Journal of Corporate Finance 64 (2020) 101691

Contents lists available at ScienceDirect

Journal of Corporate Finance

journal homepage: www.elsevier.com/locate/jcorpfin

Firm type variation in the cost of risk management

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ARTICLE INFO

Keywords:
Risk management
Private firms
Family firms
Insurance
Procurement

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.

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 et al., 2014; Gilje and 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 and 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 transferred 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

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https://doi.org/10.1016/j.jcorpfin.2020.101691
Received 20 February 2020; Received in revised form 23 June 2020; Accepted 3 July 2020
Available online 15 July 2020
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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.

Existing evidence finds a small risk premium for holding long positions in crude oil futures.[1] 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.[2] One reason firms may value risk management is if they face financial constraints and distress costs (Froot et al., 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 and 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 and Rabinovitch (2013). These should be more severe 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 and 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 2 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.

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.

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. Bolton et al. (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 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.

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 and 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.[3] This paper also helps inform

[1] See Erb and Harvey (2006), Basu and Miffre (2013), Ahn and Kogan (2012), Alquist and Kilian (2010), and Kellogg (2014)

[2] 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.

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

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 and Zona, 1993; Pesendorfer, 2000; Bajari and 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 and 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 et al. (2006), Acharya et al. (2007), Purnanandam (2008), Lin and Paravisini (2013), and Chen and 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 and Roberts, 2012), and innovation (Acharya and 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 et al. (2012). Finally, existing work has studied the pass-through of costs and taxes to the consumer, but not risk (Campa and Goldberg, 2005; Weyl and 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 (Section 2.1), explains how firms manage risk in practice (Section 2.2), and then describes the insurance policy in Kansas that is used for identification (Section 2.3).

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 and 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.[4]

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 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. 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 6 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.

2.2. Why transfer risk? Hedging in practice

To understand how a policy transferring risk to the state may be helpful, it is useful to consider how this industry manages risk in the absence of state-provided insurance. In general, firms can manage risk with hedges, insurance, diversification, or cash holdings. In practice, paving firms very rarely hedge in financial markets. Similar to practices among farmers, electric utilities, and airlines, paving firms usually fully insure by signing physical forward contracts with suppliers before the auction. This fact and the institutional details that follow are based primarily on on interviews with 20 of the top bidders across both states.

The paving firm typically signs a physical forward contract with one supplier before the auction. The contract commits the paving firm to purchase the bitumen at the quoted price at the time of work start if the firm wins the auction. The price is good only for the DOT project specified in the contract, but the bitumen can in most cases be taken any time during the construction season. Sometimes, however, paving firms do not fully insure at the time of the auction. They can also sign a contract in the interim between the auction and the time work begins, or wait to buy until the time of work. In interviews, executives 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

[4] 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.

shock occurs. While the parent may trade derivatives at a global level, interviews indicated that the subsidiary is not involved in that trading.

The counterparties in the forward contracts are suppliers. The price of bitumen and crude oil are highly correlated – the correlation coefficient is 0.8 during this period – but there are no liquid spot or futures markets for bitumen in the U.S. In practice, bitumen is purchased from local suppliers in one-off, non-public transactions. Suppliers purchase bitumen from oil refineries, which produce it year-round as a byproduct. Suppliers 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. Bitumen is costly to transport and store, so suppliers naturally form a territorial oligopoly (Appendix Fig. 1).

To explore the cost of risk, I use data on actual physical forward hedging behavior which is, to my knowledge, new to the literature. I observe 105 forward physical contracts between paving firm Z (identity protected) and all four regional bitumen suppliers. Firm Z, based in Iowa, is among the top three firms in number of total bids in the Iowa, and near the mean among regular Iowa bidders in win percentage. Example contracts are in Figs. 1 and 2. Volatility may help to explain why the price in the 2009 contract in Fig. 2 is so much higher than the 2008 contract in Fig. 1, even though oil prices fell across the two dates. Volatility was low in early 2008 but peaked at over 70% in early 2009.

The Firm Z forward contracts can be used to estimate the realized cost of risk in the forwards relative to the bitumen index price that Kansas used to implement its policy (discussed below). Firm Z's per ton contract prices for bitumen are graphed in panel A of Fig. 3. The contracts are tied to a specific Iowa DOT paving project, so I observe the bid item markup over the contract price. Panel B of Fig. 3 shows that The markup is stable at around $22 per ton regardless of oil prices or volatility. 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.

The cost of risk 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). The average risk cost is 24% of the forward contract price, with a standard deviation is 10%. These risk costs are graphed in Fig. 4. By choosing the index over their forward contracts, paving firms avoid paying this cost 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%.

The physical forward contracts represent a reservation price of hedging; hedging in financial markets must be at least as costly as the forward contracts, since in practice firms choose forward contracts. The fact that firms do not in practice hedge using the theoretically relatively efficient financial markets and instead pay what seem to be high costs to insure via physical forwards suggest that there may be a role for the state to reduce its paving costs by providing firms insurance directly.

2.3. 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 transfer might lower bids, and in general were not related to particular economic conditions in the states.[5]

The Kansas DOT implemented its bitumen insurance policy (called a "price adjustment policy") in August 2006. One official had a personal interest in oil prices and had become interested in price adjustment policies following a federal DOT report on them. The precipitating event, according to Kansas DOT officials, was a contractor bidding an outrageously high price for a contract in which he was the only bidder, claiming that he could not get a firm bitumen price from suppliers. The policy was not necessarily a surprise. This is not required for the 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.[6] 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

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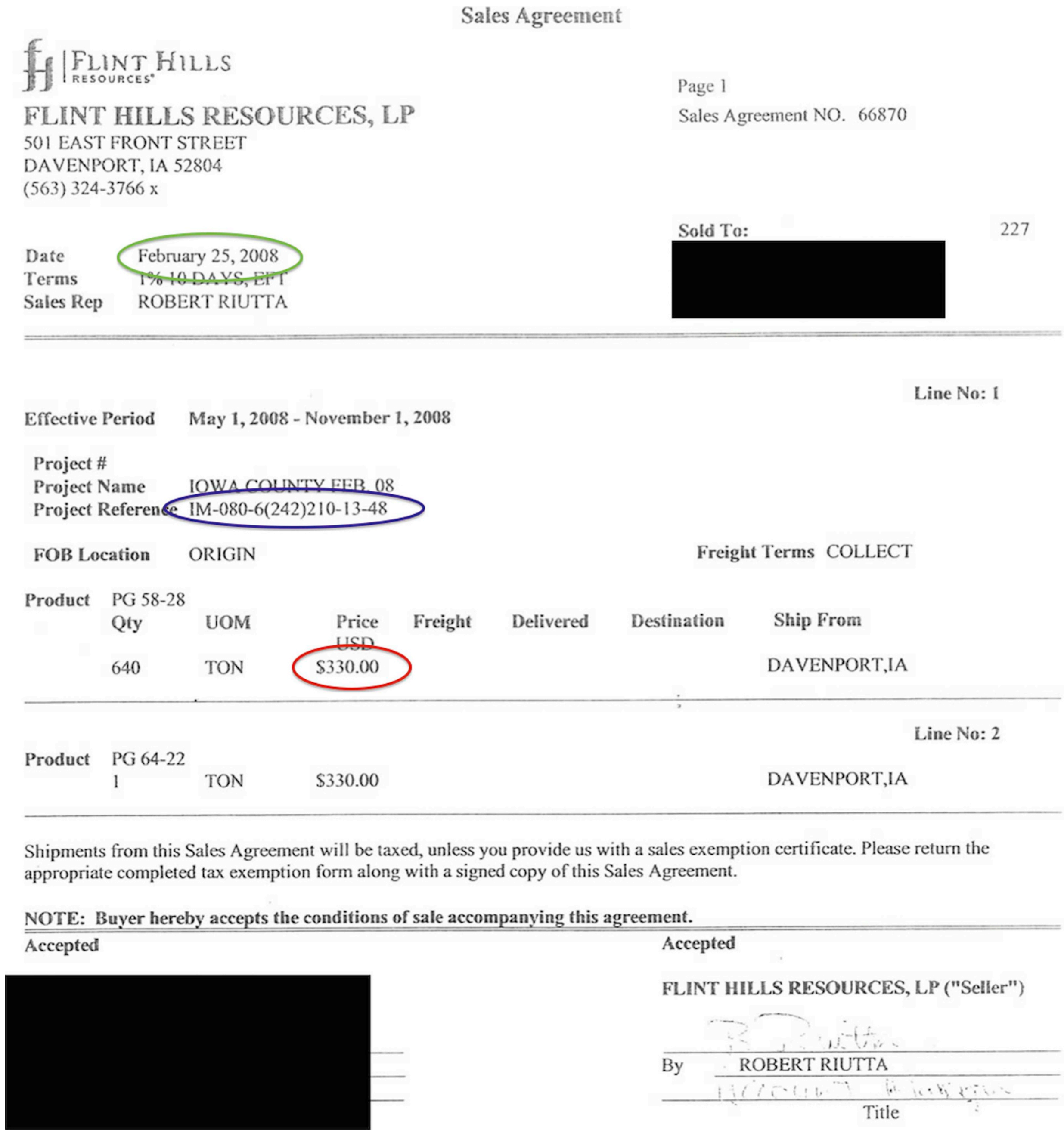
[5] A 1980 U.S. DOT Technical Advisory began with the following statement: "Price volatility of construction materials and supplies such as asphalt, fuel, cement and steel can result in significant problems for contractors in preparing realistic bids. In many cases, prospective bidders cannot obtain 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).

[6] Interviews for both Iowa and Kansas DOTs were conducted in person, on the phone, or over email. Interviewees include Steven Belzung, Roger Bierbaum, LouAnn Hughes, Kevin Martin, Abe Rezayazdi, Greg Sheiber, and Sandy Tommer.



Sales Agreement

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501 EAST FRONT STREET
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(563) 324-3766 x

Page 1
Sales Agreement NO. 66870

Sold To: 227
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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

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

Accepted
[redacted]

Accepted
FLINT HILLS RESOURCES, LP ("Seller")
By ROBERT RIUTTA
Title

Fig. 1. Example firm Z physical forward contract, February 2008.
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.

DOT officials indicated that despite experiencing similar cost escalation, they were not interested in the policy. Iowa and Kansas were on similar economic growth paths before and after Kansas' insurance policy (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

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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

Fig. 2. Example firm Z physical forward contract, February 2009.
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.

down, the paving firm receives the bid less the bitumen price index decrease.[7] In auctions in Kansas, paving firms choose whether or not to use the insurance policy when they submit their bids. All bidders have opted for the policy (a few exceptions appear to be mistakes). Fig. 5 shows the contract price adjustment for each contract in Kansas after the policy, measured in dollars per ton of bitumen. Each adjustment represents the difference for a particular contract between the index at the time of bidding and the time of work. The time on the x-axis is the contract completion date, when the ex-post overall adjustment is observed. The adjustments are related to recent oil price changes, but with lags that differ depending on the time between the auction and the performance of work. To demonstrate this lag, oil prices in dollars per barrel are also shown.

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

[7] 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.

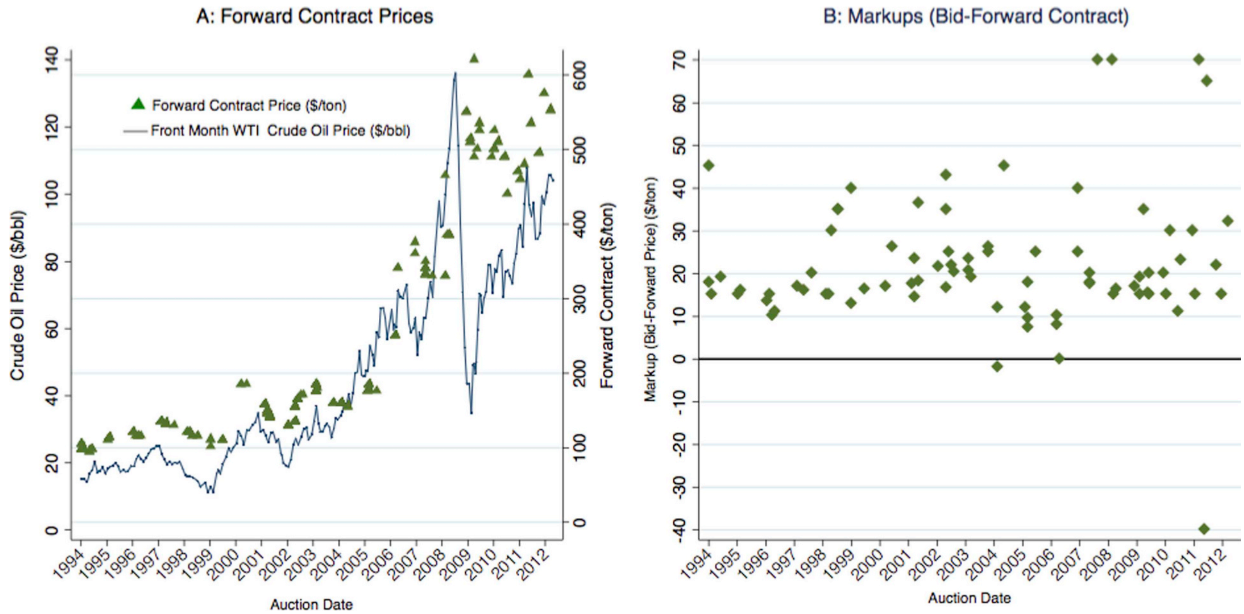

Fig. 3. Firm Z physical forward bitumen contracts.
Note: This figure shows the bitumen prices in 100 forward physical contracts between one large paving firm and bitumen suppliers, as well as the spot oil price.

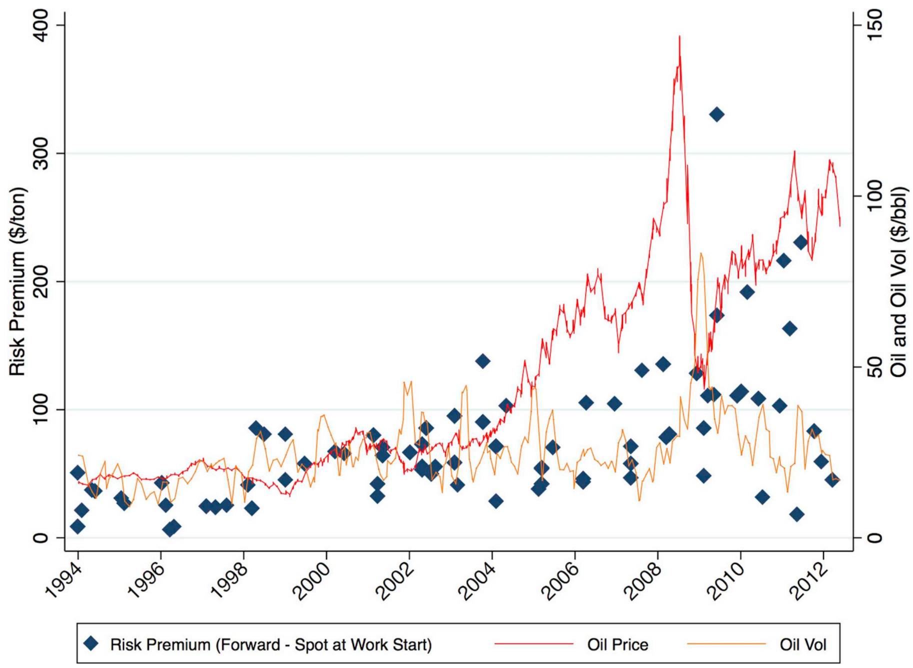

Fig. 4. Firm Z forward contract risk premiums.
Note: This figure shows the risk costs embedded in Firm Z's forward contracts, which are signed at the time of the auction (typically in winter). The risk cost represents spot price in the week work starts (typically in the summer) subtracted from the forward contract price.

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.[8]

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

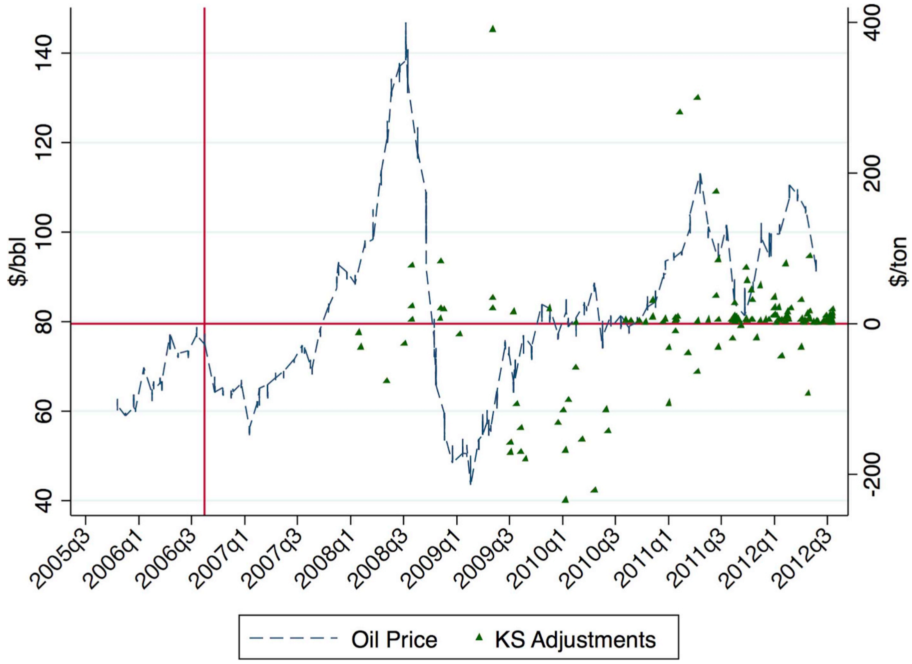

Fig. 5. Price adjustments and oil price.
Note: This figure shows Kansas price adjustments (green triangles) after the policy in dollars per ton. Each adjustment represents the difference for a particular contract between the index at the time of bidding and at the time of work. Therefore, they are related to recent oil price changes, but with lags that depend on the time between the auction and work performance. To demonstrate this relationship, oil prices in dollars per barrel (WTI) are shown on the left axis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

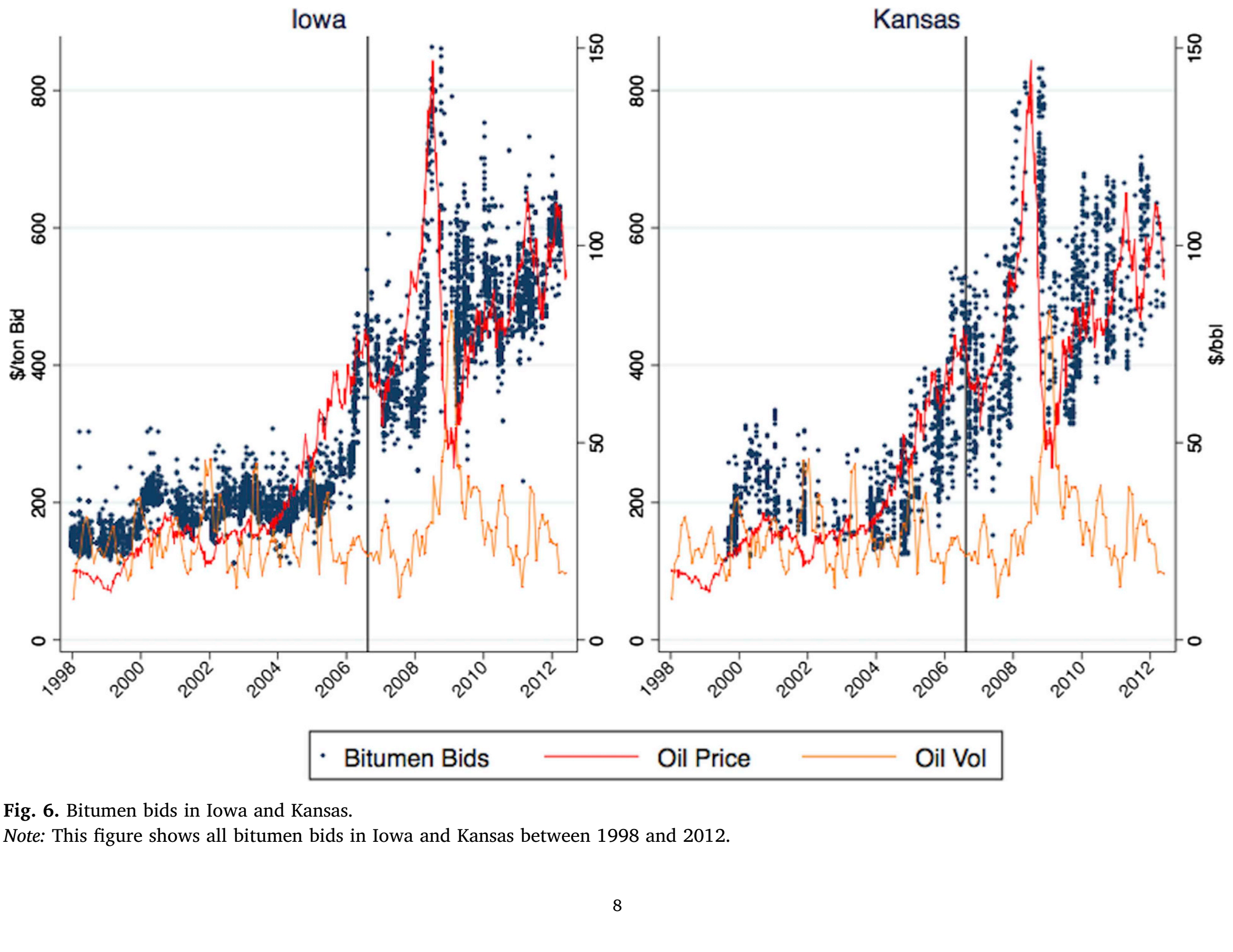

Fig. 6. Bitumen bids in Iowa and Kansas.
Note: This figure shows all bitumen bids in Iowa and Kansas between 1998 and 2012.

Table 1
Summary statistics of iowa and kansas auction data, 1998–2012.

	Iowa			Kansas			Diff	All		
	Mean	SD	N	Mean	SD	N	IA - KS	Mean	SD	N
Panel 1: Contracts (Auctions)										
Number of bidders	3.40	2.00	1363	3.40	1.60	433	−0.08	3.40	2.00	1796
Months auction to work start	4.60	2.80	1363	5.70	9.70	433	−1.10	4.70	2.80	1796
Money on the table	0.06	0.07	1187	0.04	0.09	433	0.02***	0.06	0.08	1796
Panel 2: Bids										
Total bid ($ millions)	2.30	3.30	4669	2.60	4.50	2215	−0.30***	2.40	3.90	6884
Bitumen bid item ($ bid per ton)	304	150	4669	347	164	2215	−43***	318	156	6884
Bitumen fraction of total bid $\left(\frac{\text{tons} * \text{bid item}}{\text{total bid}}\right)$	0.14	0.11	4669	0.16	0.13	2394	−0.02***	0.15	0.11	6884
Total bid per ton bitumen ($ thousands)	10	29	4669	17	82	2394	−7***	12	53	6884
Miles to project	75	57	4669	111	182	2394	−36***	87	117	6884

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[a]	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[b]
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).

[a] Public firms purchased private firms during span of data. Primary business is based on 8-digit SIC codes.

[b] 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.

3. Data used in Main analysis

This paper primarily relies on comprehensive, detailed data on Iowa and Kansas DOT auctions and payments between 1998 and 2012. The sample is restricted to asphalt road paving projects, which are bitumen-intensive. The primary outcome variable in the analysis is the unit item bitumen bid, which is the per ton bitumen bid within the larger total project bid. A secondary outcome variable is the total bid for the paving project per ton of required bitumen, which accounts for the possibility that different strategies for allocating profit among items could distort the true effect of volatility on the metric that matters to DOT (the overall bid for the

Table 3
Average differences across states before and after price adjustment policy.

	Iowa			Kansas			IA - KS
	Mean	SD	N	Mean	SD	N	
Panel 1: Before policy							
Bitumen bid ($ per ton)	196	44	2824	224	73	1166	−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

	Iowa			Kansas			IA - KS
	Mean	SD	N	Mean	SD	N	
Panel 2: After policy							
Bitumen bid ($ per ton)	469	95	1845	484	125	1049	−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.

project). Bitumen comprises 11.3% of the total bid amount on average for the contracts in my data, but can be up to 40%.[9] Fig. 6 shows Iowa and Kansas bitumen bids over time, as well as the crude oil price and historical oil price volatility.

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.

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). 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. 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 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.

Finally, oil price and volatility data are from Bloomberg (summary statistics in Appendix Table 1). I use six-month WTI oil futures as a measure of expected oil prices, because the average time to work start is 5 months and the six-month contract is standard and highly liquid. Risk is measured with historical oil price volatility, which is an annualized standard deviation of daily returns, and implied volatility, which is derived from the Black and 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 3 months.

4. Estimation approach

This section first presents the estimation strategy (Section 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 (Section 4.2).

[9] 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.

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.

$$\ln bid_{ijt} = \alpha + \beta_1 \mathbf{I}_{Kansasj} \cdot \mathbf{I}_{post\ \ policy_t} \cdot \ln Vol_t^{oil} + \beta_2 \ln Vol_t^{oil} + \beta_3 \mathbf{I}_{post\ \ policy_t} + \beta_4 \mathbf{I}_{post\ \ policy_t} \cdot \ln Vol_t^{oil} + \beta_5 \mathbf{I}_{Kansasj} \cdot \mathbf{I}_{post\ \ policy_t} + \beta_6 \mathbf{I}_{Kansasj} \cdot \ln Vol_t^{oil} + \beta_7 \ln price_t^{oil} + \gamma' \cdot controls_{ij} + \delta_1 \mathbf{I}_{county_j} + \delta_2 \mathbf{I}_{year_j} + \delta_3 \mathbf{I}_{month_j} + \varepsilon_{ijt}. \tag{1}$$

The coefficient of interest in Eq. (1), β_1, is the effect of volatility on bids in Kansas relative to Iowa after oil price risk transferred to the public sector. The log bitumen bid ($\ln bid_{ijt}$) is the dependent variable, $\mathbf{I}_{post\ \ policyt}$ is an indicator for whether the auction took place after August 2006, and $\mathbf{I}_{Kansasj}$ is an indicator for whether the auction took place in Kansas. The oil futures price is $price_t^{oil}$, and Vol_t^{oil} is its volatility in dollar terms. County and year fixed effects control for unobserved characteristics of products in the county as well as economic shocks, and the 12 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, as well as an indicator for whether the firm is located in Kansas. At the project level, controls include log bitumen tons proposed, average total bid in the auction, and the number of bidders. County and time fixed effects subsume any average changes in the market 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.

In an alternative model, indicators for the year around the policy implementation year are substituted for $\mathbf{I}_{post\ \ policyt}$ to test for pre-trends and examine the dynamics. Each year is defined as starting in August to correspond to the policy implementation beginning in August of 2006. In this model, $\mathbf{I}_{Kansasj} \cdot \ln Vol_t^{oil}$ is interacted with dummies for each year around 2006, with 5 years before and 5 years after included, and the year before the policy (2005) omitted. The time dummies are also interacted with $\ln Vol_t^{oil}$ and $\mathbf{I}_{Kansasj}$.

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. The first approach is to split the sample in Eq. (1) by firm type.

The second approach is to measure risk as the forward market interacted with oil price volatility. Specifically, I measure risk as $\sqrt{Wait_j} \cdot \ln Vol_t^{oil}$, 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. Eq. (2) formalizes this estimation approach using one example of firm type; an indicator for the firm being publicly owned ($\mathbf{I}_{publicj}$).

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

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

Appendix Figs. 7 and 8 use data from the Iowa and Kansas DOTs to show the number of asphalt paving procurement contracts in each state, and the total annual tons of bitumen used in these contracts. These last graphs exhibit the least correlation across the two states. In particular, Iowa experienced a larger jump as a result of the ARRA in 2009. To ensure that this jump for Iowa does not bias the results, 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).[10] 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.

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

Table 4
Marginal effect of oil price volatility on bids.

Dependent variable: Log bitumen bid (except Column 2)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t} \cdot \ \ln Vol_t^{oil}$	−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)
$\mathbf{I}_{post\ \ policy_t} \cdot \ \ln Vol_t^{oil}$	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	−0.097***	0.580***	0.540***	0.440*	0.440***
	(0.120)	(0.240)	(0.130)	(0.027)	(0.120)	(0.120)	(0.240)	(0.120)
$\mathbf{I}_{Kansas_j} \cdot \ \ln Vol_t^{oil}$	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)
$\ln Vol_t^{oil}$	0.001	0.006	0.046***	0.013	−0.026***	0.006	0.000	0.000
	(0.009)	(0.010)	(0.016)	(0.040)	(0.009)	(0.010)	(0.023)	(0.009)
$\mathbf{I}_{post\ \ policy_t}$	−2.300***	−0.930***	−2.400***	0.690***	−1.700***	−2.300***	−2.200***	−2.200***
	(0.130)	(0.250)	(0.160)	(0.061)	(0.120)	(0.130)	(0.340)	(0.130)
$\ln price_t^{oil}$	0.270***	0.140***	0.340***	0.240***		0.270***	0.270***	0.270***
	(0.032)	(0.042)	(0.051)	(0.038)		(0.033)	(0.059)	(0.032)
Controls	Y	Y	Y	Y	N	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y	Y	N	Y	Y
Year f.e.	Y	Y	Y	Y	Y	N	Y	Y
N	6111	4542	3714	1780	6111	6111	6111	6111
R^2	0.922	0.970	0.895	0.937	0.917	0.914	0.922	0.922

Note: This table reports regression estimates of Eq. (1). The triple interaction coefficient gives the effect of the risk transfer policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy. The dependent variable is the bitumen bid item (the part of the bid for bitumen) in log dollars per ton. Column 1 is the main model. In Column 2, the dependent variable is the log total bid divided by the tons of bitumen used, and the sample is restricted to contracts with at least $50,000 in bitumen cost. Column 3 restricts the sample to a narrower bandwidth of years around the policy, including only 2005 through 2008. In Column 4, the sample is restricted to periods of top quartile volatility, relative to the sample average. Column 5 omits auction and bidder controls, and Column 6 omits county fixed effects. Standard errors clustered by firm in columns 1–6. In column 7, standard errors are clustered by state-month, and in column 8 they are clustered by firm-month. Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, an indicator for the state of the firm being Kansas, and the number of bidders. *** $p < .01$.

Beyond a potential violation of parallel trends, there may be three other concerns. First, firms in Iowa might 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. There are also controls for important project characteristics, including size and date, which further address a selection concern. Second 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 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 and competition were affected in the new, post-policy market equilibrium.

5. Insurance policy effect on risk pass-through

Estimates from Eq. (1) of the insurance policy's on average risk pass-through are shown in Table 4. The coefficient of −0.14 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). In column 2, the log total bid per ton of bitumen is the dependent variable, and the effect is similar.[11] Column 3 shows that the effect declines somewhat but remains statistically significant using a narrow bandwidth of 2 years around the policy. When the sample is restricted to periods of volatility above the 75th percentile, the coefficient becomes −0.097 (column 4). This confirms the main result that volatility drives the triple difference coefficient.[12]

[11] This coefficient is similar for three reasons. First, the sample is restricted to contracts with at least $50,000 in bitumen cost. Second, oil is a primary input for many bid items besides bitumen, and is the largest variable cost in many projects. Third, oil expectations is the largest driver of variation across bids in these simple paving projects.

[12] 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 2 columns 3–4).

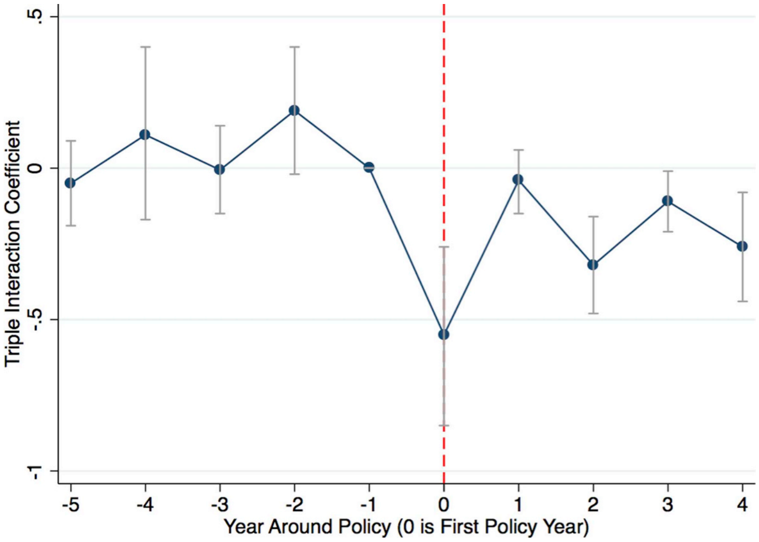

Fig. 7. Effect of the policy by year around implementation.
Note: This figure shows coefficients from estimating Eq. (1), but restricting the sample to 5 years on either side of the policy implementation year (2006), and including indicators for the year rather than a post-policy indicator. Each year is defined as starting in August to correspond to the policy implementation beginning in August of 2006.

Fig. 7 uses the treatment-year approach discussed in Section 4.1 to test for pre-trends and consider dynamics. As this requires many interactions with the time dummies, it is a bit noisy. There is a very large effect in the first year, after which the effect is negative and closer to the overall main effect. The initial large negative effect may reflect the policy being especially salient, and firms experimenting with different bidding approaches after learning about it. The figure provides comforting confirmation that there are no significant pre-trends.

To shed light on the mechanism, it is helpful to vary fixed effects. Firm fixed effects test whether the main result reflects differences in sophistication. With firm instead of county fixed effects, the coefficient of interest on the triple interaction is slightly larger, at −0.18 (Appendix Table 3 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. 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. The result does not reflect firms expanding into new markets, as the specifications in Appendix Table 3 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.

5.1. Robustness tests

A wide variety of robustness tests confirm the main result. First, when auction and bidder controls are omitted, the coefficient increases to −0.19 (Table 4 column 5). Therefore, these controls do not independently determine the result. Column 6 omits the county fixed effects. The result is essentially unchanged at −0.17. Clustering standard errors by state-month, in column 7, doubles the standard error of the triple interaction, but it remains significant at the 10% level. If there are unobserved firm-specific exposures, clustering by firm should render the main effect less significant. Firm-month clusters in column 8, and other alternative error assumptions in Appendix Table 4 columns 1–3, continue to find robust results.

Table 5 column 1 shows that there is no effect before the policy. Column 2 shows that there is no independent effect of being in Kansas after the policy; note the significant coefficient in other columns represents the relationship when oil price volatility is zero, which is never the case, and thus it does not have an economic interpretation. 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 3 shows that the effect is −0.13 excluding 2009. Column 4 shows robustness to excluding years after 2009. Placebo tests are in columns 5 and 6, where the policy implementation year is artificially set to 2004 or 2008. The sample is restricted to the narrow bandwidth approach from Table 4 column 3 of 2 years around the policy to avoid including periods before and after the actual policy. In both placebo tests, the interaction effect is insignificant.

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

Table 5
Robustness tests of marginal effect of oil price volatility on bids.

Dependent variable: Log bitumen bid					Placebo policy in	
					2004	2008
Sample:	Before policy	Full	No 2009	No post-2009	2002–06	2006–2010
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t} \cdot \ln Vol_t^{oil}$			−0.130***	−0.150***	0.096	−0.038
			(0.050)	(0.037)	0.092	0.073
$\mathbf{I}_{post\ \ policy_t} \cdot \ln Vol_t^{oil}$			0.830***	0.780***	−0.002	−0.019
			(0.060)	(0.047)	0.021	0.055
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t}$		−0.017	0.420**	0.450***	−0.094	0.090
		(0.016)	(0.160)	(0.130)	0.314	0.22
$\mathbf{I}_{Kansas_j} \cdot \ln Vol_t^{oil}$	−0.013		0.068**	0.009	−0.102	−0.009
	(0.032)		(0.029)	(0.032)	0.085	0.067
$\ln Vol_t^{oil}$	0.023***	0.052***	0.004	0.034**	−0.080***	0.108**
	(0.009)	(0.013)	(0.009)	(0.014)	0.018	0.029
$\mathbf{I}_{post\ \ policy_t}$		0.110***	−2.500***	−2.300***	0.411***	0.508***
		(0.032)	(0.180)	(0.150)	0.067	0.178
$\ln price_t^{oil}$	0.360***	0.055*	0.350***	0.290***	0.152***	−0.073
	(0.011)	(0.030)	(0.034)	(0.035)	0.049	0.047
Controls	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y
N	3532	6111	5554	5111	2445	2693
R^2	0.549	0.912	0.915	0.896	0.80	0.59

Note: This table reports regression estimates of Eq. (1). The triple interaction coefficient gives the effect of the risk transfer policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy. The dependent variable is the log bitumen item bid. Column 2 omits the triple interaction to show that there is no independent effect of being in Kansas after the policy. Columns 5–6 show results from creating a placebo policy in either 2004 or 2008, and including 2 years around the policy as in Table 4 column 3. Unreported controls are log total non-bitumen bid, log bitumen tons proposed, log paver miles to project, average total bid in the auction, an indicator for the state of the firm being Kansas, and the number of bidders. Standard errors clustered by firm. *** $p < .01$.

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 2. 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 3 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.

Individual effects are in Appendix Table 3 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 3 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 4 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 contribution, 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 (Section 6.2). The second uses the alternative risk measure to compare types of firms within a single regression (Section 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

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)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t} \cdot \ \ln Vol_t^{oil}$	−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 f.e.	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y
N	894	4991	3609	2254
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)
$\mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t} \cdot \ \ln Vol_t^{oil}$	−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 f.e.	Y	Y	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
N	633	4358	1584	3355	2795	1977	3498	2387
R^2	0.960	0.928	0.905	0.949	0.930	0.951	0.922	0.936

Note: This table reports regression estimates of Eq. (1). The triple interaction coefficient gives the effect of the risk transfer policy on an additional unit of historical oil price volatility in Kansas vs. Iowa after vs. before the policy. 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, an indicator for the state of the firm being Kansas, and the number of bidders. In Columns 2–4, 5–10, $\mathbf{I}_{SmallFirmi}$ is also a control. Standard errors clustered by firm. $^{***} p < .01$.

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 and 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 and Duffie, 1995; Breeden and Viswanathan, 2016).

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 and Vishny, 1986; Schulze et al., 2001; Bertrand and Schoar, 2006). If concentrated ownership contributes to the risk premium, family firms may 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 and Whited, 2007). Second, if distress costs are related to the value of insurance, as in Rampini and Viswanathan (2013), and Purnanandam (2008), firms with higher credit risk or less industry diversification should most benefit from the insurance policy.

6.2. Sample splits

In Table 6, panel 1, Eq. (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

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)
$\mathbf{I}_{X_j} \cdot \sqrt{wait_j} \cdot \ln Vol_t^{oil}$	−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)
$\sqrt{wait_j} \cdot \ln Vol_t^{oil}$	0.006	0.003	0.004	−0.013	−0.014
	(0.013)	(0.013)	(0.018)	(0.019)	(0.019)
$\mathbf{I}_{X_j} \cdot \ln Vol_t^{oil}$	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)
$\ln Vol_t^{oil}$	0.001	0.014	0.015	0.050	0.055
	(0.027)	(0.028)	(0.048)	(0.052)	(0.050)
$price_t^{oil}$	0.170***	0.170***	0.170***	0.170***	0.170***
	(0.035)	(0.038)	(0.037)	(0.041)	(0.041)
Controls	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y
N	4744	4054	4711	4029	4054
R^2	0.937	0.938	0.938	0.940	0.938

Note: This table reports estimates of the effect of the risk by firm type, where risk is measured as volatility interacted with the time between the auction and work start, using variations on Eq. (2). 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. *** $p < .01$.

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 and Moeller (2007) and Faccio et al. (2011) also find that well-diversified firms are less risk-averse. The diversification result is not driven by family owned firms (see Appendix Table 5 column 1). Finally, the result is larger for small firms than large firms using the revenue and employment measure (columns 11 and 12).

The main heterogeneity findings should translate to certain Kansas firms being relatively less sensitive to volatility after the policy. I therefore examine within-Kansas effects across firm types. Appendix Table 6 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 Eq. (2), where a firm characteristic is interacted with risk measured as $\sqrt{Wait_j} \cdot \ln Vol_t^{oil}$. 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).

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)
$\mathbf{I}_{X_j}\cdot\sqrt{wait_j}\cdot\ln Vol_t^{oil}$	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)
$\sqrt{wait_j}\cdot\ln Vol_t^{oil}$	−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)
$\mathbf{I}_{X_j}\cdot\ \ln Vol_t^{oil}$	−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)
$\ln Vol_t^{oil}$	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)
$price_t^{oil}$	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	Y	Y	Y	Y	Y	Y	Y	Y
Month-of-year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y	Y	Y	Y	Y
N	4582	4079	4007	4653	4660	4019	3624	3353
R^2	0.945	0.944	0.941	0.939	0.939	0.941	0.939	0.940

Note: This table reports estimates of the effect of the risk by firm type, where risk is measured as volatility interacted with the time between the auction and work start, using variations on Eq. (2). 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.*** $p < .01$.

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. The explanation of the market structure in Section 2.2 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 bargaining power to vary with risk, because the triple difference isolates the effect of risk. The relationship between firm size and the cost of risk is weak relative to other characteristics, making it unlikely that bargaining power alone explains the main results.

The interviews discussed in Section 2.2. indicated 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, this 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 and Harvey, 2006; Basu and Miffre, 2013), measure very low oil equity betas (Ahn and Kogan, 2012), and have found that oil prices behave close to a random walk (Alquist and 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.[13] This requires a performance bond, or "margin," which is marked-to-

[13] 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.

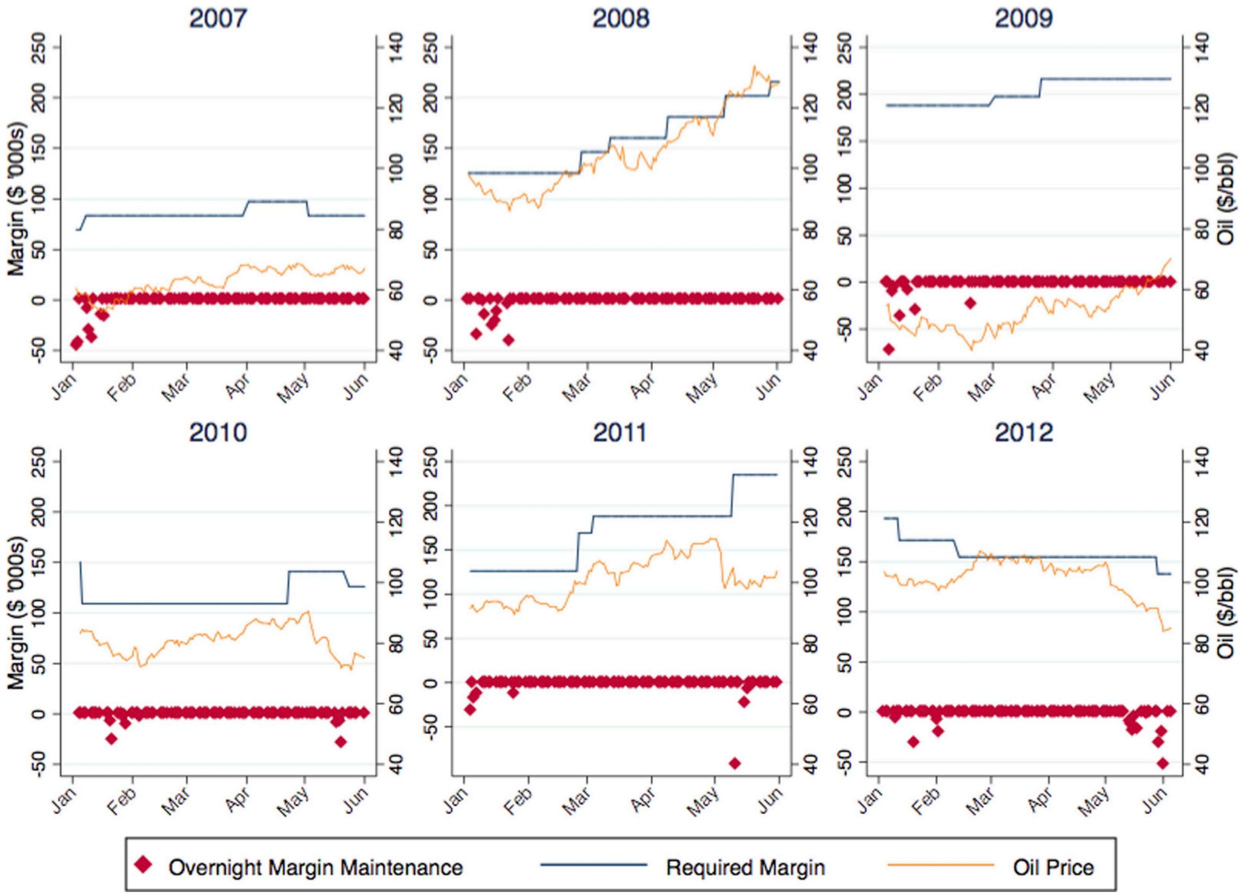

Fig. 8. Hypothetical margin requirements for hedging with oil futures.
Note: This figure shows the capital an average firm needs to hedge annual bitumen (purchase 16 6 month crude oil futures contracts in Jan., as auctions are usually in winter, work in summer). Overnight maintenance is the amount the firm needs to deposit overnight to maintain its margin.

market every day and changes with volatility.[14] 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. Fig. 8, using historical margin requirement data from CME, shows the results of this exercise. 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 h 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%, or 64% annualized given that the average time between the auction and work start is 4.7 months.[15] 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.

As mentioned above, the Kansas government did not hedge after the policy. If the state were to hedge, it could do so at low cost. Specifically, to hedge average annual statewide bitumen needs, Kansas would initially need $3.2 million in its margin account each year.[16] This amount is about one-fourth the annual savings from the insurance policy (see Section 7.3) Kansas has in recent decades

[14] 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.

[15] Four percent of the overall average bid of $318 is $12.7. With an initial margin account of $150,00 to hedge 2970 tons of bitumen with 16 oil futures contracts implies a 25% cost of capital $\left(\frac{1}{12.7}\cdot\frac{150{,}000}{2{,}970}\right)$.

[16] The assumptions are that the state buys 253 oil futures contracts, has a 10% margin, and that oil is at its post-policy average of $84 per barrel.

borrowed at less than 1%, which would make the cost of borrowing this amount $21,250 per year on average, or about 46 cents per ton of bitumen.[17] This calculation highlights the fact that all else equal, risk should be allocated to the party in a transaction with a lower cost of bearing it.

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 (Section 7.1), then assesses the effects on cost and competition, which is crucial to efficient government procurement (Section 7.2).

7.1. Empirical approach

A difference-in-differences design (Eq. (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.[18] 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 Eq. (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). Other variables are as defined in Eq. (2).

$$Cost_j = \alpha + \beta_1 \mathbf{I}_{Kansas_j} \cdot \mathbf{I}_{post\ \ policy_t} + \beta_2 \mathbf{I}_{post\ \ policy_t} + \gamma' \cdot controls_j + \delta_1 \mathbf{I}_{county_j} + \delta_2 \mathbf{I}_{year_j} + \delta_3 \mathbf{I}_{month_j} + \varepsilon_{jt}. \quad (3)$$

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. 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 9 column 2. The insurance policy increased the number of bidders in auctions by 0.800, relative to an average of 3.4. Appendix Table 8 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 9 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.[19] 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 Fig. 9, the bar heights indicate the win percentages by number of firms in each category of auction. Kurtosis and skewness both declined significantly after the insurance policy; the former from 4.9 to 3.0. This means that firm "winningness" was more evenly distributed across firms after the policy. The distributional changes are consistent with a more competitive market. There was little firm entry or exit.

Paving firms and bitumen suppliers are in oligopolistic, territorial equilibria. Appendix Figs. 9–12 show the location of auction wins and losses for five large bidders. Wins are concentrated in a portion of the state while losses predominate outside that territory. Other major bidders exhibit similar patterns. Spatial oligopoly is a natural result of high transportation costs; even with perfect competition rents would be zero on territory boundaries and positive within. In an interview, a CEO said that imperfect competition permits even very risk averse pavers to stay in business.

The bitumen suppliers form a second layer of imperfect competition. Like the paving firms, suppliers enjoy markups within their territories at least as large as the differential transportation cost for the next-closest supplier. Suppliers provide quotes to paving firms before each auction, and itemized bids are published immediately afterwards. In interviews, the suppliers suggested that recent

[17] 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 and 1% in early November 2015.

[18] The average increase was $7.5 per ton, with a standard deviation of $16 (across 1444 contracts).

[19] 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.

Table 9
Risk transfer 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)
$\mathbf{I}_{post\ \ policy_t}$	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 f.e.	Y	Y	Y	Y
Year f.e.	Y	Y	Y	Y
N	6111	1794	6324	5921
R^2	0.818	0.288	0.220	0.225

Note: This table reports estimates of the effect of the risk transfer policy in Kansas vs. Iowa after vs. before the policy, using variations on Eq. (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, and an indicator for the state of the firm being Kansas. The number of bidders is also included except in in column 2. Standard errors clustered by project. *** $p < .01$.

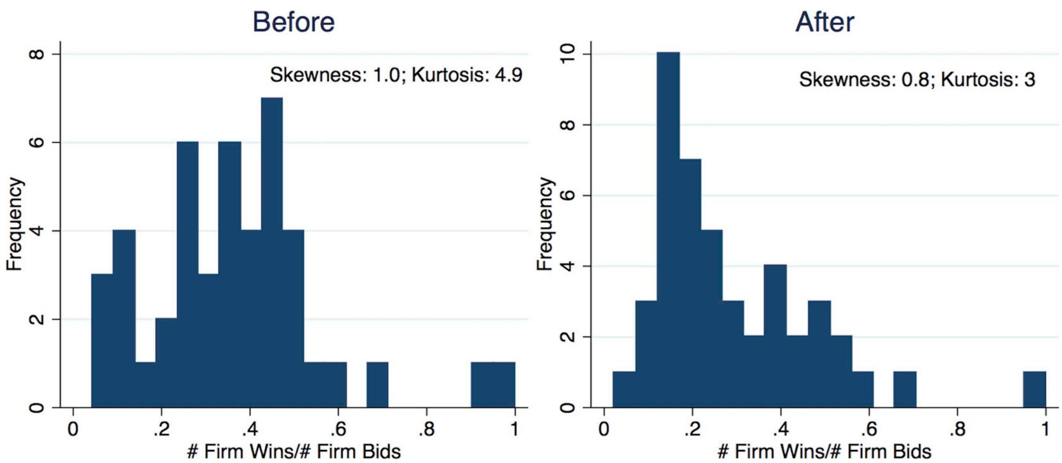

Fig. 9. Kansas win distribution around risk transfer policy.
Note: These figures show the frequency of of firms by win percentage. The changing distributions indicate that after the policy wins were more evenly spread across firms.

Table 10
Risk transfer policy effect on cost to kansas government.

Dependent variable: \$/ton to DOT								
	(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)
$\mathbf{I}_{post\ \ policy_t}$	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 f.e.	Y	Y	Y	Y	Y	Y	N	Y
Year f.e.	Y	Y	Y	Y	Y	Y	N	Y
N	1637	645	785	1637	1637	1637	1637	1637
R^2	0.804	0.654	0.685	0.804	0.804	0.791	0.776	0.819

Note: This table reports estimates of the effect of the risk transfer policy in Kansas vs. Iowa after vs. before the policy, using variations on Eq. (1) with data between 1998 and 2012, except where noted. Each observation is an auction. Column 1 is the main model. Column 2 restricts the sample to 2005–08, and Column 3 restricts the sample to 2004–9. Column 4 clusters standard errors by firm-month, and column 5 by state-month. Otherwise, they are robust. Column 6 omits controls. Column 7 omits fixed effects, and column 8 adds firm fixed effects. 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, an indicator for the state of the firm being Kansas, and the number of bidders. $^{***}\ p < .01$.

auctions might serve as a signaling mechanism, as in Friedman (1971).[20] The suppliers apparently charge the pavers a large fraction of, if not their full, cost of risk.

Thus this context features imperfect competition in two layers of product markets. It seems likely that imperfect competition compounds financial frictions to impede efficient risk allocation, allowing firms to pass high and heterogeneous insurance premiums to the consumer. Relatedly, Scharfstein and Sunderam (2013) find that imperfect competition in mortgage lending decreases the pass-through of lower mortgage-backed security yields to mortgage rates, vitiating government policies aimed at home buyers.

7.3. Effect of the policy on costs

Table 10 shows estimates of Eq. (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.[21]

Narrower bandwidths of 2 and 3 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 7 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 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 1 columns 1 and 2, show savings from the policy of \$49–\$54 per ton of bitumen, quite similar to the main specification.

It is important to emphasize that these estimates of the average policy effect on ex-post costs to the state are different objects from the marginal cost of additional risk estimated in Table 4. The average effect in Kansas should be substantially larger than the marginal effect holding competition constant and evaluated at the mean across the whole period. More importantly, the dependent variable in Table 10 is dollars per ton that DOT actually paid, after any price adjustments. In contrast, the dependent variable in Table 4 is the log bitumen bid before any adjustments. While the goal of Table 4 is to estimate the cost of risk to the paver, the goal of Table 10 is to estimate the cost of risk to the state, after insuring pavers.

[20] 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.”

[21] Interviews led to the following estimates. The insurance policy requires a \$5295 per year subscription to Poten & Partner's bitumen price index, and about 1 h of employee time per project. There were 166 projects post-policy. I assume employee time is valued at \$30/h in real terms between 2006 and 2012.

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 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. 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.

Acknowledgements

I am grateful for comments at the NBER Corporate Finance Meeting, the Western Finance Association Conference, the IDC Herzliya Eagle Labs Conference, the University of Michigan Ross School of Business, the Tsinghua PBC School of Finance, and the NYU Solomon Center Five Star Conference, as well as from many individuals including Joseph E. Aldy, Yakov Amihud, Jean-Noel Barrot, Douglas Cumming, Erik Gilje, Gary Gorton, Ryan Kellogg, Josh Lerner, Jonathan Levin, Arik Levinson, Gregory Lewis, Ariel Pakes, Thomas Philippon, Robert Pindyck, Adriano Rampini, David Scharfstein, Tom Wollman, and anonymous referees. I also thank the Iowa and Kansas Departments of Transportation, as well as Jun Wong for excellent research assistance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcorpfin.2020.101691.

References

Acharya, V., Xu, Z., 2017. Financial dependence and innovation: the case of public versus private firms. J. Financ. Econ. 124 (2), 223–243.
Acharya, V.V., Almeida, H., Campello, M., 2007. Is cash negative debt? A hedging perspective on corporate financial policies. J. Financ. Intermed. 16 (4), 515–554.
Ahn, D.P., Kogan, L., 2012. Crude or Re Fined: Identifying Oil Price Dynamics through the Crack Spread. SSRN Working Paper Series.
Alquist, R., Kilian, L., 2010. What do we learn from the price of crude oil futures? J. Appl. Econ. 25 (4), 539–573.
Bajari, P., Ye, L., 2003. Deciding between competition and collusion. Rev. Econ. Stat. 85 (4), 971–989.
Basu, D., Miffre, J., 2013. Capturing the risk premium of commodity futures: the role of hedging pressure. J. Bank. Financ. 37 (7), 2652–2664.
Bertrand, M., Schoar, A., 2006. The role of family in family firms. J. Econ. Perspect. 20 (2), 73–96.
BIS, 2015. Interest Rate Risk in the Banking Book. Consultative Document. Technical report. Bank for International Settlements.
Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. J. Polit. Econ. 637–654.
Bolton, P., Chen, H., Wang, N., 2011. A unified theory of tobin's q, corporate investment, financing, and risk management. J. Financ. 66 (5), 1545–1578.
Brav, O., 2009. Access to capital, capital structure, and the funding of the firm. J. Financ. 64 (1), 263–308.
Breeden, D.T., Viswanathan, S., 2016. Why do firms hedge? An asymmetric information model. J. Fixed Income 25 (3), 7–25.
Campa, J.M., Goldberg, L.S., 2005. Exchange rate pass-through into import prices. Rev. Econ. Stat. 87 (4), 679–690.
Campello, M., Lin, C., Ma, Y., Zou, H., 2011. The real and financial implications of corporate hedging. J. Financ. 66 (5), 1615–1647.
CBO, 2011. Spending and Funding for Highways. Technical report. Congressional Budget Office.
Cernat, L., Kutlina, Z., 2015. International Public Procurement: From Scant Facts to Hard Data. Technical report. European Commission, Chief Economist Note.
Chen, J., King, T.-H.D., 2014. Corporate hedging and the cost of debt. J. Corp. Finan. 29, 221–245.
Cheng, I.-H., Xiong, W., 2014. Why do hedgers trade so much? J. Leg. Stud. 43 (3), 8.
Cornaggia, J., 2013. Does risk management matter? Evidence from the us agricultural industry. J. Financ. Econ. 109 (2), 419–440.
Cumming, D., Li, D., 2013. Public policy, entrepreneurship, and venture capital in the United States. J. Corp. Finan. 23, 345–367.
DeMarzo, P.M., Duffie, D., 1995. Corporate incentives for hedging and hedge accounting. Rev. Financ. Stud. 8 (3), 743–771.
Erb, C.B., Harvey, C.R., 2006. The strategic and tactical value of commodity futures. Financ. Anal. J. 62 (2), 69–97.
Faccio, M., Marchica, M.-T., Mura, R., 2011. Large shareholder diversification and corporate risk-taking. Rev. Financ. Stud. 24 (11), 3601–3641.
Fama, E.F., Jensen, M.C., 1983. Separation of ownership and control. J. Law Econ. 26 (2), 301–325.
Friedman, J.W., 1971. A non-cooperative equilibrium for supergames. Rev. Econ. Stud. 38 (1), 1–12.
Froot, K.A., Scharfstein, D.S., Stein, J.C., 1993. Risk management: coordinating corporate investment and financing policies. J. Financ. 48 (5), 1629–1658.
Gao, H., Harford, J., Li, K., 2013. Determinants of corporate cash policy: insights from private firms. J. Financ. Econ. 109 (3), 623–639.
Géczy, C., Minton, B.A., Schrand, C., 1997. 'Why firms use currency derivatives. J. Financ. 52 (4), 1323–1354.
Gilje, E.P., Taillard, J.P., 2017. Does hedging affect firm value? Evidence from a natural experiment. Rev. Financ. Stud. 30 (12), 4083–4132.
Haushalter, G.D., 2000. Financing policy, basis risk, and corporate hedging: evidence from oil and gas producers. J. Financ. 55 (1), 107–152.
Hennessy, C.A., Whited, T.M., 2007. How costly is external financing? Evidence from a structural estimation. J. Financ. 62 (4), 1705–1745.
Kellogg, R., 2014. The effect of uncertainty on investment: evidence from Texas oil drilling. Am. Econ. Rev. 104 (6), 1698–1734.
Kim, Y.S., Mathur, I., Nam, J., 2006. Is operational hedging a substitute for or a complement to financial hedging? J. Corp. Finan. 12 (4), 834–853.

Kobe, K., 2012. Small Business Gdp: Update 2002–2010. Technical report. Small Business Administration.
Kosmopoulou, G., Zhou, X., 2014. Price adjustment policies in procurement contracting: an analysis of bidding behavior. J. Ind. Econ. 62 (1), 77–112.
Kumar, P., Rabinovitch, R., 2013. Ceo entrenchment and corporate hedging: evidence from the oil and gas industry. J. Financ. Quant. Anal. 48 (03), 887–917.
Lin, H., Paravisini, D., 2013. The effect of financing constraints on risk. Rev. Finan. 17 (1), 229–259.
Lin, C., Lin, P., Zou, H., 2012. Does property rights protection affect corporate risk management strategy? Intra-and cross-country evidence. J. Corp. Finan. 18 (2), 311–330.
MacKay, P., Moeller, S.B., 2007. The value of corporate risk management. J. Financ. 62 (3), 1379–1419.
Michaely, R., Roberts, M.R., 2012. Corporate dividend policies: lessons from private firms. Rev. Financ. Stud. 25 (3), 711–746.
Nance, D.R., Smith, C.W., Smithson, C.W., 1993. On the determinants of corporate hedging. J. Financ. 48 (1), 267–284.
Pérez-González, F., Yun, H., 2013. Risk management and firm value: evidence from weather derivatives. J. Financ. 68 (5), 2143–2176.
Pesendorfer, M., 2000. A study of collusion in first-price auctions. Rev. Econ. Stud. 67 (3), 381–411.
Porter, R.H., 2005. Detecting collusion. Rev. Ind. Organ. 26 (2), 147–167.
Porter, R., Zona, J., 1993. Detection of bid rigging in procurement auctions. J. Polit. Econ. 101 (3), 518–538.
Purnanandam, A., 2008. Financial distress and corporate risk management: theory and evidence. J. Financ. Econ. 87 (3), 706–739.
Rampini, A.A., Viswanathan, S., 2010. Collateral, risk management, and the distribution of debt capacity. J. Financ. 65 (6), 2293–2322.
Rampini, A.A., Viswanathan, S., 2013. Collateral and capital structure. J. Financ. Econ. 109 (2), 466–492.
Rampini, A.A., Sufi, A., Viswanathan, S., 2014. Dynamic risk management. J. Financ. Econ. 111 (2), 271–296.
Scharfstein, D.S., Sunderam, A., 2013. Concentration in Mortgage Lending, Refinancing Activity and Mortgage Rates. Technical report. National Bureau of Economic Research.
Schulze, W.S., Lubatkin, M.H., Dino, R.N., Buchholtz, A.K., 2001. Agency relationships in family firms: theory and evidence. Organ. Sci. 12 (2), 99–116.
Shaad, J., 2006. Asphalt price indexes smooth process for road project bids'. Kansas City Business Journal.
Shleifer, A., Vishny, R.W., 1986. Large shareholders and corporate control. J. Polit. Econ. 461–488.
Skolnik, J., 2011. Price Indexing in Transportation Construction Contracts. Technical report. Jack Faucett Associates, in Association with Oman Systems.
Stulz, R.M., 1996. Rethinking risk management. Journal of applied corporate finance 9 (3), 8–25.
USDOT, 1980. Development and Use of Price Adjustment Contract Provisions, Technical Report. U.S. Department of Transportation Federal Highway Administration.
Weyl, E.G., Fabinger, M., 2013. Pass-through as an economic tool: principles of incidence under imperfect competition. J. Polit. Econ. 121 (3), 528–583.