.003	-0.190***	-0.084	-0.150***	-0.091*
	(0.120)	(0.051)	(0.052)	(0.120)	(0.056)	(0.110)	(0.048)	(0.045)
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	4,358	1,584	3,355	2,795	1,977	3,498	2,387
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. In Panel 2, only private firms are included. Controls are log oil price, 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 Columns 2-4, 5-10, $\mathbf{I}_{SmallFirm_i}$ is also a control. Standard errors clustered by firm. *** $p < .01$.

Table 7: Ownership Heterogeneity in Effect of Risk on Bids

Dependent variable: Log bitumen bid

$X_j =$	Public firm		Family firm		
Sample:	All	Low risk	All	Private	Low risk
	(1)	(2)	(3)	(4)	(5)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	-0.065**	-0.090***	-0.012	0.006	0.013
	(0.028)	(0.031)	(0.023)	(0.024)	(0.023)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j}$	0.200**	0.280**	0.041	-0.020	-0.043
	(0.100)	(0.120)	(0.074)	(0.078)	(0.075)
$\sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	0.006	0.003	0.004	-0.013	-0.014
	(0.013)	(0.013)	(0.018)	(0.019)	(0.019)
$\mathbf{I}_{X_j} \cdot Vol_t^{\text{oil}}$	0.180***	0.230***	0.019	-0.012	-0.025
	(0.047)	(0.042)	(0.053)	(0.057)	(0.055)
$\mathbf{I}_{X_j}$	-0.600***	-0.740***	-0.051	0.048	0.096
	(0.160)	(0.150)	(0.170)	(0.180)	(0.180)
$\sqrt{wait_j}$	-0.022	-0.008	-0.016	0.041	0.048
	(0.042)	(0.044)	(0.059)	(0.062)	(0.060)
Vol_t^{oil}	0.001	0.014	0.015	0.050	0.055
	(0.027)	(0.028)	(0.048)	(0.052)	(0.050)
$price_t^{\text{oil}}$	0.170***	0.170***	0.170***	0.170***	0.170***
	(0.035)	(0.038)	(0.037)	(0.041)	(0.041)
Controls, county·year f.e., month-of-year f.e.	Y	Y	Y	Y	Y
N	4,744	4,054	4,711	4,029	4,054
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 8: Diversification, Size, and Risk Heterogeneity in Effect of Risk on Bids

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)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	0.041*	0.050**	0.061***	0.072***	0.071***	0.078***	0.077*	0.150***
	(0.024)	(0.021)	(0.022)	(0.025)	(0.025)	(0.029)	(0.043)	(0.051)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j}$	0.290*	-0.160**	-0.200***	-0.240***	-0.240***	-0.260***	-0.280*	-0.520***
	(0.160)	(0.068)	(0.073)	(0.084)	(0.082)	(0.098)	(0.150)	(0.180)
$\sqrt{wait_j} \cdot Vol_t^{\text{oil}}$	-0.043**	-0.028*	-0.041**	-0.022	-0.022	-0.029**	-0.022	0.004
	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)	(0.014)	(0.015)	(0.014)
$\mathbf{I}_{X_j} \cdot Vol_t^{\text{oil}}$	-0.083*	-0.086**	-0.110**	-0.096*	-0.097*	-0.100*	-0.100	-0.230**
	(0.048)	(0.040)	(0.046)	(0.054)	(0.053)	(0.062)	(0.110)	(0.093)
$\mathbf{I}_{X_j}$	0.290*	0.290**	0.380**	0.360**	0.360**	0.390*	0.390	0.810**
	(0.160)	(0.130)	(0.150)	(0.180)	(0.180)	(0.210)	(0.400)	(0.340)
$\sqrt{wait_j}$	0.130***	0.091*	0.130***	0.069	0.069	0.093**	0.065	-0.011
	(0.047)	(0.049)	(0.050)	(0.045)	(0.045)	(0.046)	(0.049)	(0.046)
Vol_t^{oil}	0.100***	0.058**	0.100***	0.057*	0.059*	0.075**	0.045	0.004
	(0.032)	(0.029)	(0.034)	(0.032)	(0.032)	(0.032)	(0.029)	(0.030)
$price_t^{\text{oil}}$	0.150***	0.150***	0.160***	0.170***	0.170***	0.170***	0.100***	0.120***
	(0.037)	(0.033)	(0.041)	(0.036)	(0.036)	(0.040)	(0.036)	(0.036)
Controls, county·year f.e., Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
N	4,582	4,079	4,007	4,653	4,660	4,019	3,624	3,353
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.*** $p < .01$

Table 9: 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	1,637	645	785	1,637	1,637	1,637	1,637	1,637
R^2	0.804	0.654	0.685	0.804	0.804	0.791	0.776	0.819

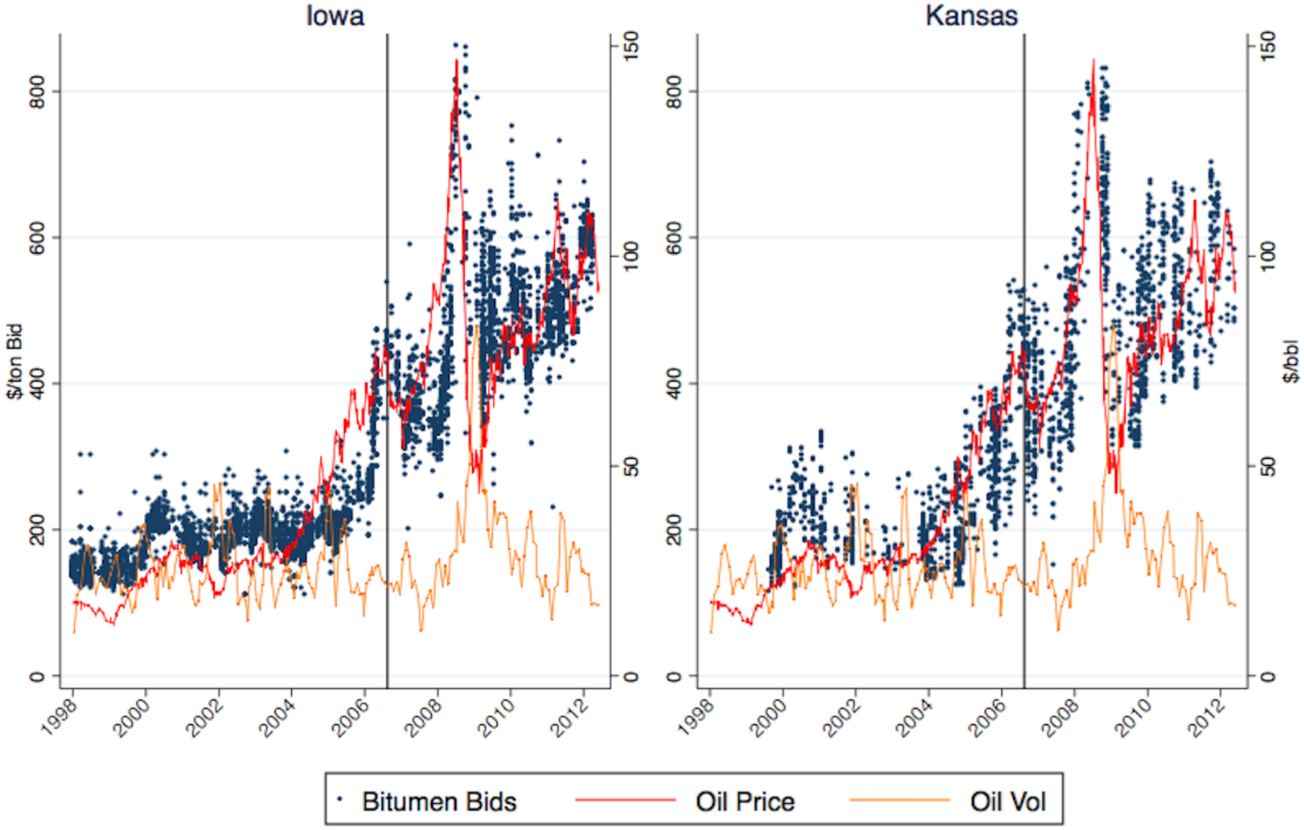
Note: This table reports estimates of the effect of the risk shifting policy in Kansas vs. Iowa after vs. before the policy, using variations on equation 1 with data between 1998 and 2012, except where noted. Each observation is an auction. Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, oil price, and the number of bidders. Standard errors robust, except in 3 and 4. *** $p < .01$.

Table 10: 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)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t}$	-0.076***	0.800***	-0.120	-0.083
	(0.025)	(0.210)	(0.110)	(0.062)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot \mathbf{I}_{privately-owned_i}$			0.190*	
			(0.110)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ policy_t} \cdot \mathbf{I}_{paving\ only_i}$				0.200***
				(0.073)
$\mathbf{I}_{Kansas_j}$	0.150***	-0.350	0.210*	0.140***
	(0.018)	(0.220)	(0.120)	(0.046)
$\mathbf{I}_{post\ policy_t}$	0.830***	-0.540***	0.017	0.014
	(0.012)	(0.140)	(0.093)	(0.039)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{privately-owned_i}$			-0.150	
			(0.110)	
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{privately-owned_i}$			-0.023	
			(0.100)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{paving\ only_i}$				-0.067
				(0.063)
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{paving\ only_i}$				-0.004
				(0.026)
$\mathbf{I}_{Privately-owned_i}$			0.039	
			(0.110)	
$\mathbf{I}_{paving\ only_i}$				-0.064***
				(0.018)
Controls	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
N	6,111	1,794	6,324	5,921
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 project. *** $p < .01$.

Figure 1: Bitumen Bids in Iowa and Kansas



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

Figure 2: Example Firm Z Physical Forward Contract, February 2008

Sales Agreement

FLINT HILLS RESOURCES

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

Page 1
Sales Agreement NO. 66870

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 3: Example Firm Z Physical Forward Contract, February 2009

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

[redacted]

DATE: 02-24-09

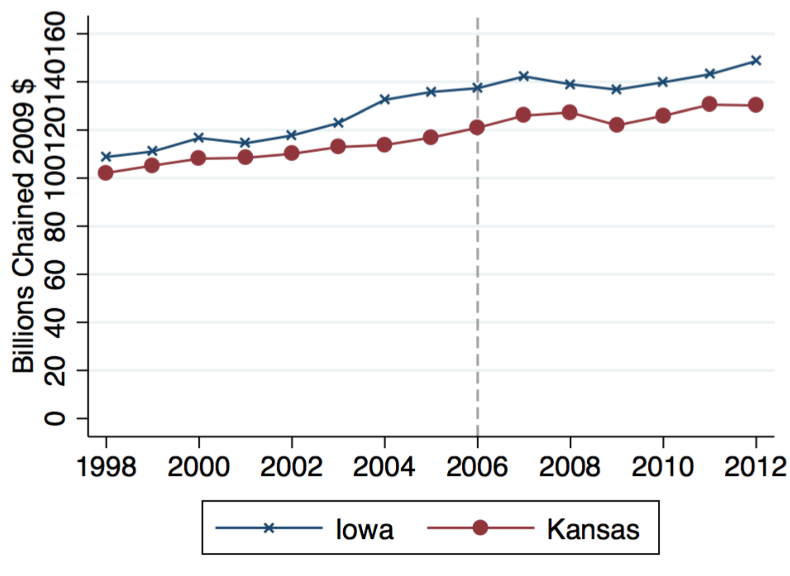
Subject to the terms and conditions on the reverse side hereof, this document constitutes a firm offer which will automatically expire without notice if not accepted by______________________________. This offer expressly limits acceptance to the terms and conditions of this offer. Acceptance must be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

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

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

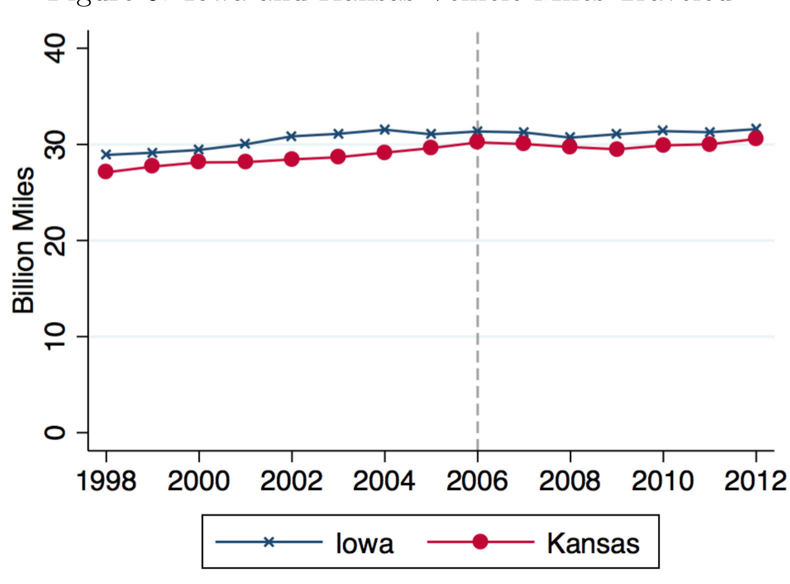
Note: This figure shows a physical forward contract between a large paver in my data and a local bitumen supplier. These contracts have long been and remain the industry standard for purchasing bitumen.

Figure 4: Iowa and Kansas State GDP (Real 2009 $ Billions)



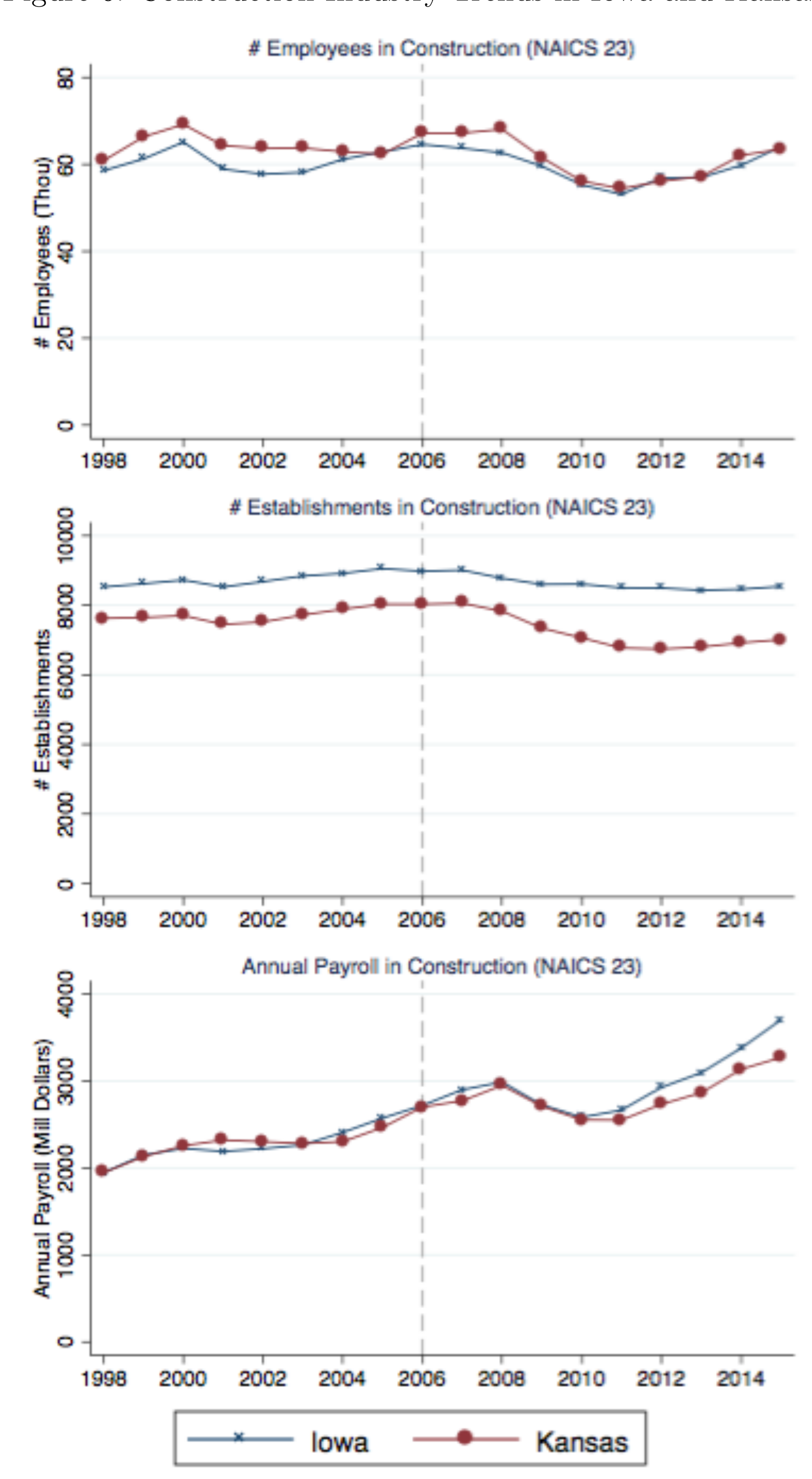
Note: This figure shows state-level GDP for Iowa and Kansas. Source: BEA Regional Data, available at http://www.bea.gov/regional/index.htm.

Figure 5: Iowa and Kansas Vehicle Miles Traveled



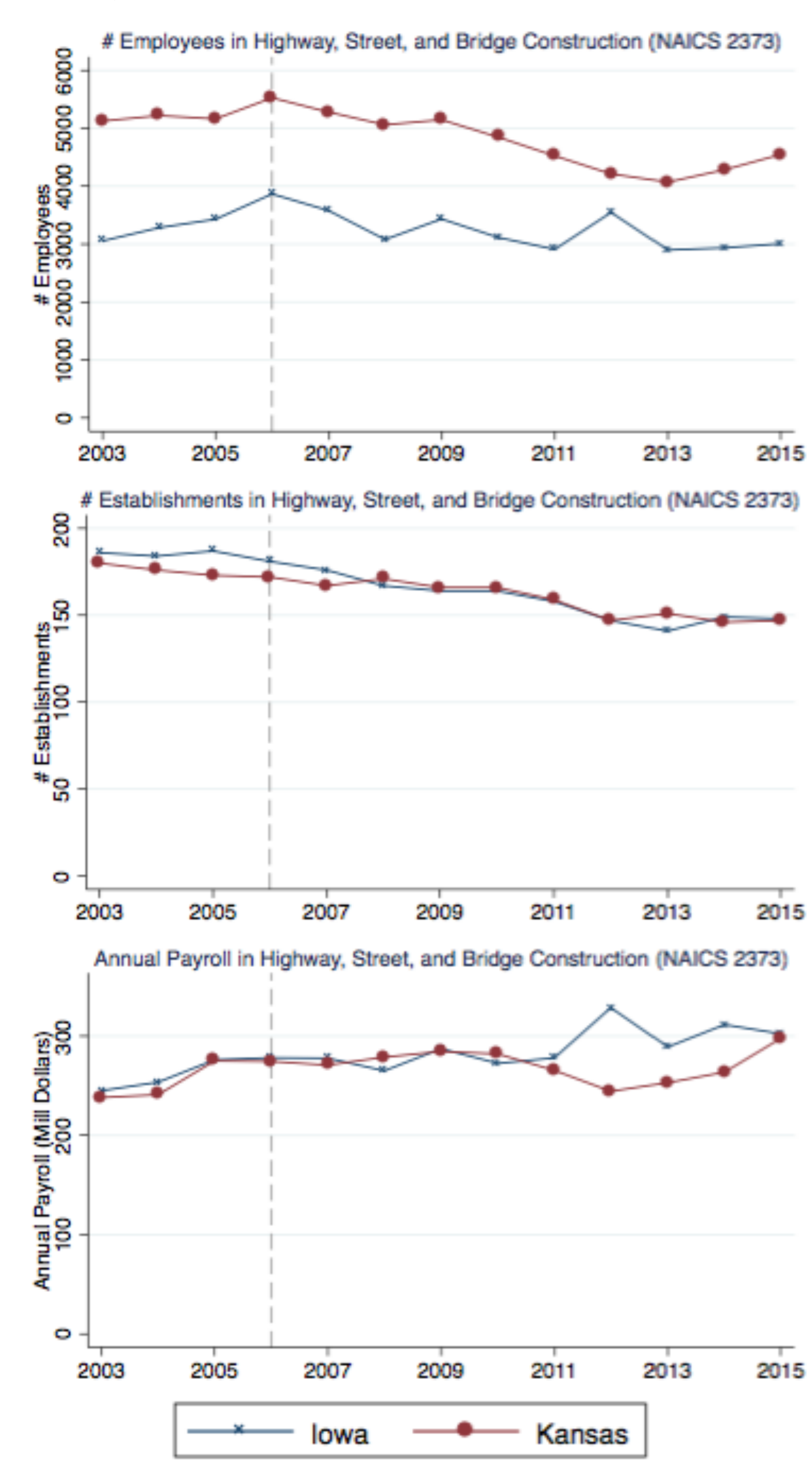
Note: This figure shows state-level vehicle miles traveled on public roads in Iowa and Kansas. Source: Federal Highway Administration, Office of Highway Policy Information, available at http://www.fhwa.dot.gov/policyinformation/index.cfm.

Figure 6: Construction Industry Trends in Iowa and Kansas



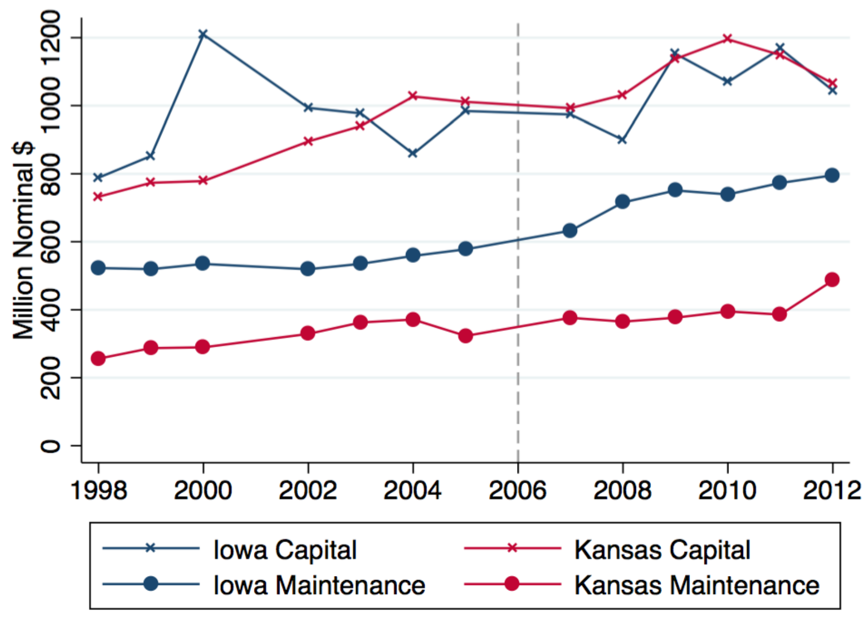
Note: This figure shows state-level construction industry data for Iowa and Kansas. Source: U.S. Census County Business Patterns, available at https://www.census.gov/programs-surveys/cbp/data/tables.html

Figure 7: Highway Construction Industry Trends in Iowa and Kansas



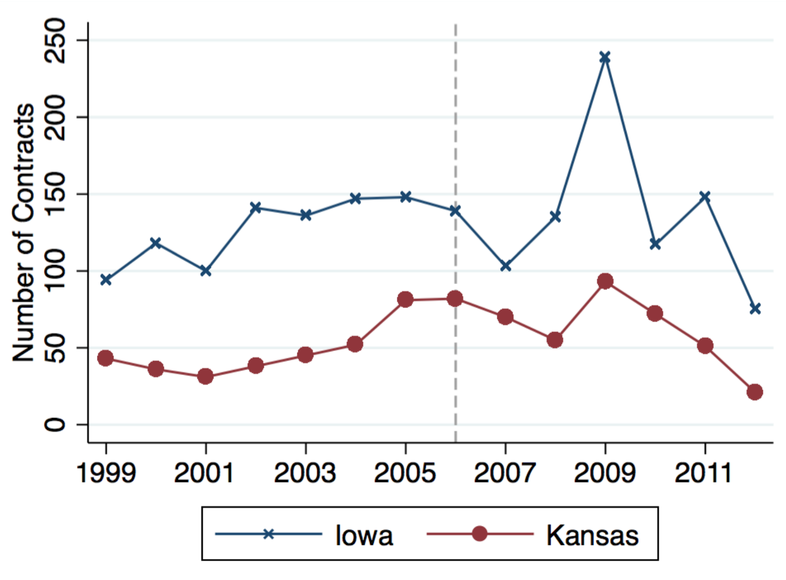
Note: This figure shows state-level highway, street, and bridge construction industry data for Iowa and Kansas (not available prior to 2003). Source: U.S. Census County Business Patterns, available at https://www.census.gov/programs-surveys/cbp/data/tables.html

Figure 8: Iowa and Kansas State Highway Spending (Capital and Maintenance Outlays)



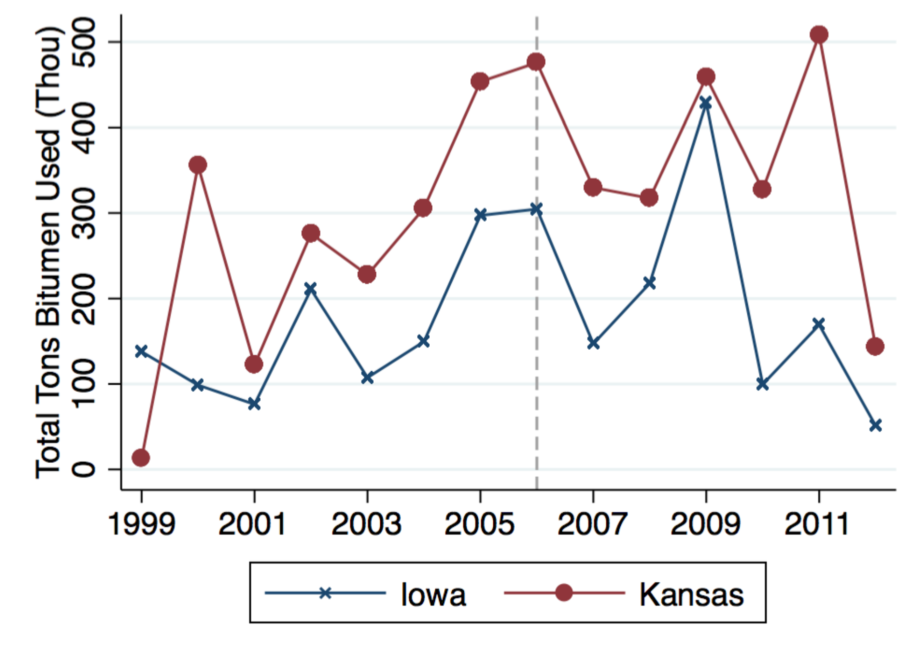
Note: This figure shows state and federal highway spending for Iowa and Kansas (2001 and 2006 missing). Federal Highway Administration, Office of Highway Policy Information, available at http://www.fhwa.dot.gov/policyinformation/index.cfm.

Figure 9: Iowa and Kansas Asphalt Paving Contracts



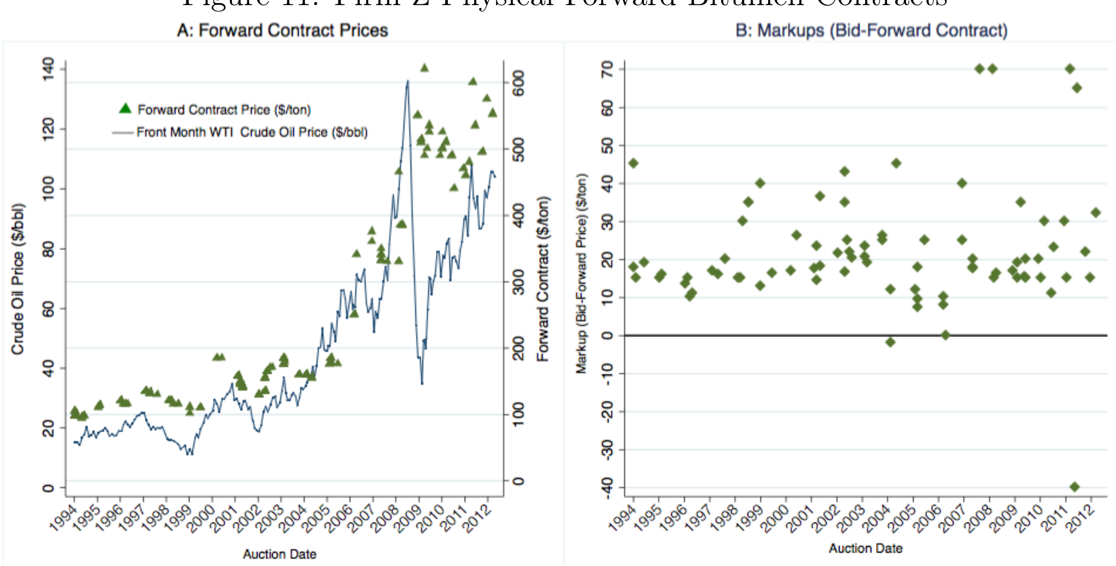
Note: This figure shows the total number of asphalt paving contracts auctioned by each state.

Figure 10: Iowa and Kansas Asphalt Paving Contracts Tons Bitumen Used



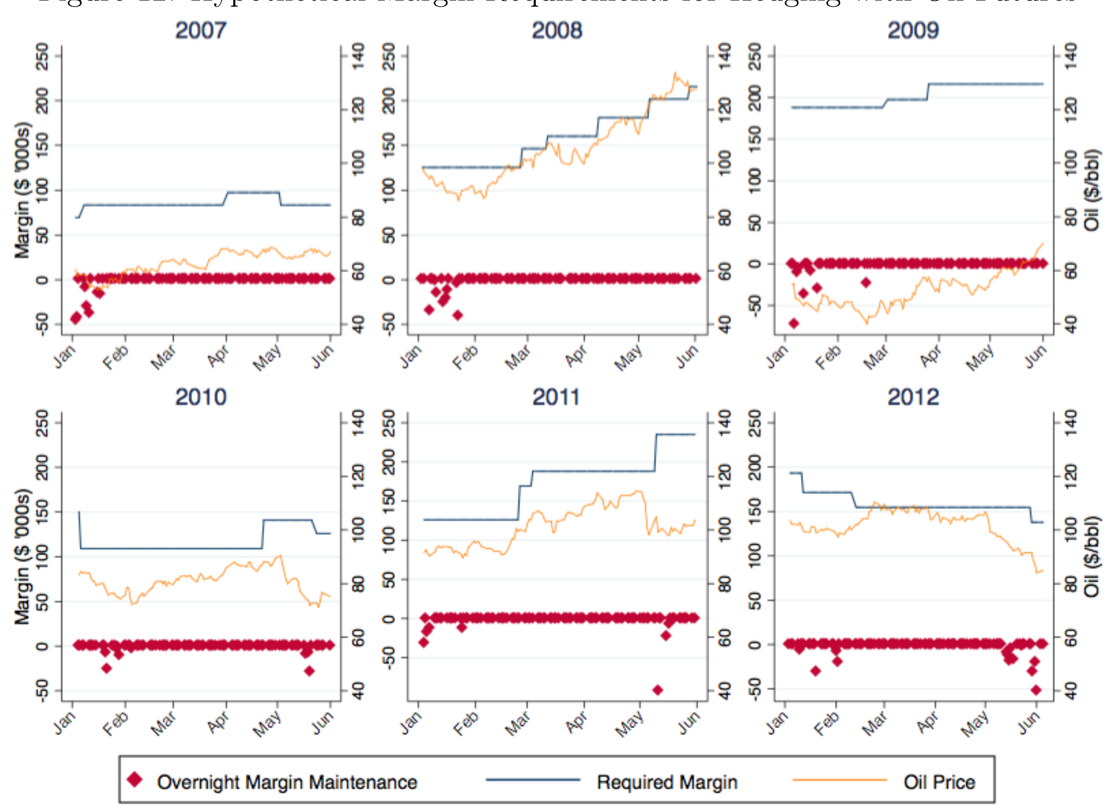
Note: This figure shows the total tons of bitumen required in asphalt paving contracts auctioned by each state.

Figure 11: Firm Z Physical Forward Bitumen Contracts



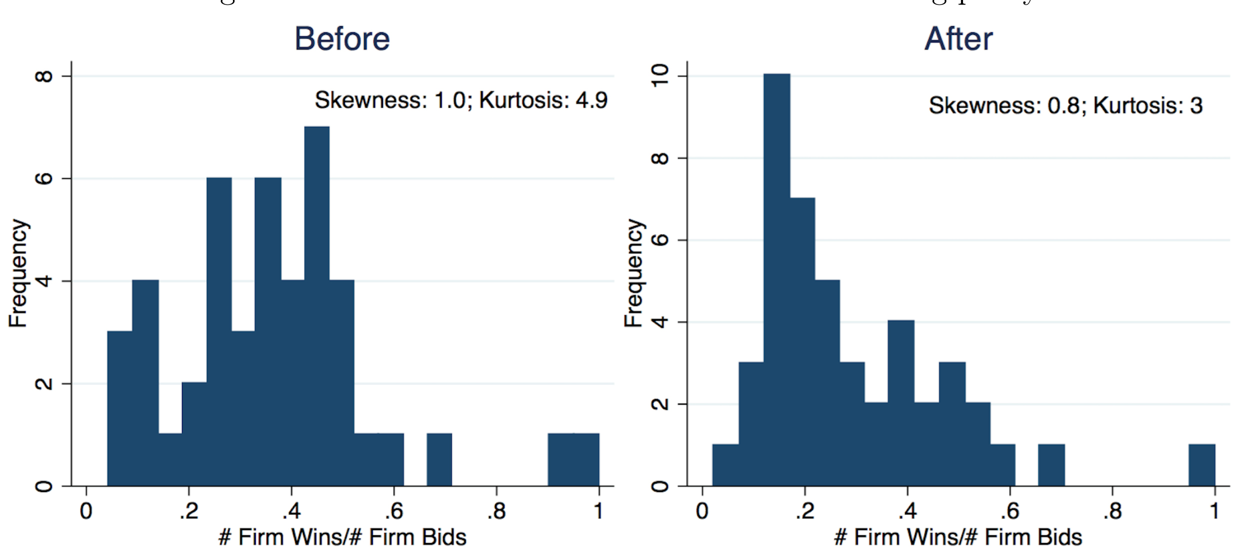
Note: This figure shows the bitumen prices in 100 forward physical contracts between one large paving firm and bitumen suppliers, as well as the spot oil price.

Figure 12: Hypothetical Margin Requirements for Hedging with Oil Futures



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

Figure 13: 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.

Online Appendix

1 Simple Model of Paver Problem

Consider the following simple model describing a paving firm's profit maximization problem when bidding in a highway procurement auction. The firm submits unit price bids for bitumen, b_B, and for everything else, b_O. He knows the actual quantities that he will use, q_B^a and q_O^a, but his total bid B is calculated based on the DOT estimated quantities, q_B^e and q_O^e.[1] Conditional on his optimal total bid B, which determines his chances of winning the project (he wins if he submits the lowest total bid), the paver solves:

$$\begin{aligned} \max_{b_B, b_O} \pi &= b_B q_B^a + b_O q_O^a - \frac{1}{2}\eta \left[(b_B - \tilde{c}_B)^2 - (b_O - c_O)^2 \right] \\ \text{s.t.} &\quad b_B q_B^e + b_O q_O^e \leq B \end{aligned} \tag{1}$$

The firm's cost for of bitumen is $\tilde{c}_B = c_B + \rho$, where ρ is a non-negative risk premium, or the value of hedging to the firm. I do not microfound this parameter; it may be due to financial constraints, agency problems, or owner preferences. The last term in Equation 2 reflects a penalty for excessive skewing. To the extent that $q^e \neq q^a$ on any item, the bidder has an incentive to skew his bid toward the quantity that has been underestimated. He can then lower B, increasing his chance of winning, but in expectation get paid the same. Following Bajari et al. (2014), I use a quadratic penalty η for for deviating from the engineering cost estimates.

The firm's FOC is:

$$\frac{\partial}{\partial b_B} : \; q_B^a - \lambda q_B^e = \eta \left(b_B - \tilde{c}_B \right) \tag{2}$$

where λ is a Lagrange multiplier, which I assume may be a function of everything unrelated to oil price risk, such as the marginal benefit of bidding a bid that scores higher, how others are skewing, etc. Specifically, $\lambda = \frac{\eta}{(q_B^e)^2 + (q_O^e)^2} \left[q_B^e \tilde{c}_B + q_O^e c_O + \frac{1}{\eta} \left(q_B^a q_B^e + q_O^a q_O^e \right) - B \right]$. Solving for the bitumen bid b_B gives:

$$b_B = \tilde{c}_B + \frac{1}{\eta} \left(q_B^a - \lambda q_B^e \right) = c_B + \rho + \frac{1}{\eta} \left(q_B^a - \lambda q_B^e \right) \tag{3}$$

[1] This simplifies the notion that the paving firm is more informed than the state about the quantities he will use.

This unit item bid is the expected cost plus a markup that includes the paving firm's cost of risk. This markup is:

$$m_B = b_B - c_B = \rho + \frac{1}{\eta}\left(q_B^a - \lambda q_B^e\right). \tag{4}$$

Equation 5 leads to the reduced form estimation in Section 6.2.

2 Additional Tables and Figures

Table 1: Selection into Projects by Firm Type (Part 1)

Project characteristic	Mean	N	Mean	N	P-value of difference
			Panel 1: Public ownership		
	Public firms		Private firms		
Bitumen quantity (tons)	940.0	4857	980.7	816	0.37
Distance firm to project (miles)	82.9	4857	93.9	816	0.02**
Number of bidders	4.7	4857	3.6	816	0.00***
Months to start	4.8	4233	4.6	627	0.13
			Panel 2: Family ownership		
	Non family-owned firms		Family-owned firms		
Bitumen quantity (tons)	869.2	2140	992.4	3533	0.00***
Distance firm to project (miles)	89.8	2140	81.2	3533	0.01**
Number of bidders	4.2	2140	4.8	3533	0.00***
Months to start	4.8	1663	4.8	3197	0.89
			Panel 3: Diversification		
	Diversified		Paving only		
Bitumen quantity (tons)	979.7	2708	965.1	2614	0.66
Distance firm to project (miles)	83.0	2708	83.8	2614	0.78
Number of bidders	4.1	2708	4.9	2614	0.00***
Months to start	4.7	2474	4.9	2267	0.02**

Note: This table summarizes means of project characteristics (used as control variables in the regressions) by firm type. The p-values give statistical significance on the difference between the two means.

Table 2: Selection into Projects by Firm Type (Part 2)

Project characteristic	Mean	N	Mean	N	P-value of difference
			Panel 4: Size (Measure 1)		
	Multiple Location		Single Location		
Bitumen quantity (tons)	1132.10	3990	477.3	1474	0.00***
Distance firm to project (miles)	83.77	3990	81.3	1474	0.45
Number of bidders	4.42	3990	4.8	1474	0.00***
Months to start	4.80	3650	4.7	1108	0.45
			Panel 5: Size (Measure 2)		
	Large firms		Small firms		
Bitumen quantity (tons)	1014.1	4085	791.03	1402	0.00***
Distance firm to project (miles)	85.4	4085	75.78	1402	0.00***
Number of bidders	4.6	4085	4.45	1402	0.10
Months to start	4.8	3619	4.80	1186	0.70
			Panel 6: Credit risk		
	Low risk		High risk		
Bitumen quantity (tons)	982.3	4146	678.6	474	0.00***
Distance firm to project (miles)	82.4	4146	105.9	474	0.00***
Number of bidders	4.6	4146	3.9	474	0.00***
Months to start	4.8	3579	4.8	282	0.9

Note: This table summarizes means of project characteristics (used as control variables in the regressions) by firm type. The p-values give statistical significance on the difference between the two means.

Table 3: Oil Price Data Summary Statistics, 1998-2012

	Mean (sd)	N
Oil futures price (WTI, 6 mo. contract)	55 (29)	6,107
Hist vol (12 week, 6 mo. contract)	28 (9.2)	6,107
Hist vol (26 week, 6 mo. contract)	29 (9.5)	6,107
Implied vol (3 mo. expiration, 6 mo. contract)	34 (7.3)	6,107

Note: This table summarizes the oil price and volatility data used in the regression analysis.

Table 4: Policy effect within Kansas across Contracts and Contract Items

Dependent variable:	Log item bid		Log bitumen bid	
	Bitumen vs. other items in bid		Sample restricted to firms that bid:	
			in both states	in one state
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Bitumen\ Item} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	-.44***	-.45***		
	(.12)	(.13)		
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			-.067	-.19***
			(.12)	(.038)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.25***	.26***	.77***	.76***
	(.061)	(.061)	(.07)	(.047)
$\mathbf{I}_{Bitumen} \cdot Vol_t^{\text{oil}}$	.46***	.46***		
	(.12)	(.13)		
$\mathbf{I}_{Bitumen} \cdot \mathbf{I}_{Post\ Policy_t}$	2***	2***		
	(.4)	(.41)		
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$			.27	.57***
			(.38)	(.13)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$			-.071	.062**
			(.086)	(.031)
$\mathbf{I}_{Kansas_j}$			.36	-.091
			(.28)	(.098)
Vol_t^{oil}	-.21***	-.21***	-.027*	.015
	(.059)	(.061)	(.015)	(.011)
$\mathbf{I}_{Bitumen}$	-10***	-10***		
	(.39)	(.4)		
$\mathbf{I}_{Post\ Policy_t}$	-.99***	-1***	-2.3***	-2.3***
	(.21)	(.21)	(.18)	(.15)
$\ln price_t^{\text{oil}}$	.069***	.058***	.19***	.3***
	(.02)	(.019)	(.059)	(.036)
Controls†	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
Firm f.e.	N	Y	N	N
N	12450	12450	915	5196
R^2	0.982	0.982	0.938	0.911

Note: Columns 1-2 report regression estimates of the effect of the risk removal policy on an additional unit of historical oil price volatility on bitumen items vs. non-bitumen items ($\mathbf{I}_{Bitumen}$) after vs. before the policy, using variations on Equation 3 with only Kansas data. Non-bitumen items are summed together, so that the total bid has two parts, $\mathbf{I}_{Bitumen}$=1 and $\mathbf{I}_{Bitumen}$=0. The dependent variable is the log bitumen item bid. Columns 3-4 show the main result in alternative samples. †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 5: Further Robustness Tests of Main Result (Part 1)

Dependent variable: Log bitumen bid	Differences			Fixed Effects					Alternative oil measures		
	None	Policy-vol	Falsification w/other bid items	Firm f.e.	No month f.e.	. State-year f.e.	State-month f.e.	Quarter f.e.	Implied vol	26-week hist vol	5-month CL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$			.058**	-.18***	-.15***	-.21***	-.1**	-.14***	-.36***	-.14**	-.13***
			(.024)	(.039)	(.037)	(.043)	(.047)	(.037)	(.069)	(.067)	(.035)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$		.68***	-.14***	.77***	.79***	.67***	.047	.13	.65***	.33***	.75***
		(.042)	(.028)	(.044)	(.043)	(.059)	(.49)	(.087)	(.05)	(.039)	(.041)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$			-.12	.53***	.49***	.35**	.33**	.45***	1.2***	.44**	.4***
			(.078)	(.13)	(.13)	(.14)	(.15)	(.12)	(.25)	(.22)	(.12)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$			-.11***	.047	.044	.067**	.00044	.04	.21***	.096	.019
			(.02)	(.032)	(.031)	(.029)	(.033)	(.03)	(.05)	(.059)	(.029)
Vol_t^{oil}	.052***	-.00021	.0013	-.0038	.0043	.016	.19***	.02	-.019	-.0073	.0038
	(.013)	(.0083)	(.0084)	(.0087)	(.0084)	(.01)	(.067)	(.014)	(.023)	(.015)	(.0097)
$\mathbf{I}_{Kansas_j}$	.11***	.1***	.45***		-.029			-.042	-.62***	-.21	.046
	(.01)	(.01)	(.07)		(.1)			(.095)	(.18)	(.19)	(.096)
$\mathbf{I}_{Post\ Policy_t}$	.1***	-2***	.42***	-2.3***	-2.4***	-1.8***	.56		-2***	-.93***	-2.2***
	(.03)	(.12)	(.097)	(.14)	(.14)	(.18)	(1.7)		(.18)	(.15)	(.13)
$\ln price_t^{\text{oil}}$	.059**	.28***	-.093***	.28***	.31***	.32***	.31*	.21***	.27***	.24***	.26***
	(.03)	(.032)	(.021)	(.036)	(.028)	(.036)	(.16)	(.048)	(.029)	(.031)	(.03)
Controls†	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
County and year f.e.	Y	Y	Y	N	N	N	N	N††	Y	Y	Y
N	6111	6111	6111	6111	6111	6111	6111	6111	6111	6111	6111
R^2	0.912	0.921	0.989	0.925	0.921	0.922	0.938	0.938	0.921	0.916	0.921

Note: This table reports regression estimates of the effect of the risk removal policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 3. 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. ††County f.e. included. Standard errors clustered by firm. *** $p < .01$.

Table 6: Further Robustness Tests of Main Result (Part 2)

Dependent variable: Log bitumen bid	Error Cluster Assumptions			Percentile volatility	
	Firm-month of year clusters	Robust (none)	Month clusters	Vol_t^{oil} 10 quantiles	Vol_t^{oil} 20 quantiles
	(1)	(2)	(3)	(4)	(5)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	-.14***	-.14***	-.14*	-.015***	-.0075***
	(.044)	(.04)	(.086)	(.004)	(.002)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.75***	.75***	.75***	.37***	.25***
	(.049)	(.036)	(.11)	(.021)	(.014)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.44***	.44***	.44	.048	.043
	(.14)	(.13)	(.29)	(.029)	(.028)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	.034	.034	.038	.0042	.0018
	(.038)	(.034)	(.077)	(.003)	(.0015)
Vol_t^{oil}	.00031	.00031	.00068	-.00045	-.00019
	(.01)	(.0078)	(.031)	(.001)	(.00048)
$\mathbf{I}_{Kansas_j}$	.0033	.0033	-.017	.085***	.089***
	(.12)	(.11)	(.25)	(.019)	(.019)
$\mathbf{I}_{Post\ Policy_t}$	-2.2***	-2.2***	-2.3***	-2.2***	-2.2***
	(.16)	(.12)	(.34)	(.13)	(.13)
$\ln price_t^{\text{oil}}$	.27***	.27***	.27***	.27***	.27***
	(.029)	(.021)	(.065)	(.031)	(.031)
Controls†	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y
County and year f.e.	Y	Y	Y	Y	Y
N	6111	6111	6111	6111	6111
R^2	0.922	0.922	0.922	0.921	0.921

Note: This table reports regression estimates of the effect of the risk removal 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 7: Marginal Effect of Oil Price Volatility after the Policy

Dependent variable: Log bitumen bid	Paving only, not family-owned	Family-owned, not paving only	High risk, not family-owned	Family-owned, not high risk
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	-.21*	-.11**	-.22***	-.17***
	(.1)	(.045)	(.055)	(.058)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.78***	.88***	.48***	.71***
	(.11)	(.086)	(.13)	(.041)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	.71**	.32*	.65***	.55***
	(.34)	(.16)	(.17)	(.19)
$\mathbf{I}_{Kansas_j} \cdot Vol_t^{\text{oil}}$	-.0043	-.029	-.014	.06
	(.093)	(.048)	(.058)	(.043)
Vol_t^{oil}	-.018	.026	.11**	.0029
	(.024)	(.02)	(.053)	(.0098)
$\mathbf{I}_{Kansas_j}$	.16	.25	.17	-.089
	(.31)	(.16)	(.2)	(.14)
$\mathbf{I}_{Post\ Policy_t}$	-2.5***	-2.6***	-1.4***	-2.1***
	(.34)	(.24)	(.37)	(.13)
$\ln price_t^{\text{oil}}$	.12**	.33***	.17***	.27***
	(.057)	(.078)	(.038)	(.042)
Controls†	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County and year f.e.	Y	Y	Y	Y
N	753	1372	509	3230
R^2	0.915	0.899	0.869	0.924

Note: This table reports regression estimates of the effect of the risk removal policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy, using variations on Equation 3. †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: Within-Kansas Estimates of Policy Effect by Firm Type

Dependent variable: Log bitumen bid

$X_j =$	Public vs. Private		High risk vs. Low risk	
	(1)	(2)	(3)	(4)
$\mathbf{I}_{X_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.13*	.15*	-.16*	-.17*
	(.08)	(.085)	(.088)	(.098)
$\mathbf{I}_{X_j} \cdot \mathbf{I}_{Post\ Policy_t}$	-.39	-.42	.48	.49
	(.27)	(.28)	(.3)	(.32)
$\mathbf{I}_{Post\ Policy_t} \cdot Vol_t^{\text{oil}}$	.29***	.2***	.44***	.37***
	(.064)	(.054)	(.058)	(.075)
$\mathbf{I}_{X_j} \cdot Vol_t^{\text{oil}}$	-.031	-.04	.088	.09
	(.059)	(.069)	(.059)	(.078)
$\mathbf{I}_{X_j}$	.063		-.25	
	(.21)		(.21)	
$\mathbf{I}_{Post\ Policy_t}$	-.3	-.04	-.73***	-.51**
	(.21)	(.17)	(.19)	(.24)
Vol_t^{oil}	-.2***	-.15***	-.25***	-.21***
	(.05)	(.042)	(.051)	(.063)
Controls†, Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.,	Y	N	Y	N
Firm f.e.	N	Y	N	Y
N	1442	1442	1404	1404
R^2	0.775	0.751	0.770	0.744

Note: This table reports estimates of how the policy affected different types of firms within Kansas. In columns I-II, $X_j = 1$ if the firm is public and 0 if private, and in columns III-IV, $X_j = 1$ if the firm is high risk, and 0 if not. Estimates are variants on Equation 3. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

Table 9: Robustness Tests of Policy Effect on Cost to Kansas

Dependent variable: \$/ton paid by DOT	Bitumen-intensive vs. non-bitumen-intensive paving contracts‡		Error Cluster Assumptions	
			None (robust)	Firm-state
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$			-43**	-43***
			(20)	(13)
$\mathbf{I}_{Bitumen\ Intensive_j} \cdot \mathbf{I}_{Post\ Policy_t}$	-54***	-49***		
	(8.5)	(8.9)		
$\mathbf{I}_{Kansas_j}$			273***	273***
			(12)	(7.2)
$\mathbf{I}_{Post\ Policy_t}$	324***	317***	39***	39***
	(8.6)	(10)	(11)	(8.8)
$\mathbf{I}_{Bitumen\ Intensive_j}$	39***	34***		
	(3.2)	(2.9)		
Controls†	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y
County·year f.e.	Y	Y	Y	Y
Firm f.e.	N	Y	N	N
N	2887	2887	1637	1637
R^2	0.821	0.840	0.798	0.798

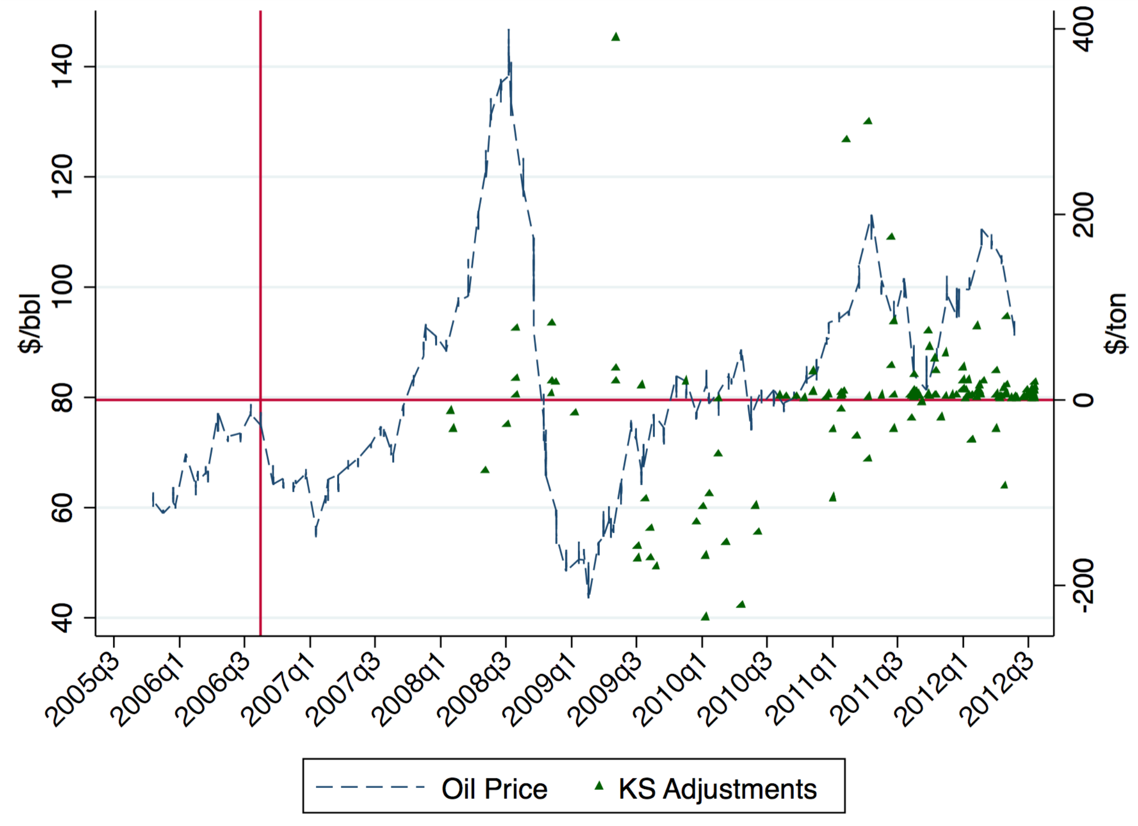
Note: This table reports estimates of Equation 1. Columns 1-2 report the effect of the policy on the actual price paid per ton of bitumen by Kansas, comparing contracts that are more bitumen-intensive to those that are less bitumen-intensive. All contracts use some bitumen. For example, a less-intensive contract may have some road paving but also some bridge building. The definition of more intensive is that defined for inclusion in the main analysis; the portion of the bid for bitumen must be at least \$50,000. †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. *** $p < .01$.

Table 10: Risk Shifting Policy Effect on Real Outcomes without Fixed Effects

Dependent variable:	Log bid	# bidders	Prob. of winning across firm types	
			Private vs. public	Paving-only vs. diversified
	(1)	(2)	(3)	(4)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t}$	-.081***	1.1***	-.11	-.12*
	(.028)	(.23)	(.098)	(.063)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$			.14	
			(.1)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Paving\ Only_i}$				.2***
				(.073)
$\mathbf{I}_{Kansas_j}$	.16***	-.0025	.19**	.18***
	(.021)	(.25)	(.091)	(.047)
$\mathbf{I}_{Post\ Policy_t}$	.84***	-.95***	-.099	-.082***
	(.012)	(.16)	(.09)	(.021)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Privately-owned_i}$			-.096	
			(.084)	
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Privately-owned_i}$			.046	
			(.083)	
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{Paving\ Only_i}$				-.051
				(.063)
$\mathbf{I}_{Post\ Policy_t} \cdot \mathbf{I}_{Paving\ Only_i}$				.013
				(.025)
$\mathbf{I}_{Privately-owned_i}$			-.029	
			(.079)	
$\mathbf{I}_{Paving\ Only_i}$				-.081***
				(.017)
Controls†	Y	Y	Y	Y
Month-of-year f.e.	N	N	N	N
County·year f.e.	N	N	N	N
N	6111	1794	6324	5921
R^2	0.797	0.179	0.171	0.177

Note: This table reports estimates of the effect of the risk shifting policy in Kansas vs. Iowa after vs. before the policy, using variations on Equation 1. Each observation is an auction in I and III, and a bid in II, IV, V. The dependent variable in IV and V is 1 if the firm won the auction, and each column interacts the policy effect with a firm type. N is lower in I because KDOT lost some payments data. †Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, oil price. The number of bidders is also included in I and III. Standard errors clustered by firm. *** $p < .01$.

Figure 1: Price Adjustments and Oil Price



Note: This figure shows Kansas price adjustments based on oil price changes after the policy.

Figure 2: Firm Z Project Locations Coded by Bitumen Supplier

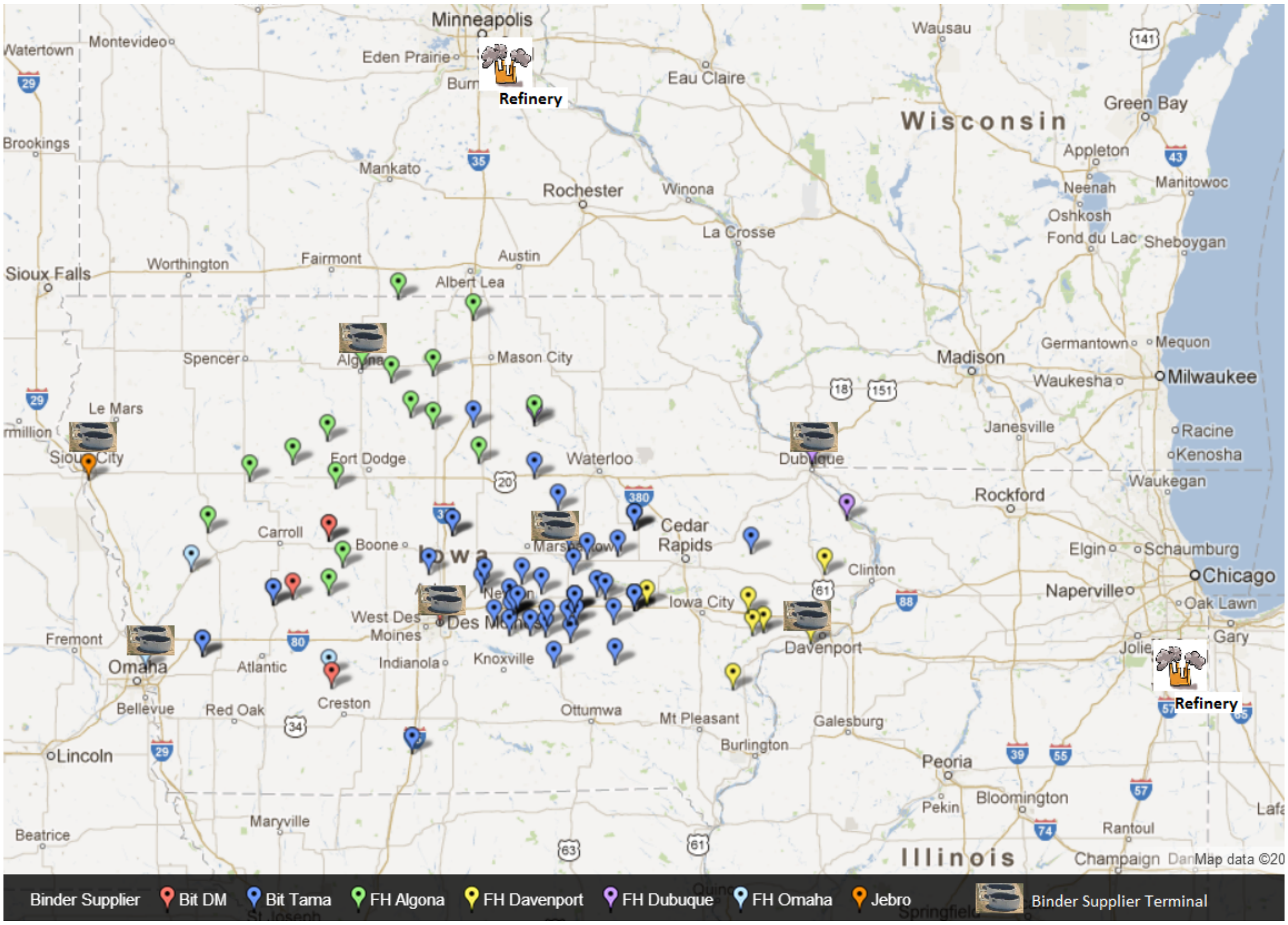
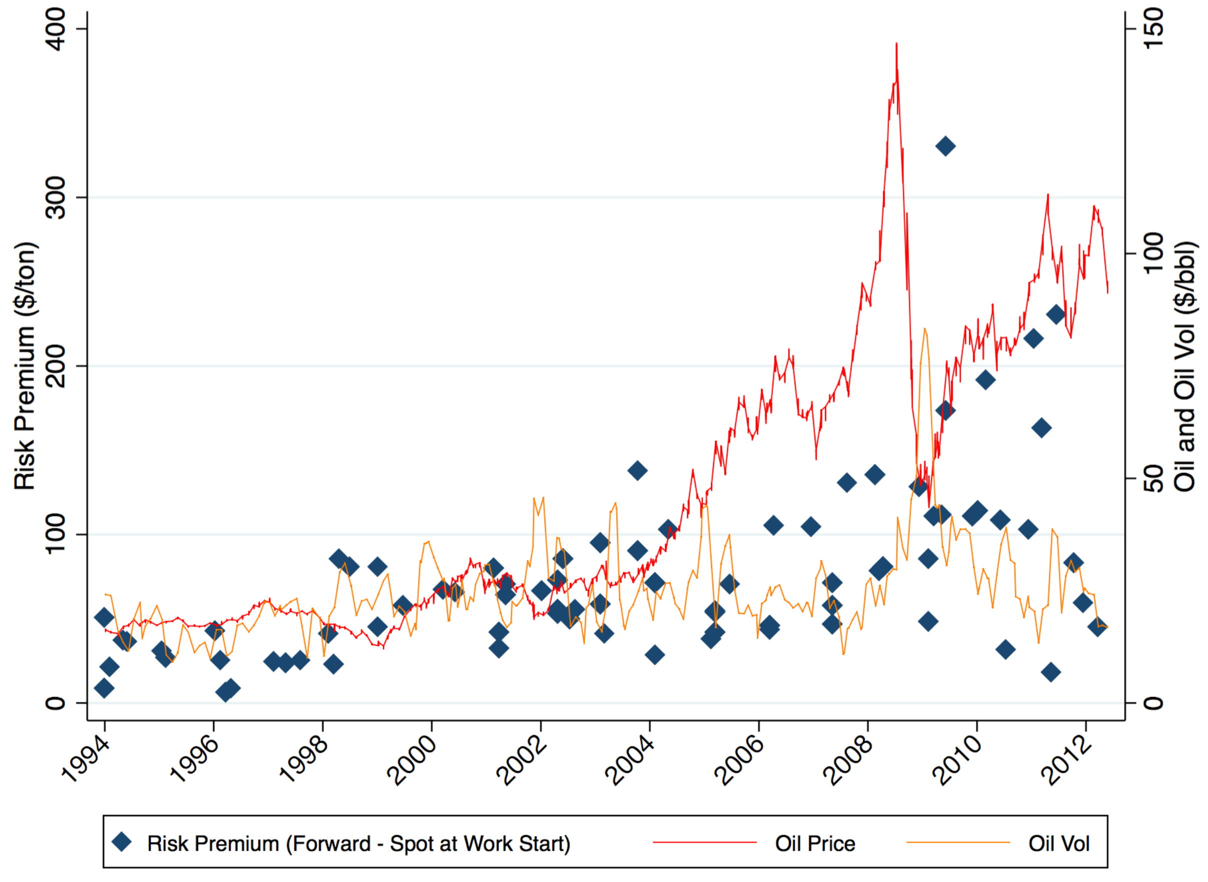
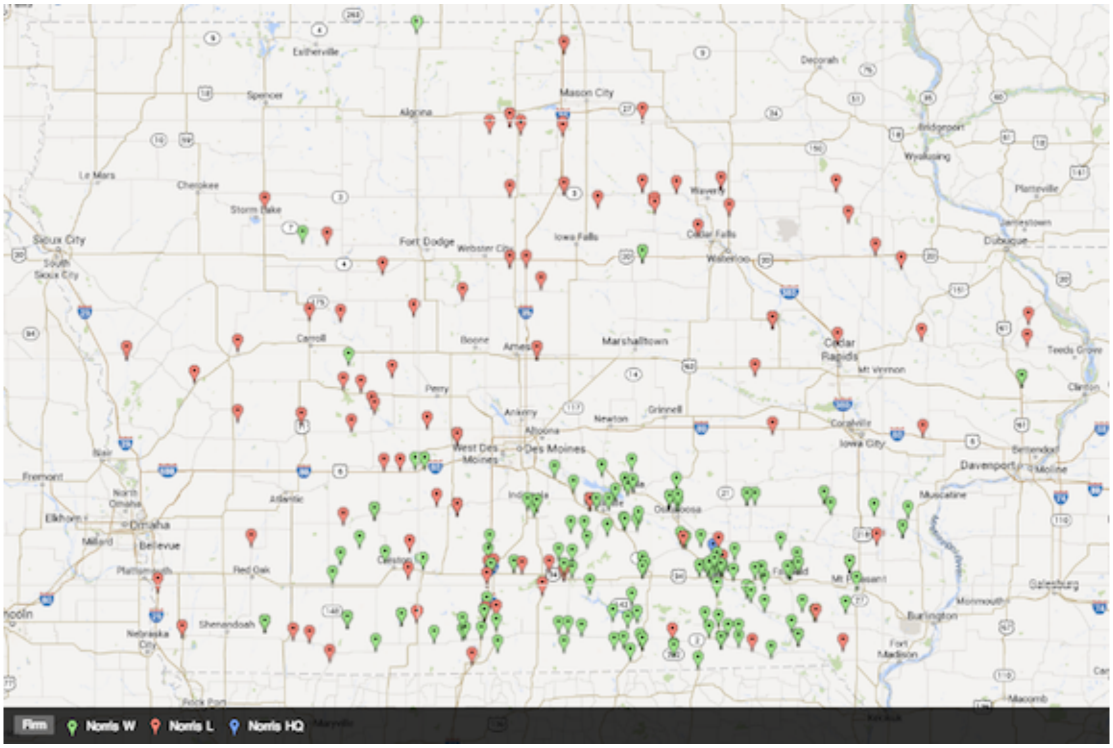


Figure 3: Firm Z Forward Contract Risk Premiums



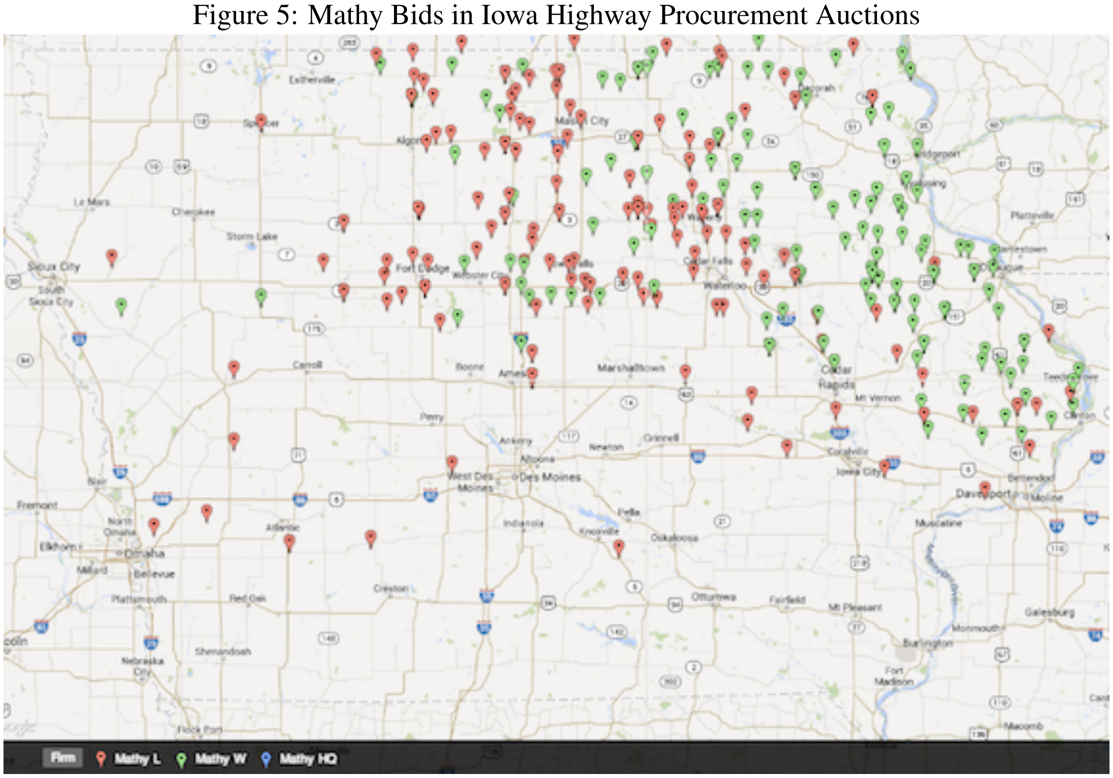
Note: This figure shows the risk premiums embedded in Firm Z's forward contracts, which are signed at the time of the auction (typically in winter). I subtract the spot price in the week work starts (typically in the summer) from the forward contract price to get the risk premium.

Figure 4: Norris Bids in Iowa Highway Procurement Auctions



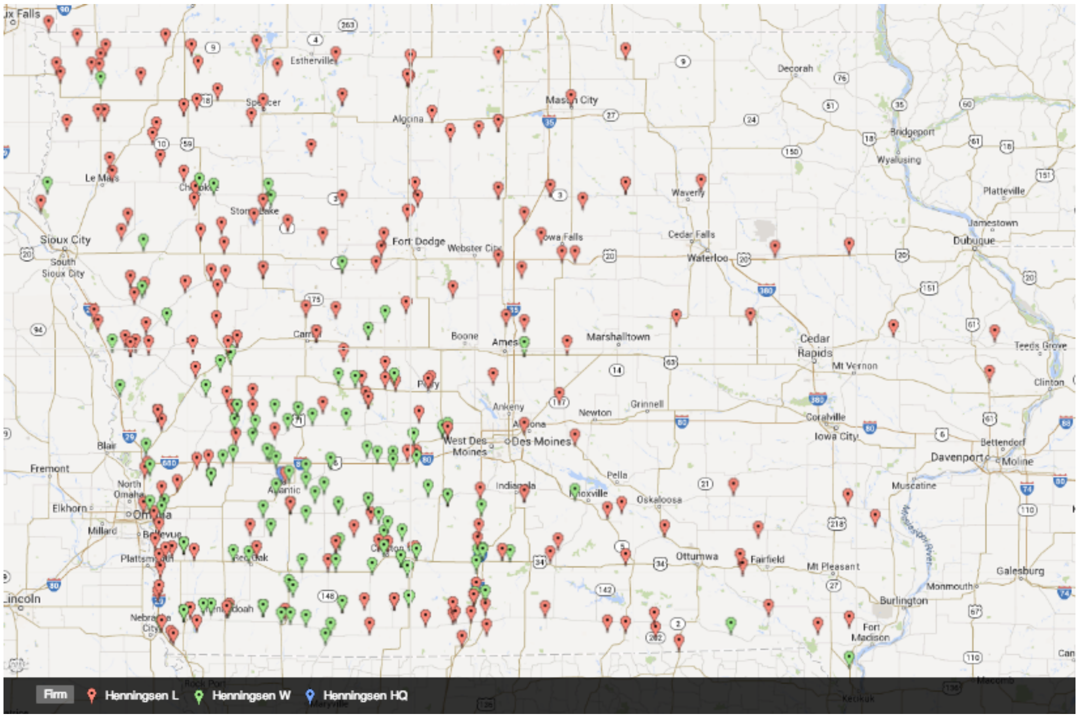
Note: This figure shows the location of one firm's auction wins (green) and losses (red).

Figure 5: Mathy Bids in Iowa Highway Procurement Auctions



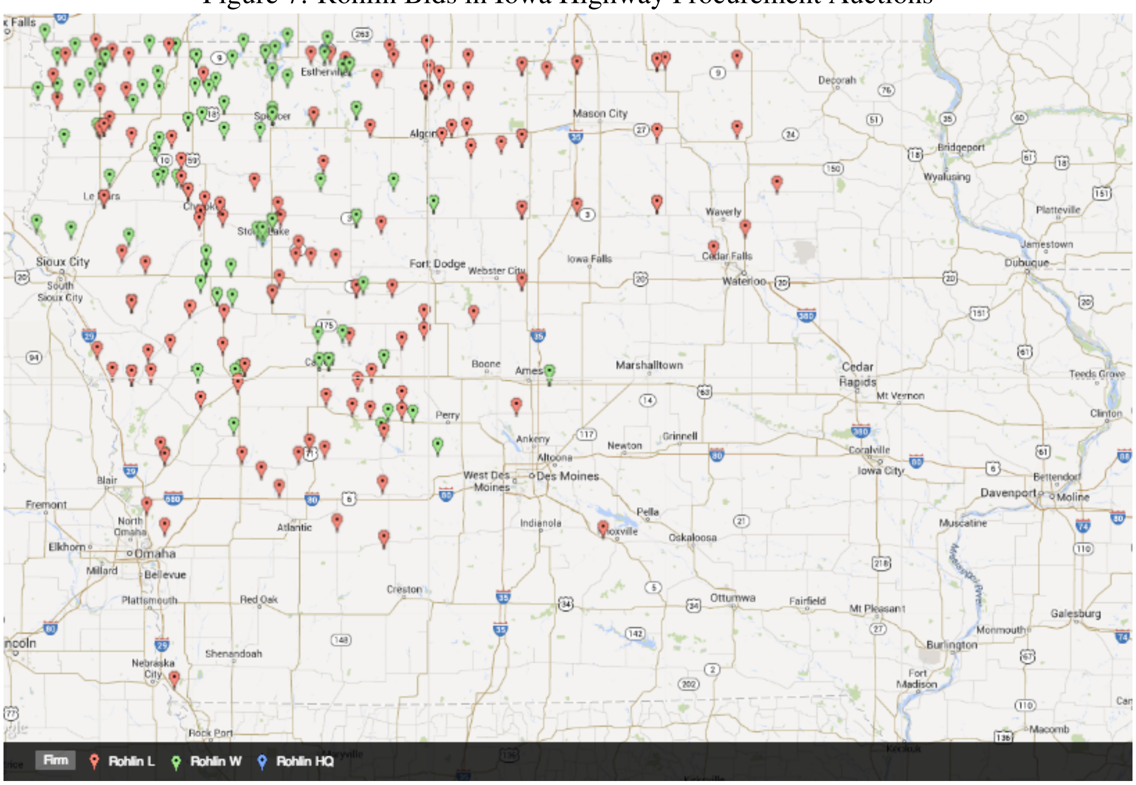
Note: This figure shows the location of one firm's auction wins (green) and losses (red).

Figure 6: Henningsen Bids in Iowa Highway Procurement Auctions



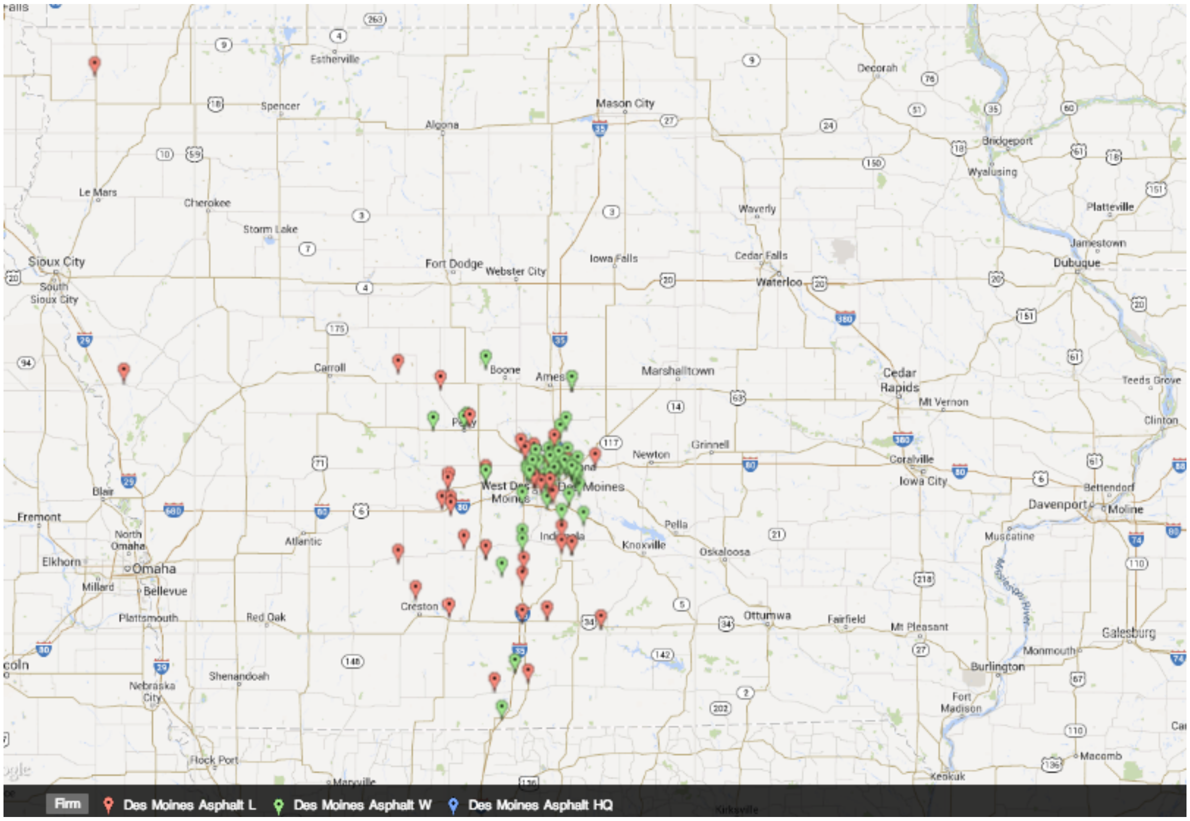
Note: This figure shows the location of one firm's auction wins (green) and losses (red).

Figure 7: Rohlin Bids in Iowa Highway Procurement Auctions



Note: This figure shows the location of one firm's auction wins (green) and losses (red).

Figure 8: Des Moines Asphalt Bids in Iowa Highway Procurement Auctions



Note: This figure shows the location of one firm's auction wins (green) and losses (red).