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VERMONT AGENCY OF TRANSPORTATION

Materials & Research Section
Research Report

RENEGOTIATION OF HIGHWAY CONSTRUCTION CONTRACTS: AN ECONOMIC ANALYSIS OF CHANGE ORDERS ISSUED BY THE VERMONT AGENCY OF TRANSPORTATION, 2004-2009

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AGENCY OF TRANSPORTATION

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16. Abstract

We provide a complete report of our research on change orders and strategic bidding in Vermont over the period 2004-2009. Our investigation provides the Vermont Agency of Transportation with a quantitative view of the scope of change orders, and their statistical determinants during this period.

In part one of the report we provide descriptive statistics and figures on the pattern of change orders on Vermont transportation projects. In part two of the report we provide econometric analysis of change orders and bidding behavior. Our econometric model focuses on three groups of factors: (1) the characteristics of the project (type of construction and items required), (2) the characteristics of the economic environment (e.g., fuel price volatility, macroeconomic conditions), and (3) bidding environment (the number of characteristics of bidding firms) and strategic interactions. Our analysis lends support to the hypothesis that bidders act strategically to take into account the possibility of renegotiation when they submit bids. We model several important strategic considerations in the analysis of number and size of change orders. In part three we perform simulation exercises to evaluate whether alternative policies can reduce costs to the public. Finally, we link specific behavior to strategic manipulation of bids in the face of renegotiation and propose ways to avoid higher costs.

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EXECUTIVE SUMMARY

We provide a complete report of our research on change orders and strategic bidding in Vermont over the period 2004-2009. Our investigation provides the Vermont Agency of Transportation with a quantitative view of the scope of change orders, and their statistical determinants during this period.

Over eighty percent of highway and bridge projects have change orders. On average, change orders increase the costs of a project by eight percent, but in many cases the cost increase can be significantly higher. Change orders are not distributed evenly either across firms or items. In particular, we estimate that the probability that Vermont's top construction firms will submit change orders on a project that they win is 20 percentage points higher than that of other firms. In terms of items, change orders appear most frequently for asphalt and fuel price adjustments, pavement, steel and flaggers/traffic control. In addition, we estimate that change orders are more likely to occur in more large, complex projects than in smaller, simpler ones.

The evidence strongly suggests that contractors correctly anticipate Items that will later be subject to change orders, and adjust their bids accordingly. In particular, firms often use strategic bidding practices, bidding more aggressively in an auction to increase the probability of winning, and later recovering their foregone profits by frequently claiming change orders. The strategic bidding most often takes the form high bid prices on items later subject to a positive quantity adjustment, and lower prices on items that will be subject to negative quantity adjustments. Items that are the most frequently renegotiated have bids 7.5% higher, on average, than those that are not subject to change orders.

In accordance with these findings, we recommend that the Agency consider implementation of a reserve-price rule, either for the bid or on particular items we identified in the study. In addition, we recommend adopting smaller, simpler projects when feasible and examining the possibility of expanding usage of the design-build approach to contracting.

Additional important findings are that increasing competition could yield substantial financial savings. We estimate that for every additional bidder, project bids of all firms decline on average by nearly two percent. We recommend a number of possible initiatives for increasing competition. Also, there are potentially large rewards available from adjusting the timing of the Agency's construction program in response to overall business activity. We found that a one percentage point increase in the unemployment rate is associated with four percent lower bids.

While there is no magic bullet that will address the problem of change orders, the evidence we found suggests that the combined effect of our recommendations could have a major impact on cost-savings and improved contractual performance.

Finally, we specify several possible directions for future research that could yield substantial cost-savings. In particular, further investigation would yield more precise understanding of how the fuel and asphalt price adjustment mechanisms could be altered in a manner to maximize cost-savings. Additionally, study of firm performance during the recovery from Tropical Storm Irene would yield recommendations about how the Agency might pursue new strategies to foster greater competition in project bids.

INTRODUCTION

We provide a complete report of our research on change orders and strategic bidding in Vermont over the period 2004-2009. Our investigation provides the Vermont Agency of Transportation with a quantitative view of the scope of change orders, and their statistical determinants during this period.

In part one of the report we provide descriptive statistics and figures on the pattern of change orders on Vermont transportation projects. In part two of the report we provide econometric analysis of change orders and bidding behavior. Our econometric model focuses on three groups of factors: (1) the characteristics of the project (type of construction and items required), (2) the characteristics of the economic environment (e.g., fuel price volatility, macroeconomic conditions), and (3) bidding environment (the number of characteristics of bidding firms) and strategic interactions. Our analysis lends support to the hypothesis that bidders act strategically to take into account the possibility of renegotiation when they submit bids. We model several important strategic considerations in the analysis of number and size of change orders. In part three we perform simulation exercises to evaluate whether alternative policies can reduce costs to the public. Finally, we link specific behavior to strategic manipulation of bids in the face of renegotiation and propose ways to avoid higher costs.

AN OVERVIEW OF CHANGE ORDERS ON VERMONT TRANSPORTATION CONTRACTS

We first examined the incidence of change orders on different types of projects. The following table shows that both bridge and highway projects have a high occurrence of change orders (85.47% vs. 81.10%). Bridge projects have higher frequency of supplemental agreements and special provisions while highway projects have a significant number of price adjustments.

Table 1: Project Description

Projects types	Number of contracts	Projects with Change Orders (CO)	Relative Frequency of CO	Supplemental Agreements	Special Provisions	Price Adjustment Clauses
Highway	164	133	81.10	97	72	100
Bridge	117	100	85.47	67	53	27
All other projects	31	23	74.19	15	13	6

Next we examine some of the key variables that both theory and intuition suggest should be related to the incidence of both bidding behavior and change orders over the 312 projects undertaken between May 2004 and December 2009. These include the number of bidders and the number of pre-qualified plan-holders, as indicators of competition and potential competition. Any firm could become a plan-holder by purchasing the plans for a project, but only pre-qualified firms are able to bid on the project[1]. The complexity of the project is defined as the number of different items in the contract. We use relative bids (RB=bid/engineering cost estimate) to measure bidding

[1] Prequalification status is achieved by the successful completion of two procedures:(1) annual prequalification: the prequalification committee at VTrans annually assign for each firm the certain limitations of value of projects and number contracts allowed to bid; (2) contract prequalification: the process to obtain permission to submit a bid for a particular contract for a contractor who already obtained annual prequalification. See the Vermont Agency of Transportation Policies and Procedures on prequalification, bidding, and award of contracts for more details.

aggressiveness. We restrict attention to project bids. On average firms bid 9.9% above the engineering cost estimate (RB=1.099) while they win with bids that are 2.3% below the engineering cost estimate (RWB=0.977). The final relative payment amount after the change orders occur is 5.6% above the engineering cost estimate. In other words, on average winning bidders negotiate a 7.9% (2.3+5.6) increase in payment relative to the winning bid.

Table 2: Descriptive Statistics - All contracts

Variable	Observations	Mean	Std. Dev.	Min	Max
Bidders (per contract)	312	3.349	1.958	1.000	11.000
Plan-holder (per contract)	312	5.026	3.163	1.000	16.000
Complexity (# of distinct items per contract)	312	60.228	35.346	2.000	245.000
Bidding amount	1043	$1,811,988	$2,597,417	$24,952	$31,700,000
CO amount	256	$173,582	$323,097	$-116,848	$2,331,255
Relative bid (bid/engineering cost estimate - before COs)	1043	1.099	0.282	0.436	2.998
Winning bid amount	312	$1,805,793	$2,260,423	$24,952	$22,000,000
Engineering cost estimate of the winning contract	312	$1,910,227	$2,431,891	$26,224	$24,600,000
Relative winning bid (before COs)	256	0.977	0.190	0.436	1.564
Relative payment amount (After COs)	256	1.056	0.228	0.532	2.014

Note: We calculate the total engineering cost estimate for each awarded contract by summing up the engineering cost estimates for all pay items in the contract. We should note that each bidder might select different optional items on a contract, and therefore each bidder might have a different total engineering cost estimate. We named the engineering cost estimate as "engineering cost estimate of the winning contract" because we are interested in winners' relative bids, which are the winners' bids divided by engineering cost estimates.

We now compare the behavior of these variables in highway and bridge projects. Highway projects have a smaller number of bidders and a larger average size relative to bridge projects. Overall, relative bids may be higher in bridgework and more dispersed but relative winning bids and payments have a similar relative magnitude between bridge and highway projects.

Table 3

Highway					
Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Bidders (per contract)	164	2.659	1.591	1.000	11.000
Plan-holder (per contract)	164	3.543	2.470	1.000	15.000
Complexity (# of distinct items per contract)	164	61.524	38.240	4.000	245.000
Bidding amount	435	$2,392,316	$3,654,486	$24,952	$31,700,000
CO amount	133	$264,888	$403,029	$-116,848	$2,331,255
Relative bid (bid/engineering cost estimate - before COs)	435	1.072	0.261	0.616	2.339
Winning bid amount	164	$2,323,888	$2,797,889	$24,952	$22,000,000
Engineering cost estimate of the winning contract	164	$2,473,540	$3,043,610	$26,224	$24,600,000
Relative winning bid (before COs)	133	0.980	0.180	0.616	1.564
Relative payment amount (After COs)	133	1.073	0.212	0.627	1.704

Bridge					
Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Bidders (per contract)	117	4.256	1.939	1.000	11.000
Plan-holder (per contract)	117	7.051	2.612	3.000	14.000
Complexity (# of distinct items per contract)	117	65.265	30.462	10.000	168.000
Bidding amount	497	$1,521,074	$1,279,785	$117,106	$9,306,707
CO amount	100	$86,045	$167,297	$-34,780	$1,161,600
Relative bid (bid/engineering cost estimate - before COs)	497	1.132	0.294	0.436	2.998
Winning bid amount	117	$1,352,446	$1,207,567	$117,106	$8,043,261
Engineering cost estimate of the winning contract	117	$1,396,333	$1,73,448	$102,196	$6,186,681
Relative winning bid (before COs)	100	0.985	0.200	0.436	1.397
Relative payment amount (After COs)	100	1.054	0.251	0.532	2.014

Next we examine the behavior of the main firms serving the Vermont market during this period of time. A key variable here is "Money Left on the Table" (MLT) which results from the difference between the winning bid and the bid of the second lowest bidder. We measure MLT as the proportional difference between the winning and the second lowest bid when there are multiple bidders. In the case of a single bidder, the money left of the table is constructed as the proportional difference between the winning bid and the engineering cost estimate. The weighted MLT is the average money left on the table per bidder weighted by the engineering cost estimate of each project won. We would expect that a larger weighted value of the MLT would be associated with higher tendency to submit change orders. This is because a firm may bid aggressively to win a contract, leaving a large amount of surplus on the table, and then try to renegotiate to regain part of its lost surplus. Money left on the table is often related to the size of the contract and other characteristics of the competitive environment that have not been captured in the table. The empirical analysis that follows controls for those factors. Without taking into account the nature of the projects most frequently undertaken, the following table suggests that the proportion of renegotiated value varies significantly across firms ranging from 0.12-11.37%. The table also shows that the firms face somewhat different competitive environments on the projects where they tend to bid. For example, one of the leading paving contractors faces an average of only 2.1 competing bids, and fares less well when they face greater competition. Whereas another leading paving contractor faces 5.92 competing bids on average and its tendency to win seems not to depend upon the number of competitors. Lastly, it should be noted that for most of these firms revenue from change orders constitutes over five percent of the payout on the contract, and in some cases significantly more.

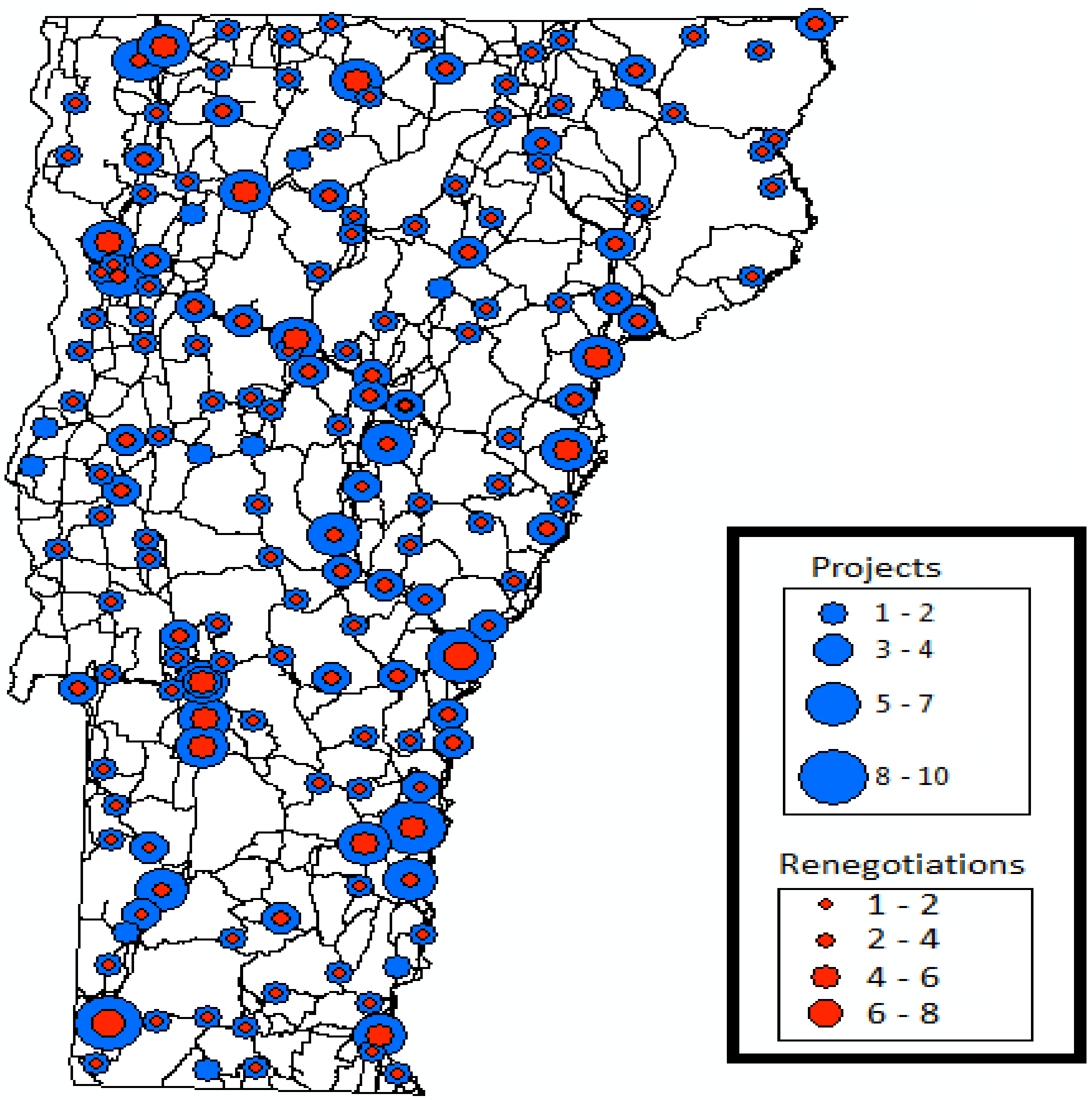
Table 4: Bidding and renegotiation activities of Top 17 firms (out of 93)

Firm Name	No. of wins	Winning %	Avg. no. of competing bids on contracts won	Avg. no. of competing bids on contracts not won	No. of contracts renegotiated	Total value of winning projects	Average value of a project won	Weighted MLT	Final CO value/Total value of projects
PIKE INDUSTRIES, INC.	71	53.38	2.21	3.65	65	$218,500,000	$3,078,018	4.46	1.085
FRANK W. WHITCOMB CONSTRUCTION CORP	33	33.33	2.79	4.05	30	$74,182,288	$2,247,948	8.2	1.114
MILLER CONSTRUCTION INC.	12	32.43	5.92	5.92	10	$14,690,565	$1,224,214	6.96	1.091
F. R. LAFAYETTE INC.	12	80.00	1.92	3.33	7	$10,237,325	$853,110	18.40	1.014
BLOW & COTE,INC.	11	19.30	3.36	5.07	9	$9,994,845	$908,622	5.62	1.054
WINTERSET, INC.	9	15.52	4.11	5.04	9	$22,473,674	$2,497,075	4.20	1.028
J. A. MCDONALD,INC.	9	27.27	4.11	5.96	8	$61,679,812	$6,853,313	9.11	1.046
KUBRICKY CONSTRUCTION CORP.	8	22.22	3.00	3.93	7	$20,416,936	$2,552,117	12.71	1.059
THE LANE CONSTRUCTION CORP.	8	36.36	3.38	4.00	6	$30,248,672	$3,781,084	7.01	1.096

RENAUD BROS.,INC.	8	40.00	4.50	5.92	8	$10,826,341	$1,353,293	11.72	1.036
A.L.ST.ONGE CONTRACTOR,INC.	8	47.06	3.50	6.11	8	$11,890,640	$1,486,330	8.32	1.036
ALPINE CONSTRUCTION, LLC	7	25.93	3.71	5.10	7	$5,989,031	$855,576	14.45	1.097
CCS CONSTRUCTORS LLC	6	14.63	3.50	4.80	6	$8,351,862	$1,391,977	27.67	1.043
NICOM COATINGS CORP	6	75.00	2.67	3.50	3	$2,328,567	$388,095	16.99	1.102
TREMBLAY CONSTRUCTION, LLC	6	46.15	6.67	8.43	3	$3,057,319	$509,553	2.18	0.995
EAST COAST SIGNALS,INC.	5	83.33	2.40	3.00	2	$576,040	$115,208	10.98	1.001
THE GORMAN GROUP, LLC	5	62.50	2.00	1.67	5	$5,997,489	$1,199,497	16.51	1.046

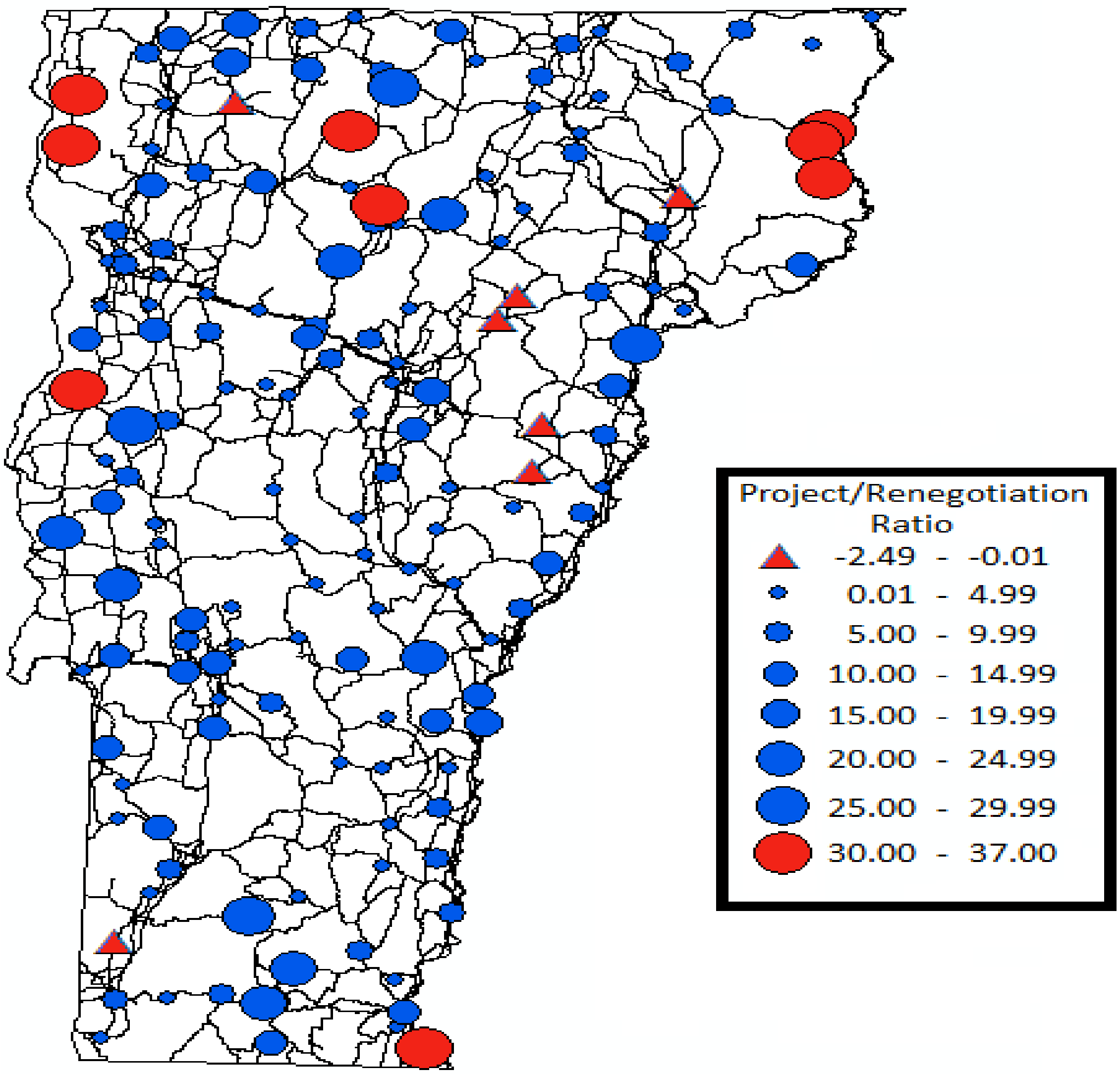
We also examined the geographic dispersion of projects and change orders during our sample period, 2004-2009. In Map 1 we display the geographic distribution of projects and change orders across the state.

Map 1



The map shows that both projects and change orders are dispersed widely across the state, with a slightly smaller than average proportion of projects subject to change orders in Windsor County, and a somewhat larger than average proportion of projects with change orders in Rutland, Caledonia, Essex and Lamoille. Map 2 displays the ratio of the cost of the change orders to overall project costs.

Map 2



The costliest change orders, in a proportional sense, have occurred to an unusual degree in certain locations in Essex and Grand Isle Counties. In the econometric analysis below, we highlight characteristics of projects and contractors that contribute to this geographic spread.

In Table 5 we show the frequency of change orders for a number of important items. The information in this table can be used in the following way. For example, item 630.15 (flaggers) was subject to change orders approximately on twenty percent of contracts [54 / (208+54)]. When change orders were involved, they averaged 56.38% of the final pay amount on that item. The final pay amount on flaggers averaged 2.47% of the contract payment, so change orders on flaggers were responsible for about 1.24% of the total payout on the contract. Items subject to price adjustment clauses are noted in the table. Note that we display the data on the frequency at which items were renegotiated in Vermont transportation contracts over our sample period in Appendix. Appendix 1A displays the items most frequently subject to change orders. A substantial number of these change orders were due to price adjustments, either for fuel or asphalt cement. Other items that appear frequently include pavement, steel and labor (flaggers and traffic control). Appendix 1B shows the very large number of items that were never subject to a change order during the period of analysis.

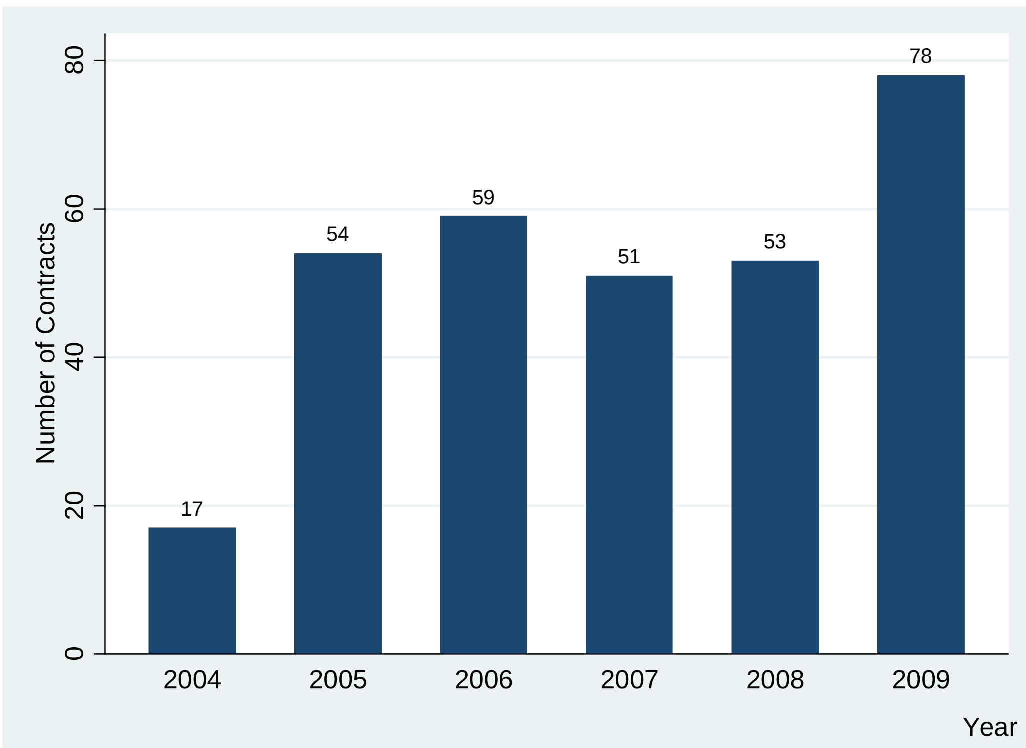
Table 5: Frequency of Change Orders and Their Financial Importance

Item NO.	#Contracts with Change orders on this Item	#Contracts Without Change Orders on this Item	Change Order Item Amount / Final Item Payment (%)	Final Item Payment / Final Contract Payment (%)
630.15	54	208	56.38	2.47
490.30***	46	42	2.53	33.55
406.50	39	87	100	3.98
404.65**	32	181	17.16	0.54
406.25***	30	53	4.96	13.76
630.10	28	202	28.19	2.34
507.15	28	90	8.35	1.18
690.50	27	79	100	1.68
210.10*	22	178	26.55	5.16
501.34*	21	74	-2.40	9.46
204.30*	21	102	11.01	1.21
301.35*	20	53	25.18	3.52
203.15*	20	165	22.32	2.98
649.31	16	153	20.69	0.53
608.25	16	163	36.42	0.51
621.90	15	58	29.88	1.80
613.11*	15	62	42.40	3.16
613.10*	15	161	39.89	0.99
675.20	14	198	38.55	1.03
514.10	14	99	6.96	0.18
204.20	14	128	28.25	0.45
646.41	13	55	-17.08	0.94
506.60	13	18	9.51	15.67
635.11	12	286	19.28	5.77
646.40	11	54	-10.95	0.64
621.20*	11	99	7.09	6.77
675.50	10	198	24.40	0.64
646.85	10	58	67.05	0.81
646.21	10	44	69.03	0.21
641.10	9	278	-11.08	2.99

Notes: "*" indicates that the item is eligible pay item according to the fuel price adjustment clause. "**" indicates that the item is eligible pay item according to the asphalt price adjustment clause. "***" indicates that the item is eligible pay item under both the fuel price adjustment and Asphalt price adjustment clauses.

In the following figures we describe some basic features of the project and bid data set. The frequency of projects over time is illustrated in Figure 1. With the exception of the partial year (2004) and the year subject to stimulus spending (2009), the number of projects is fairly evenly distributed across time. Figure 2 shows that the mean value of a contract ranged from $1.6 million in 2006 to over $2.8 million in 2004. As depicted in Figure 3, most contracts have 2-4 bidders but as Figure 4 shows contracts typically have many more plan holders. Some of those plan holders are undoubtedly firms considering making a bid.

Figure 1: Frequency of projects across time



Note: For 2004 we have only the number of contracts auctioned off between May-December.

Figure 2: Average value of a contract by year (millions of dollars)

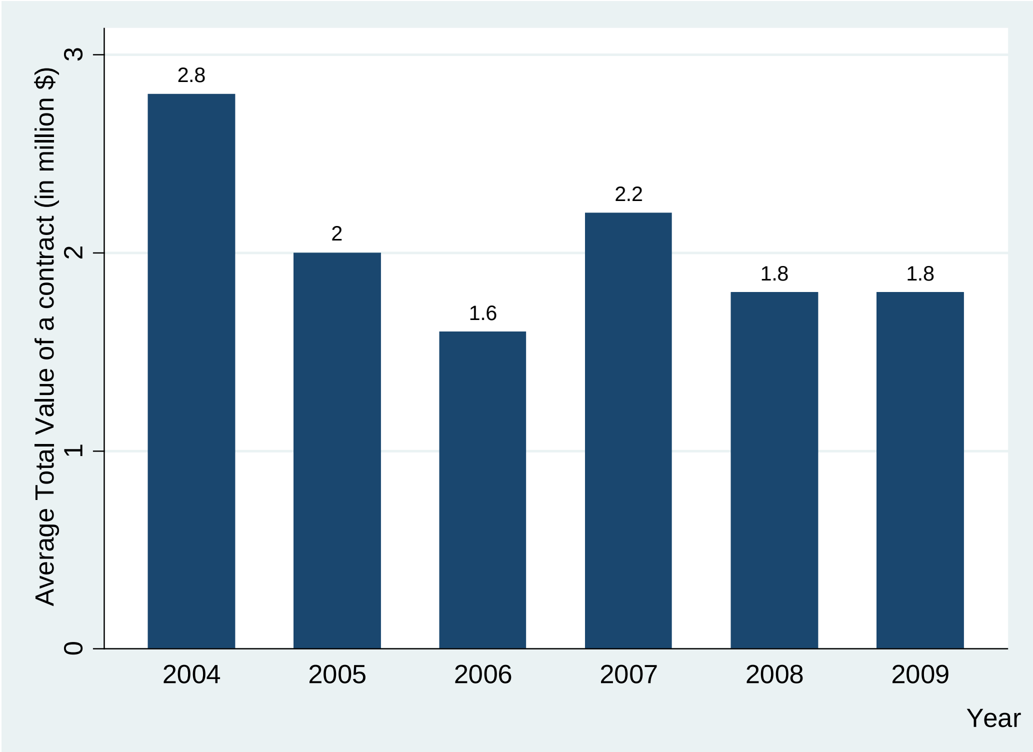


Figure 3: Number of bidders per contract

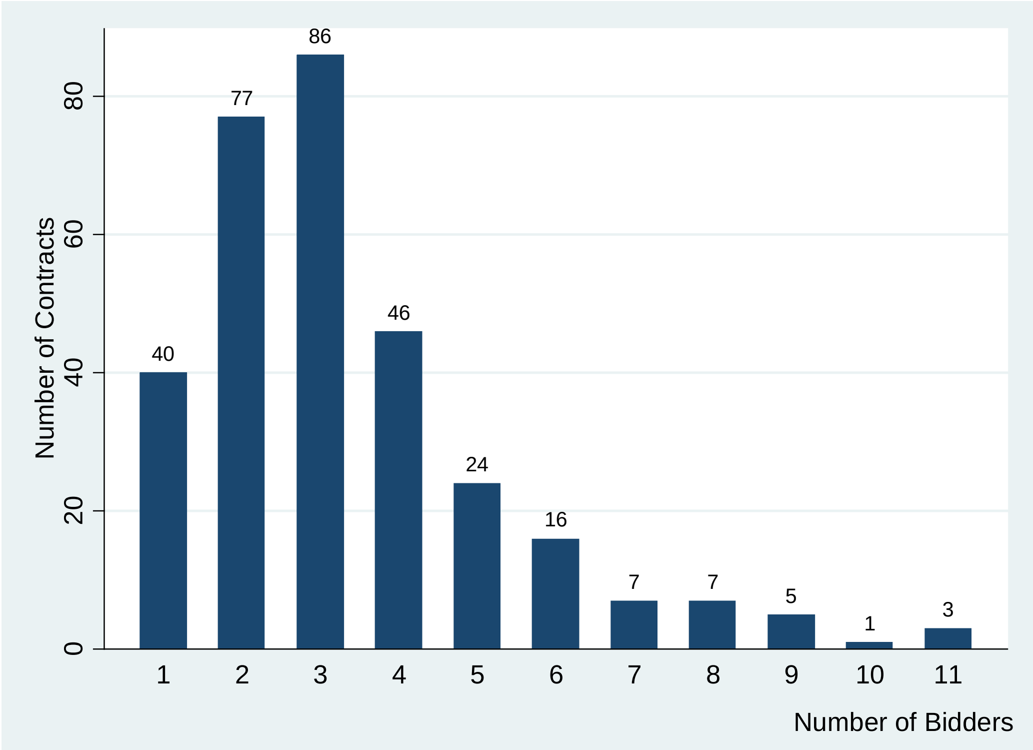
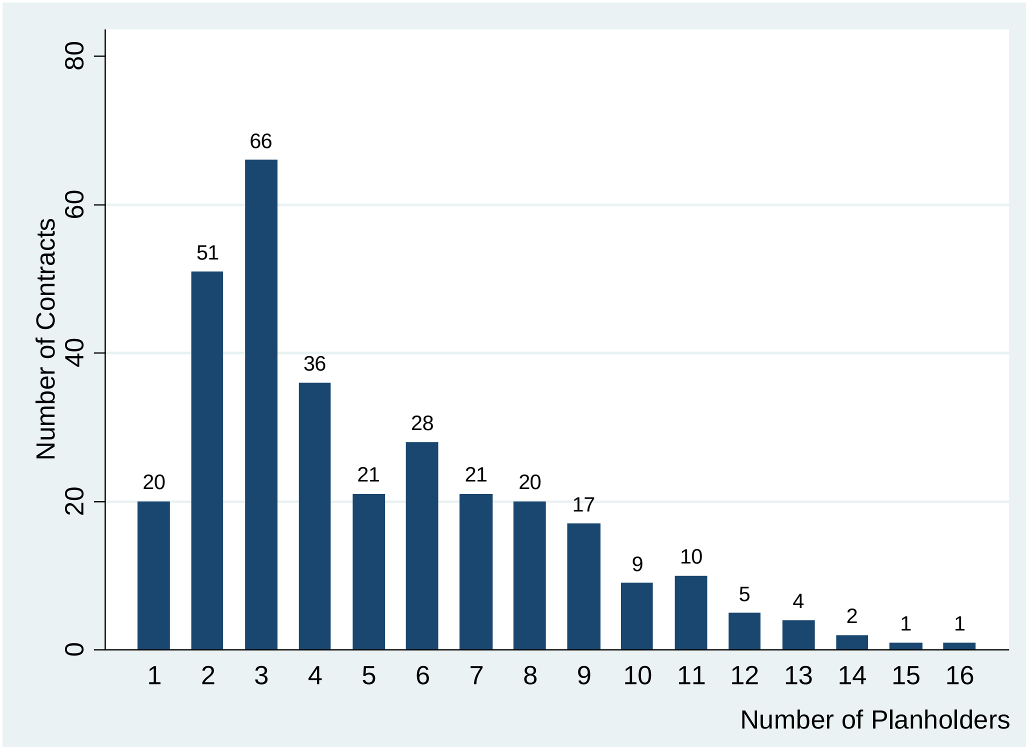


Figure 4: Number of plan-holders per contract

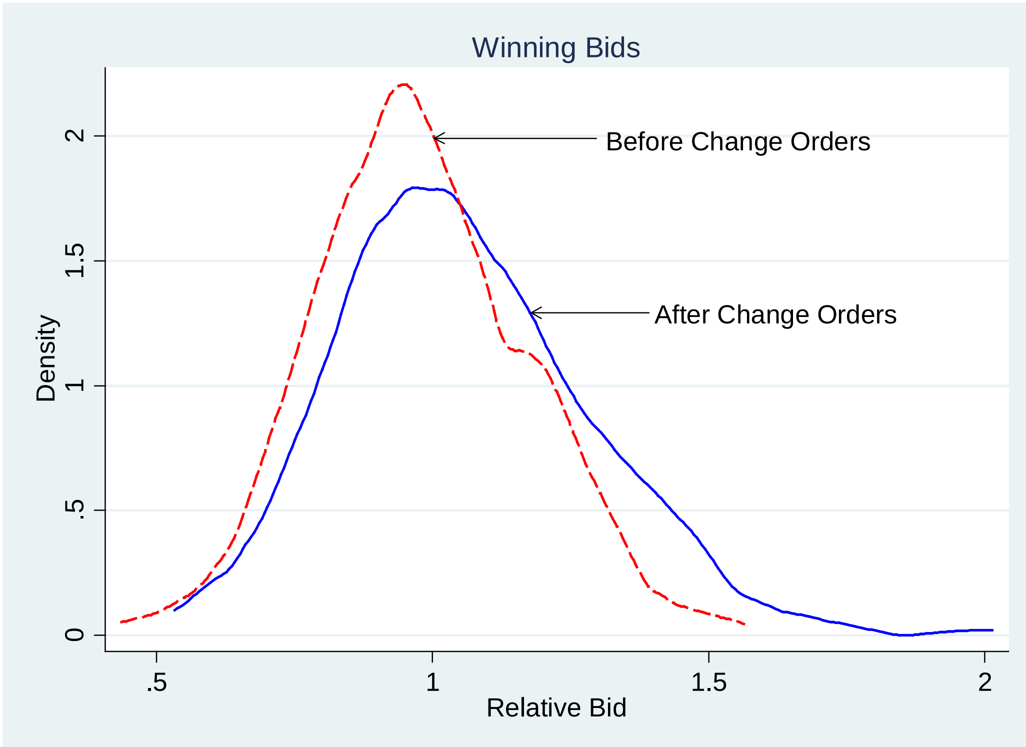


The following set of graphs present kernel density plots of relative winning bids. Relative winning bids are bids that are normalized by the engineering cost estimates. Kernel densities are closely related to histograms. They present estimates of the distribution of relative bids revealing information on the likelihood to observe a range of values for relative bids.

Figure 5 illustrates one of the basic results of the analysis, that change orders tend to increase costs by about 8% compared to the winning bid. This is visible by the shifting to the right of the distribution. It should be noted that there is greater variance in post-change order costs than pre-change order relative bids, indicating that change orders carry with them a risk of high cost outcome.

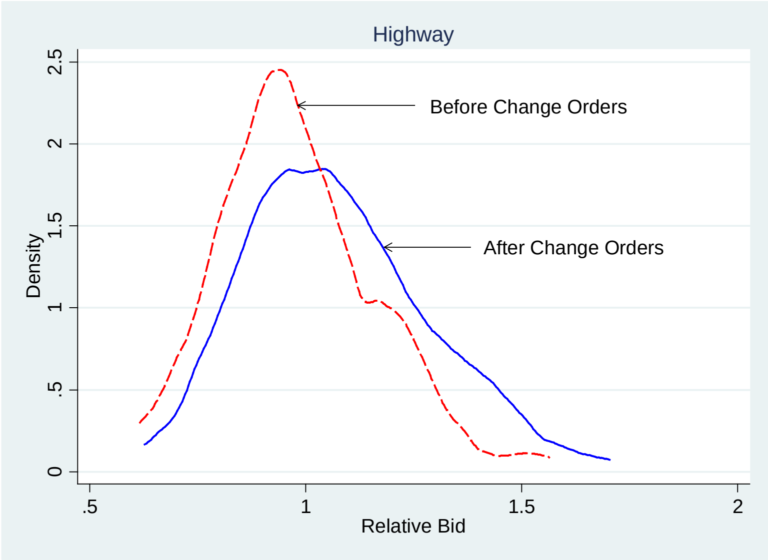
Figure 6 shows that although change orders have a slightly higher average impact on highway projects, there is less variability in their effect than on bridge projects.

Figure 5: Kernel density plots of relative winning bids (winning bids/engineering cost estimates) of initial contracts (labeled "Before Change Orders") versus relative payment amounts (payments over the engineering cost estimates) after negotiations (labeled: "After Change Orders")

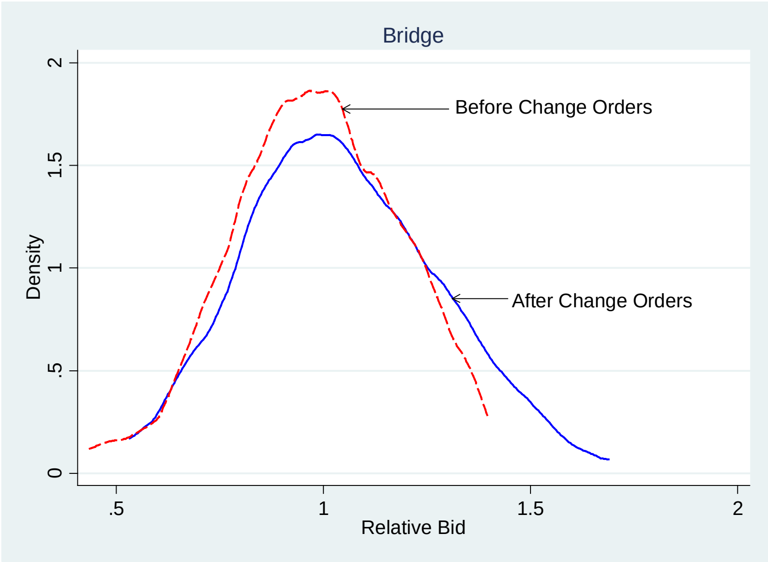


	Observations	Mean	Std. Dev.
Before Change Orders	256	0.977	0.190
After Change Orders	256	1.056	0.228

Figure 6: Kernel density plots of relative winning bids of initial contracts versus relative payment amounts after negotiations by project type



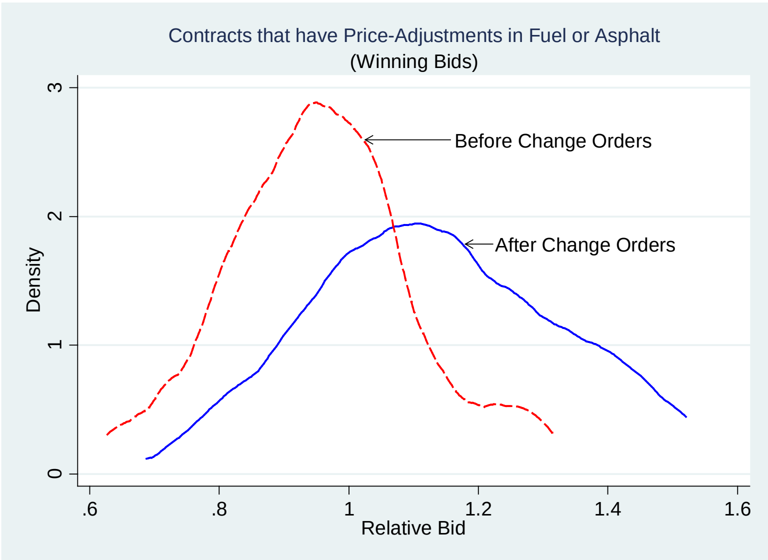
	Observations	Mean	Std. Dev.
Before Change Orders	133	0.980	0.180
After Change Orders	133	1.073	0.217



	Observations	Mean	Std. Dev.
Before Change Orders	100	0.985	0.200
After Change Orders	100	1.054	0.251

Fuel and asphalt price adjustments accounted for large increases in costs (17.4% average increase in payments relative to the engineering cost estimate) during our sample period. See Figure 7. As our econometric analysis shows, such price adjustments have the effect of encouraging bidders to bid lower ex ante because they have less exposure to price risk.

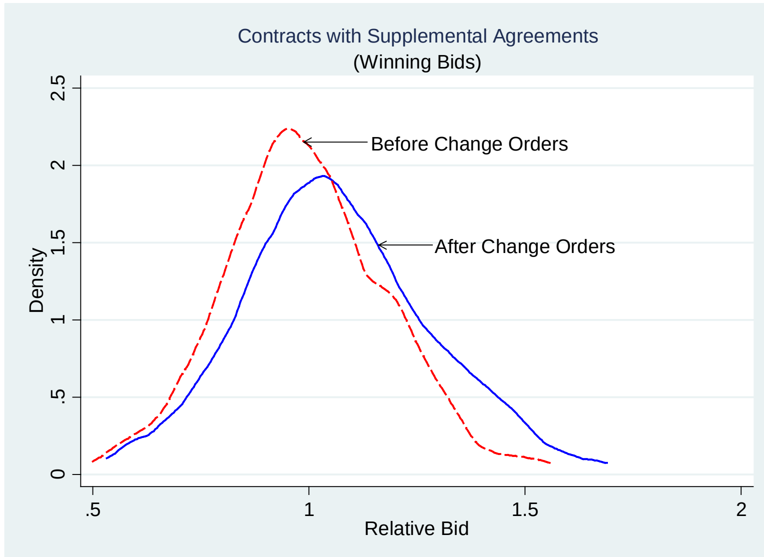
Figure 7: Relative winning bids on projects that have price adjustments in Fuel or Asphalt and COs



	Observations	Mean	Std. Dev.
Before Change Orders	41	0.958	0.148
After Change Orders	41	1.132	0.192

Finally, Figure 8 shows that contracts with supplemental agreements experienced similar increases in costs relative to the engineering cost estimates as did contracts with any kind of change order (Figure 5).

Figure 8: Relative winning bids on projects with supplemental agreements



	Observations	Mean	Std. Dev.
Before Change Orders	179	0.992	0.187
After Change Orders	179	1.064	0.217

Note: Supplemental agreement item numbers are between 900.500 and 900.583. These items are used for work that is not covered by the standard pay items and used during construction. The work may be modifying an item from the spec book or adding a new item that is not in the book.

ECONOMETRIC ANALYSIS OF CHANGE ORDERS AND STRATEGIC BIDDING

We present a comprehensive effort to model firms' bidding strategies by incorporating bidders' financial information and the list of all contractors annually prequalified. In our statistical analysis, we allow in the model for differential bidding behavior in local markets by incorporating a bidder's local market power (an account of a firm's market share). Our analysis lends support to the theory that bidders act strategically to take into account the possibility of renegotiation when they submit bids. We model several important strategic considerations in the analysis of number and size of change orders. Then, we perform simulation exercises to evaluate whether alternative policies can reduce costs to the public. Finally, we link specific behavior to strategic manipulation of bids in the face of renegotiation and propose ways to avoid higher costs.

The sample consists of road construction projects awarded in Vermont from May 2004 to December 2009. We perform our empirical analysis with reduced form regressions in order to investigate firm bidding strategies. We use two dependent variables to study bidding behavior: the log of the bid and relative (to engineer's cost estimate) bid. This study includes the log of engineer cost estimates at a project level and at the level of itemized bids.

This study includes detailed financial information on each bidder such as asset, debt and revenue. That allows us to measure their capacity and business strength more accurately, rather than resorting to constructions based on local workload as a proxy based on state level data. We construct the typical financial leverage ratio, debt to asset ratio, in order to measure how much difficulty a firm faces due to financial constraints. In addition, to control for the possibility of systematic differences in the behavior of top firms and fringe firms, we use the interaction terms between the debt to asset ratio and top firm dummy variable.

We also investigate a bidder's bidding behavior and a contractor's strategic renegotiation using its local market power. We use a firm's market share in a county as a proxy for its local market power. This simple concentration measure is constructed as the ratio of the total value of a firm's ongoing projects to the total value of all ongoing projects in a county. Without taking into account a firm's local market power, bidders' spatial distribution alone would not be a valid measure in this study because Vermont is a smaller state and almost half of the headquarters of contractors are located outside the state.

Furthermore, we also include variables that account for adjustments in auctions such as the proportion of price adjustment and the proportions of positive and negative adjustments in a project. These variables are constructed as the ratio of the total value of ex post adjustments to the engineer cost estimate in a project. It provides information on the level of misspecification of original contracts and on how bidders strategically read the plans and specifications. In particular, they improve our explanatory power for the observed bid in our regression analysis. This methodology is similar to that employed by Bajari, Houghton, and Tadelis (2011), who include the ex post changes of deductions, extra work and adjustments.

Lastly, we include the cost control variables used in Bajari, McMillan, and Tadelis (2009), Bajari, Houghton, and Tadelis (2011), De Silva, Dunne, and Kosmopoulou (2003) and De Silva, Dunne, Kankanamge, and Kosmopoulou (2008). They contain current project backlog of a bidder and firm-specific distance to each work site. We also control for seasonal effects by monthly dummies and classify auctions by project type: asphalt projects, bridge projects and other type of projects.[2] (The table in the appendix provides more detailed descriptions of the variables.)

Total Bid Estimation

Table 1 presents the first set of regression results, consisting of three models aimed at explaining the variation in all bids submitted on all projects during the period of

[2] The third type of projects, labeled other type of projects, includes traffic signaling and lighting, grading and draining and miscellaneous projects such as parking lots and landscaping.

analysis. We estimate the models using ordinary least squares, while including robust standard errors to obtain heteroskedastic-consistent standard errors. We then estimate a similar model including fixed effects to account for firms' different efficiency levels. The introduction of firm fixed effects controls for any additional idiosyncratic characteristics of the individual bidder that drive bidder's bidding strategy. Lastly, we estimate a fixed effects model with cluster-robust standard errors at the auction level. Note that we present the regression results of only the covariates of interest related to strategic manipulation of bids in this empirical analysis[3].

[3] The variables that we employ are listed and defined in the appendix, along with their corresponding summary statistics.

Table 1: Log of Bids

Dependent Variable: Log of Bids	OLS	Fixed Effect	Fixed Effect (Cluster)
Proportion of Price Adjustment	-1.229***	-1.478***	-1.478***
	(0.277)	(0.272)	(0.451)
Proportion of Positive Quantity Adjustment	0.397***	0.357**	0.357
	(0.148)	(0.145)	(0.252)
Proportion of Negative Quantity Adjustment	-0.610***	-0.634***	-0.634***
	(0.132)	(0.103)	(0.231)
Top Firm	-0.062	0.278***	0.278
	(0.071)	(0.100)	(0.379)
New Item Amount	-0.515***	-0.549***	-0.549*
	(0.186)	(0.152)	(0.329)
Quantity Adjustment	0.048**	0.048**	0.048*
	(0.023)	(0.020)	(0.028)
Price Adjustment	-0.169***	-0.214***	-0.214**
	(0.050)	(0.048)	(0.090)
Price & Quantity Adjustment	0.099***	0.099***	0.099**
	(0.034)	(0.034)	(0.048)
Log of Engineer's Estimate	0.932***	0.909***	0.909***
	(0.010)	(0.012)	(0.013)
Debt to Asset Ratio	0.030	-0.101**	-0.101*
	(0.030)	(0.039)	(0.060)
D-A Ratio*Top Firm	-0.047	-1.371***	-1.371
	(0.118)	(0.444)	(1.636)
Log of Asset	0.013**	0.049	0.049
	(0.007)	(0.053)	(0.048)
Local Market Power	-0.117***	-0.073**	-0.073*
	(0.040)	(0.033)	(0.040)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (55)	No	Yes	Yes
Number of Observations	819	819	819
R-squared	0.964	0.952	0.970

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The results in Table 1 suggest that the engineering cost estimate is positively correlated with the level of bids, and this result is consistently significant as reported in previous literature (De Silva, Dunne, and Kosmopoulou, 2003). The coefficient of 0.909 implies that a one percent increase in the engineer's cost estimate is associated with an increase of 0.909 percent, on average, in the bid. Note that we are taking the coefficient values from the last two specifications in the discussion. Given that engineer's cost estimates are private information in Vermont (i.e., they are not shared with contractors), this close tracking of the estimate with the actual bids is consistent with very similar approaches to cost estimation being undertaken by private and agency officials.

The variable on the proportion of ex post price adjustment amount is negative and statistically significant. Thus, considering the variable on price adjustment, firms bid more aggressively when they anticipate the potential of price adjustment in the future. The coefficient of -1.478 implies that for every one percentage point change in the proportion of a contract's final payout due to price adjustment, there is an associated 1.478% decline in the bid amounts. (See table in appendix for variable definitions.) As discussed further below, the evidence is consistent with the hypothesis that implementation of price adjustment clauses tends to save the Vermont Agency of Transportation more up front than it costs the agency ex post. The variable related to the proportion of ex post positive quantity adjustment amount is positive and statistically significant in the first two columns indicating that when bidders anticipate a larger proportion of positive quantity adjustment, they bid less aggressively. Specifically, for every one percentage point increase in the proportion of positive quantity adjustment, there is a 0.357% increase in bids ex ante. Meanwhile, the variable related to the proportion of ex post negative quantity adjustment amounts is negative and statistically significant (coefficient of -0.634). With these variables, we conclude that bidders are more likely to manipulate their bids with their anticipation of ex post quantity adjustments to increase their ex post payments. This implication is consistent with theory.

We differentiate between change orders that add a completely new item and change orders that add quantity to an existing item since the former indicates the incompleteness of project design. With the anticipation of adding new items in the field, bidders are more likely to bid aggressively. For every one percentage point increase in the proportion of ex post new item dollar amounts relative to total bids ex ante, there is a 0.54 percent decline in initial bids. By doing that, bidders increase the probability of winning the project, and later they recover their forgone profits with the new items in the field.

In the firm fixed effect specification, the variables on debt to asset ratio and its interaction term are significantly negative. It implies that financially constrained firms bid more aggressively. Costly financing outside the opportunity cost of losing an auction would be much higher for financially constrained firms than for unconstrained opponents. On the other hand, financially unconstrained firms would bid less aggressively to keep high markups. Firms with high local market power bid more aggressively. A firm's local market power is constructed based on its working history in a county level: the proportion of all outstanding work in a county that is undertaken by a given firm. Larger values are associated with a firm having a dominant position in that county. A one percentage point increase in that measure is associated with a 0.073% decline in a firm's bid. It is possible that the more experienced firms are more likely to anticipate true quantity used in the field and bid strategically. They bid more aggressively on the auction to increase the probability of winning, and later they recover their foregone profits by frequently claiming change orders.

Among the variables not shown in the table (in the interest of space), but which were also important statistically and economically, we mention the expected number of bidders, and the unemployment rate. Increased level of competition causes bidders to bid more aggressively. Every additional bidder is estimated to lower average bids by 1.9%, and this result is statistically significant at the one percent level. It implies that by encouraging potential bidders to participate in an auction, a state government will reduce the total cost of the project. Regarding general economic conditions, we found that bidders bid more aggressively when facing a high unemployment rate, which indicates a decline in economic activity. Every one percentage point increase in the unemployment rate is associated with bids that are on average four percent lower.

In Table 2, our dependent variable is relative bids, which are acquired by dividing the total bid by the engineer's cost estimate.

Table 2: Relative Bid

Dependent Variable: Relative Bid	**OLS**	**Fixed Effect**	**Fixed Effect (Cluster)**
Proportion of Price Adjustment	-1.403***	-1.593***	-1.593***
	(0.293)	(0.277)	(0.488)
Proportion of Positive Quantity Adjustment	0.460***	0.410**	0.410
	(0.174)	(0.159)	(0.305)
Proportion of Negative Quantity Adjustment	-0.697***	-0.740***	-0.740**
	(0.162)	(0.134)	(0.294)
Top Firm	-0.070	0.542***	0.542
	(0.066)	(0.103)	(0.376)
New Item Amount	-0.510**	-0.552***	-0.552
	(0.223)	(0.189)	(0.403)
Quantity Adjustment	0.029	0.030	0.030
	(0.027)	(0.022)	(0.034)
Price Adjustment	-0.199***	-0.226***	-0.226***
	(0.046)	(0.047)	(0.079)
Price & Quantity Adjustment	0.012	0.009	0.009
	(0.035)	(0.035)	(0.051)
Debt to Asset Ratio	0.022	-0.131***	-0.131*
	(0.034)	(0.042)	(0.077)
D-A Ratio*Top Firm	-0.033	-2.588***	-2.588
	(0.111)	(0.456)	(1.630)
Log of Asset	0.004	0.013	0.013
	(0.007)	(0.056)	(0.055)
Local Market Power	-0.142***	-0.099**	-0.099**
	(0.043)	(0.037)	(0.043)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (55)	No	Yes	Yes
Number of Observations	819	819	819
R-squared	0.206	0.209	0.326

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

We do not discuss these results in detail, as they are consistent with those observed in Table 1. The variables of interest related to strategic manipulation of bids in the face of negotiation are still statistically significant, and are of an economically important magnitude. A firm's relative advantage in geographical distance from a project is not statistically significant in both tables. Instead, the firm's local market power is still significantly effective on firm's bidding behavior. It implies that the location where a firm has done or is working projects is one of the critical determinants on a firm's bidding. It is worth noting that the R^2 is substantially lower in these models as compared with the models in Table 1. The reason is that in Table 1 much of the variation in the bids is explained by the engineer's cost estimate, whereas in Table 2 the dependent variable is the ratio of the bid to the engineer's cost estimate. Our models explains between twenty and thirty-three percent of the variation in this ratio.

Probability Model for Renegotiation

Our next step is to study the frequency of change orders in an auction by estimating a count model. In particular, we employ a Poisson model assuming that the firm's effect has a gamma distribution. The first column of Table 3 shows the coefficient estimates and the associated standard errors, while the second column shows the marginal effects.

In this estimation, we include the variable of the proportion deviation that is measured as the proportional difference between the winning bid and the engineer cost estimate. If a firm manipulates its bid to win a contract, with a view toward claiming future change orders, the proportion deviation variable should be statistically significant. In addition, the model incorporates the variable "Money Left on the Table" (MLT). This variable measures the difference between the winning bid and the second lowest bid. The bid differential is foregone revenue for the firm, and thus we call it money left on the table. Strategic bidding behavior would imply that the larger the value of the MLT, the higher the tendency to submit change orders. Without submitting change orders to recover foregone profits in the presence of uncertainty, bidders would be subject to the winner's curse effect because a winner with larger value of MLT submits lower bids relative to the engineers' cost estimates in an auction. Therefore, it would be an indicator that the change orders may take place in future renegotiation stage.

Table 3: Probability model (Poisson)

Dependent Variable: The Number of Change Orders	**Poisson (Random Effect)**	**Marginal Effect**
Log of Engineer's Estimate	0.340***	0.906***
	(0.061)	(0.175)
Expected Number of Bidders	0.064***	0.170***
	(0.020)	(0.054)
Top Firm	-0.116	-0.315
	(0.357)	(0.983)
Proportion of Deviation	0.525**	1.400**
	(0.207)	(0.564)
Debt to Asset Ratio	-0.274	-0.730
	(0.486)	(1.306)
D-A Ratio*Top Firm	0.345	0.920
	(0.611)	(1.632)
Log of Asset	0.026	0.068
	(0.070)	(0.189)
Local Market Power	0.334**	0.891**
	(0.161)	(0.444)
MLT	1.018***	2.714***
	(0.312)	(0.867)
Log of Calendar Days	0.601***	1.603***
	(0.078)	(0.265)
Auction Specific Characteristics	Yes	Yes
Bidder Specific Characteristics	Yes	Yes
General Economic Conditions	Yes	Yes
Time Dummy	Yes	Yes
Individual Effects	Yes	Yes
Number of Observations	271	271
Number of Firm	54	54

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

From the estimation point of view, the more complex a project is, the more frequently it will be renegotiated. The variables of engineer cost estimate and calendar days are proxies for the complexity of a project and are thus likely to lead to renegotiations. The variable of "proportion of deviation" is significantly positive, meaning that the more the winning bids deviate from engineer's cost estimates, the more frequent the renegotiations are expected. The variable of local market power is significantly positive, indicating that a contractor with high local market power is more likely to submit another change order in the field. By taking bidding behavior into account, we conclude that dominant bidders in a market would bid more aggressively on the auction to increase the probability of winning, and later they recover their foregone profits by frequently claiming change orders. The variable of MLT is positive and statistically significant. A firm may bid aggressively to win a contract leaving a large amount of surplus on the table and then try to renegotiate to regain part of its lost surplus. On the other hand, the variables regarding financial information are not statistically significant in this count model.

Beyond statistical significance, the interpretation of coefficients in Poisson count models is not straightforward. Therefore we have computed the marginal effects. They are interpreted as follows: when all variables are at their mean, you may calculate the effect of a change in one of the variables on the expected count of change orders by multiplying the change in that variable by the marginal effect. For example, in the table, the coefficient for MLT is 2.71. From the appendix, the standard deviation of MLT is 0.151. When all variables are at their mean value, the model predicts that an increase in MLT of one standard deviation will increase the count of change orders by 2.71*0.151 = 0.409 change orders. Similar calculations can be made for the other variables. Keep in mind that the marginal effects employed would be different if the variables are not at their means, reflecting the nonlinear nature of the estimating procedure.

Next, we estimate a model for the probability of that a project is renegotiated. We use the same control variables as Poisson model. The results obtained from a Logit random effect are reported in Table 4. Again, logit is a nonlinear model as is Poisson. However, it is aimed at predicting whether or not there is a change order, not the count of change orders. Its coefficients can be transformed into marginal effects in order to produce estimates of the change in an independent variable on the probability that at least one change order would occur on a project. Again, the marginal effects are evaluated at the mean values of the variables.

Table 4: Probability model (Logit)

Dependent Variable: Change Orders	**Logit**	**Marginal Effect**
Log of Engineer's Estimate	0.767***	0.045**
	(0.279)	(0.019)
Expected Number of Bidders	0.179*	0.010*
	(0.103)	(0.006)
Top Firm	2.257*	0.195*
	(1.259)	(0.145)
Proportion of Deviation	2.943**	0.172**
	(1.178)	(0.072)
Debt to Asset Ratio	-0.648	-0.038
	(1.485)	(0.089)
D-A Ratio*Top Firm	-1.100	-0.064
	(2.056)	(0.118)
Log of Assets	-0.114	-0.007
	(0.197)	(0.011)
Local Market Power	0.632	0.037
	(1.046)	(0.060)
MLT	2.303*	0.135*
	(1.360)	(0.082)
Log of Calendar Days	1.328***	0.078***
	(0.425)	(0.026)
Auction Specific Characteristics	Yes	Yes
Bidder Specific Characteristics	Yes	Yes
General Economic Conditions	Yes	Yes
Time Dummy	Yes	Yes
Individual Effects	Yes	Yes
Number of Observations	271	271
Number of Firm	54	54

Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

As in the count model, we observe a positive and statistically significant relationship between the complexity of a project and the occurrence of renegotiations. Furthermore, the variable indicating top firms is positive and statistically significant. The more experienced firms may have more experience of renegotiations with the state government. Therefore, they would increase the probability of the occurrence of renegotiation. However, the local market power variable is not significant in this model.

From both table 3 and table 4, we found that the complexity of a project is the key determinants of the occurrence and frequency of renegotiation in an auction. This evidence echoes the conclusions of the previous literature.[4] In addition, we observe that the proportion of deviation and MLT are also important determinants. The more the winning bids are deviating from the engineer's cost estimates, the higher the frequency of renegotiations. For the MLT variable, we interpret the marginal effects as if a one standard deviation increase in MLT will increase the probability of occurrence of the renegotiation by (13.5*0.151)% = 2.04%. For the proportion deviation, a one standard deviation increase in that variable increases the probability of a change order by (17.2*0.225) % = 3.87%.

Next, we employ the different dependent variable of the dollar amount of change orders rather than only the number of change orders on the similar control variables used in the probability model. In Table 5, the dependent variable is relative adjustment amounts, which are acquired by dividing the total amount of change orders by the engineer' cost estimate to normalize the adjustments across projects. Note that we employ the same estimation model specifications used in Table 1 and Table 2 because the probability model is no longer applicable in this setting. We observe a positive and statistically significant relationship between the variable of proportion of deviation and the adjustment amounts. This implies that the greater the deviation between the low bid and the engineer's cost estimate, the greater the ex post adjustment in terms of change orders. This result is consistent with the hypothesis that firms that underbid more

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[4] Bajari and Tadlis (2006), Bajari, McMillan, and Tadelis (2009), Bajari, Houghton, and Tadelis (2011) and Chong, Staropoli, and Yvrande-Billon (2010)

(relative to the engineer's estimate) seek to increase their payout ex post by submitting a high valuation of change orders. Furthermore, the variable of local market power is significantly positive, meaning that a contractor with high local market power is more likely to recover more adjustment amounts at the renegotiation stage. The variables regarding financial information are still not statistically significant.

Table 5: The Ratio of Adjustment Amounts to Engineer Cost Estimates

Dependent Variable: Amounts of Change Orders (Ratio)	**OLS**	**Fixed Effect**	**Fixed Effect (Cluster)**
Expected Number of Bidders	0.004*	0.006***	0.006**
	(0.002)	(0.002)	(0.003)
Top Firm	0.006	0.015	0.015
	(0.024)	(0.015)	(0.032)
Proportion of Deviation	0.050**	0.057**	0.057**
	(0.022)	(0.022)	(0.027)
Local Market Power	0.045**	0.041*	0.041
	(0.022)	(0.021)	(0.026)
Log of Calendar Days	0.012	0.016	0.016*
	(0.008)	(0.010)	(0.010)
Debt to Asset Ratio	0.017	-0.040	-0.040
	(0.026)	(0.045)	(0.056)
D-A Ratio*Top Firm	0.014	0.044	0.044
	(0.024)	(0.064)	(0.086)
Log of Asset	0.003	-0.003	-0.003
	(0.004)	(0.042)	(0.050)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (54)	No	Yes	Yes
Number of Observations	266	266	266
R-squared	0.211	0.244	0.412

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.

Our empirical analyses show that bids are likely to underbid relative to the estimated cost in anticipation of future adjustments. Regarding this finding, we analyze how much each variable of interest related to strategic manipulation of bids accounts for the deviation in Table 6. We use the log of Root Mean Square Deviation (RMSD) as the dependent variable, which is frequently used in economics to evaluate the difference between predicted values and the values actually observed (see complete variable definition in the appendix). For this model, we calculate the sum of the squared differences between engineering cost estimates and bidders' bids on an item divided by the number of tasks. This is the mean squared error. Then, we take the square root of the value and take a logarithm value of each bidder in an auction. A relatively high value means that the bidder is deviating substantially from the engineer's estimate (on average across all bid items).

From the estimation point of view, most variables are statistically significant, which is consistent with those observed in previous estimation results. The deviation from the engineer's cost estimate is mainly attributed to the anticipation of ex post change orders, implying that when bidders expect the future adjustments their bids are more likely to deviate from the engineer cost estimates. Furthermore, with the variable of the relative adjustment amounts, we observe that the magnitude of deviation becomes greater when bidders anticipate higher dollar amounts of change orders. Lastly, financially constrained top firms are less likely to deviate from the engineer cost estimates.

Table 6: Root Mean Square Deviation

Dependent Variable: Log of RMSD	OLS	Fixed Effect	Fixed Effect (Cluster)
Dummy of Change Orders	0.072	0.127***	0.127*
	(0.060)	(0.044)	(0.075)
Amounts of Change Orders (Ratio)	0.704***	0.614**	0.614**
	(0.174)	(0.237)	(0.237)
Log of Engineer's Estimate	0.584***	0.570***	0.570***
	(0.025)	(0.029)	(0.039)
Top Firm	-0.103**	-0.024	-0.024
	(0.051)	(0.048)	(0.060)
Debt to Asset Ratio	0.090	-0.217	-0.217
	(0.077)	(0.143)	(0.138)
D-A Ratio*Top Firm	-0.472***	-1.890***	-1.890**
	(0.167)	(0.250)	(0.882)
Log of Asset	0.029*	-0.135	-0.135
	(0.016)	(0.142)	(0.144)
Local Market Power	0.022	0.063	0.063
	(0.112)	(0.066)	(0.106)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (55)	No	Yes	Yes
Number of Observations	831	831	831
R-squared	0.594	0.526	0.662

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Itemized Bid Estimation

In this part of the report, the unit of observation is an itemized bid, which offers the possibility to identify the items typically renegotiated. It also provides the opportunity to pin down which items bidders manipulate in anticipation of renegotiations. We use similar methodologies as those employed so far, but now we include item fixed effects to capture different characteristics of tasks. Furthermore, we classify all items into three groups: items with ex post quantity overruns, items with ex post quantity under-runs, and items with no quantity changes ex post. There are 714 different items used during the sample period. 366 items never appear on a change order[5]. To control for different renegotiation frequency across items, we also classify all items into three groups: The most frequently renegotiated item, less frequently renegotiated item, and items never renegotiated during the sample period[6]. Table 7 presents the set of regression results with itemized bids.

The items results are consistent with previous results at the project level. The itemized bid estimation shows that bidders submit higher bids on items that are expected to have a positive quantity adjustment, and lower bids on items that are expected to have a negative quantity adjustment in order to maximize expected profit without lowering significantly the probability of winning an auction. The most frequently renegotiated items have a bid that is on average 7.5% higher than items never renegotiated, all else held equal. The less frequently renegotiated items are bid about 5% higher than items never renegotiated. These results are strong evidence consistent with the view that firms systematically adjust their itemized bids in such a way as to increase ex post payouts. A major explanatory factor of itemized bids is the engineer's cost estimate, which was what occurred in our project-level analysis. A one percent increase in the engineer's cost estimate for a particular item is associated with a slightly less than one percent increase in the average bid on that item (0.979% or 0.937% depending on the specification).

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[5] The change orders are recorded if the changes of plans or specifications are significant from the original contract. For example, in the state of Vermont, change order was recorded when it results in 5% or more increase on the item or causes an increase in the contract total pay amount.

[6] More specifically, we assign an item as less frequently renegotiated item if its frequency is below median of the frequency distribution. The number of items in the group is 202. On the other hand, the number of the most frequently renegotiated items is 146.

Table 7: Itemized Bids

Itemized Bid	OLS	Fixed Effect (Firm)	(3) Fixed Effect (Firm & Item)
Positive Quantity Adjustment	0.007***	0.007***	0.008***
	(0.002)	(0.002)	(0.002)
Negative Quantity Adjustment	-0.031***	-0.030***	-0.034***
	(0.006)	(0.006)	(0.004)
Less Frequently Renegotiated Item	0.051***	0.049***	_
	(0.008)	(0.013)	
More Frequently Renegotiated Item	0.076***	0.075***	_
	(0.007)	(0.009)	
Top Firm	0.046*	0.119	0.143
	(0.026)	(0.083)	(0.142)
Log of Engineer's Item Estimate	0.979***	0.979***	0.937***
	(0.001)	(0.003)	(0.002)
Debt to Asset Ratio	0.018*	0.030	0.040**
	(0.010)	(0.030)	(0.019)
D-A Ratio*Top Firm	-0.217***	-0.544*	-0.701
	(0.044)	(0.304)	(0.612)
Log of Assets	0.007***	-0.007	0.004
	(0.002)	(0.035)	(0.016)
Local Market Power	-0.035***	-0.020	-0.020**
	(0.010)	(0.032)	(0.010)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (55)	No	Yes	Yes
Number of Observations	46,287	46,287	46,287
R-squared	0.949	0.949	0.954

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

We also consider firm and rival characteristics with proxies to analyze bidders' bidding strategies. Firms with higher debt-to-asset ratios tend to give higher bids, but this effect is the opposite for "top firms," who tend to bid more aggressively when highly indebted. In addition, both "local market power" is associated with lower itemized bids. Among the results not reported in the table, we found that the expected number of bidders lowers bids. Further, a firm is more likely to bid aggressively to win a contract when it has enough capacity while it bids less aggressively when it faces rivals who do not have enough capacity available.

Lastly, Table 8 provides relative itemized bid estimation results. These results are consistent with the results observed in Table 5, and the coefficients are often measured with a higher degree of precision. The view that firms are bidding strategically in response to anticipated change orders is strongly supported in the data.

SIMULATION EXERCISES

The last step of this study is to simulate relative total bids with the implemented policy instruments to evaluate them in the state of Vermont. Particularly, we consider two policy instruments - the price adjustment clause and positive quantity adjustment - in these simulation exercises.

Table 9 shows the simulated relative total bids under three different scenarios based on the model presented in table 2. To evaluate each adjustment, we use the no policy case as the baseline. If there were no adjustments, relative bid would be 1.020, which means on average bidders would bid 2% above the engineer's cost estimate. If, however, there was a price adjustment clause, bidders would bid more aggressively by 22.25% because the price adjustment would relieve contractors of extreme volatility in the input prices. On the other hand, bidders would make an effort to strategically manipulate the outcome of the bidding process and bid less aggressively in anticipation of a quantity adjustment.

Table 10 presents the simulations considering three policy instruments. In the simulations, we vary the calendar days that are required to complete a project.

If the length of a project increases from 227 days (mean level of the calendar day distribution) to 245 days (median level) in a project, the anticipated proportion of price adjustment should be 0.009 to retain the same average level of bids holding everything else constant. In other words, the price adjustment ratio would have to increase by 47.15% to keep bidders' incentives constant (and their bids at the same level) after the increase in calendar days. As shown in our empirical analysis, bidders bid more aggressively in anticipation of potential price adjustments in the future, while we observe less aggressive bidding when a project requires more working days. Therefore, if the length of a project increases (signifying greater uncertainty), holding everything else the same (such as complexity or type of work) the ratio of price adjustment should increase to hold bid levels constant.

Table 8: Itemized Relative Bid

Itemized Relative Bid	OLS	Fixed Effect (Firm)	Fixed Effect (Firm & Item)
Positive Quantity Adjustment	0.005***	0.005***	0.005***
	(0.002)	(0.002)	(0.002)
Negative Quantity Adjustment	-0.011***	-0.010*	-0.010***
	(0.004)	(0.005)	(0.004)
Less Frequently Renegotiated Item	0.025***	0.023**	_
	(0.008)	(0.010)	
More Frequently Renegotiated Item	0.036***	0.034***	_
	(0.007)	(0.008)	
Top Firm	0.018	0.184**	0.181
	(0.025)	(0.081)	(0.137)
Debt to Asset Ratio	0.024**	0.030	0.038*
	(0.010)	(0.028)	(0.019)
D-A Ratio*Top Firm	-0.189***	-0.937***	-0.988*
	(0.042)	(0.299)	(0.590)
Log of Asset	0.012***	-0.010	-0.008
	(0.002)	(0.034)	(0.016)
Local Market Power	-0.045***	-0.028	-0.035***
	(0.010)	(0.030)	(0.010)
Auction Specific Characteristics	Yes	Yes	Yes
Bidder Specific Characteristics	Yes	Yes	Yes
General Economic Conditions	Yes	Yes	Yes
Time Dummy	Yes	Yes	Yes
Fixed Effects (55)	No	Yes	Yes
Number of Observations	46,287	46,287	46,287
R-squared	0.014	0.009	0.087

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 9: Simulated Relative total bids

	No Policy Instrument	Price Adjustment		Positive Quantity Adjustment	
Relative Bid	1.02	0.793	[-22.25%]	1.242	[21.76%]

Table 10: Simulated Adjustments

Policy Instruments	Calendar Days					
	213 Days		241 Days		245 Days	
Price Adjustment Ratio	0.003	[-46.47%]	0.008	[36.14%]	0.009	[47.15%]
Positive Quantity Adjustment Ratio	0.055	[22.24%]	0.034	[-23.42%]	0.032	[-29.50%]
Negative Quantity Adjustment Ratio	-0.055	[-11.99%]	-0.043	[11.57%]	-0.042	[14.71%]

Table 11 also shows that the price adjustment clause would significantly vary to the change of one of the key determinants. The fuel price adjustment clause will be activated if the index deviates by more than 5% from its current index in the state of Vermont (for asphalt price adjustment: 10%). The total transfer depends on the quantity of eligible items used and the extent of price deviation. The following simulation exercises show for specific changes in the gas price index the proportion of price adjustment that could keep relative bids unaffected.

Table 11: Simulated Price Adjustment and Relative Bids with Different Gas Price Index

	Gas Price Index					
Gas Price Index	$2.210		$2.476		$2.936	
Price Adjustment Ratio	0.004	[-33.33%]	0.005	[-16.67%]	0.007	[16.67%]
Relative Bids	0.858	[1.085]	0.860	[1.087]	0.864	[1.090]

These simulations support the view that the price adjustment clause helps the state government avoid higher costs. For example, if there were no price adjustment clause with the gas price index of $2.476, the relative bid would be 1.087 which is around 26.40% higher than with the price adjustment clause. However, it is hard to pin down the best threshold percentages to activate price adjustments. When firms are faced with high volatility of gas prices, a lower trigger value would dissuade bidders from bid inflation. On the other hand, if gas price fluctuations were not significant, a wider threshold would not increase costs to the public. The price adjustment policy instrument would not be effective due to low uncertainty of future gas prices, but it also would not create lump sum transfers to contractors.

CONCLUSION

We separate the conclusion of the report into two distinct parts. First, we summarize the salient findings of our econometric analysis are as follows. Second, we provide policy recommendations and suggestions for the further research.

Summary of Econometric Analysis

The econometric analysis has provided very strong evidence about the determinants of bidding and change orders in the Vermont Agency of Transportation's procurement over the period 2004-2009. The key findings are:

1. Financially constrained bidders bid more aggressively. The opportunity cost of losing an auction is much higher for financially constrained firms than for unconstrained opponents.

2. We construct an index of a firm's local market power based on its working history to account for a firm's market share in a county. We investigate how bidders strategically exercise their local market power in the auction letting as well as at the renegotiation stage. Dominant bidders in a market bid more aggressively in an auction to increase the probability of winning, and later they recover their foregone profits by frequently claiming change orders.

3. On average firms bid more aggressively when they anticipate ex post price adjustments related to the price adjustment clauses. In this sample, most price adjustments have been positive transfers to firms even though price adjustments could be positive or negative in general depending upon the magnitude and sign of deviation of the average fuel price from the index price during the project construction period. The price adjustment clause is reducing uncertainty. Therefore, bidders bid more aggressively on auction to increase the probability of winning, and later they recover their foregone profits.

4. Considering positive and negative quantity adjustments separately, we found that bidders bid less aggressively when they anticipate ex post positive quantity adjustment, while they bid more aggressively when they anticipate negative quantity adjustments. By doing so, they increase their final payment without lowering the probability of winning. With the knowledge that, due to Federal regulations, they cannot renegotiate the price of an item in a contract unless an item is added to the contract in the field, but they are likely to negotiate quantity, they adjust their bidding strategies ex ante in anticipation of quantity adjustments (which could be costly to the state).

5. We differentiate between change orders that add a completely new item and change orders that add quantity to an existing item since the former indicates the incompleteness of project design. With the anticipation of adding new items in the field, bidders are more likely to bid aggressively.

6. We also include controls for the top firms, which are defined as those firms whose total revenue is greater than 20% of the entire revenue generated each year during the sample period. Top firms are more likely to strategically manipulate bids having more knowledge and experience in the market.

7. The expected number of bidders is a measure of the degree of competition in the market. Due to the concern of endogenous entry, we use the expected number of bidders instead of the actual number of bidders, considering whether the plan holders' identities are publicly announced prior to the letting. We found that increased competition leads to lower bids.

8. In our analysis of bidding behavior, we also consider firm and rival characteristics. We found that a firm's bidding behavior is affected by its own and its rivals' project backlogs (i.e., existing unfinished workload commitment). A firm is more likely to bid aggressively to win a contract when it has enough capacity while it bids less aggressively when it faces rivals who do not have enough capacity available. After accounting for firms' financial information this study provides strong evidence of this hypothesis. It indicates that incorporating financial information in the empirical model is critical to improve its fit.

9. With the probability models, we found that the more complex a project is, the more frequently it will be renegotiated when we control for firm characteristics and other

economic conditions. The larger the money left on the table (MLT- the percentage difference between the lowest and the second lowest bid), the higher the likelihood to submit another change order. A firm may bid aggressively to win a contract leaving a large amount of surplus on the table and then try to renegotiate to regain part of its lost surplus.

10. In the model of the dollar amounts of change orders (see Table 5), we found that the more complex a project is, the higher the dollar amounts of change orders will be, which is consistent with the probability model. With the RMSE model (Table 6), we also observe that when bidders expect the ex post renegotiation, they are more likely to deviate from the engineer cost estimates. Furthermore, the magnitude of deviation becomes greater when bidders anticipate higher dollar amounts of change orders.

11. In the itemized bid model, we found that bidders bid less aggressively on renegotiated items. In particular, we observe that relative bids are much higher on the most frequently renegotiated items than on less frequently renegotiated items. In addition, in the estimation we show that firms' bidding behaviors are still consistent in anticipation of positive and negative quantity adjustment at the item level.

12. By performing simulation exercises, we found that the price adjustment policy would have to vary significantly with changes in key determinants of bidding behavior to sustain the same competitive level of bidding. Bidders inflate their bids if there is no price adjustment clause.

In sum, our research shows that the incidence of change orders is mainly affected by two classes of variables. The first relates to the complexity of the task at hand, as illustrated by the log of the engineer's cost estimate and the log of calendar days variables in tables 3 and 4 of part two. The second relate to strategic effects – the view that bidders seek to increase profits ex post that they appeared to have foregone ex ante by being the low bidder. These variables include "proportion of deviation," "local market power," and "MLT" in tables 3 and 4. The hypothesis that firms bid low in anticipation of recouping funds later is strongly supported by results at the project level (tables 1-2 of part two) and at the itemized bid level (tables 7-8), where a strong association is shown between quantity adjustments, price adjustments and bidding behavior.

Policy Recommendations

The econometric findings suggest several avenues for improving efficiency in Vermont's highway and bridge construction procurement program. One of the most important goals should be to increase the degree of competition for construction projects in Vermont. As we mentioned in the concluding remarks of our last report, dominant bidders are more likely to frequently claim change orders. More competition would lead bidders to lower bids, implying lower costs to the state government. The Agency can foster competition in the local market by providing incentives for smaller local firms to participate in an auction. Bid preference programs for small businesses can accomplish this. The bid preference programs that have been applied in many states give qualified firms typically a 5% bidding advantage. These programs can induce more aggressive bidding from large competitors while helping small qualified firms. Training programs similar to the Learning Information Networking and Collaboration programs (LINC) established in Texas can also help small firms. The goal of the program in Texas is to improve "race neutral" participation of small firms and minority businesses by providing information, networking opportunities, project management and bid training sessions. Training programs or the release of elaborate information through pre-bid meetings/advertising about the nature of a project and tasks can help smaller firms become more competitive in the process. Any of these suggested policies could help small firms survive longer and would encourage potential local entrants to enter the market. The estimated effect of an additional bidder is to reduce overall bids on average by almost two percent. Thus, so long as the programs to foster competition are not overly costly, they promise to yield non trivial savings for the state. We strongly recommend investigating further the feasibility of adopting such programs in Vermont.

In addition to seeking to increase the number of bids submitted by smaller local firms, the Agency could investigate the possibility of outreach to major contractors in nearby states. Some of these firms may have developed some knowledge of Vermont's market through the extraordinary experiences following Tropical Storm Irene. If the few dominant firms in Vermont were more concerned about the possible entrance of capable, experienced out-of-state firms, it is very likely that they would bid more competitively.

Future research of Vermont's procurement experience in the aftermath of Tropical Storm Irene can help identify firms that are particularly promising candidates for such outreach.

Another recommendation is to introduce a reserve price rule. To our understanding, in the state of Vermont, there is no formal threshold for rejecting bids, while in Oklahoma for example if a bid is more than 7% above the engineering cost estimate it will be officially rejected. Item-specific reserve prices could be imposed on the items that historically have been most susceptible to costly change orders, thereby mitigating to some extent the possibility of unbalanced bids. With a reserve price policy, the state government would prevent incurring high costs especially when competition is low and there is only a single bidder in an auction letting (This is typically a large firm in the sample).

Whether or not the Agency chooses to implement a reserve-price rule, we strongly recommend that future bids be analyzed with an eye toward the items that are most susceptible to change orders as identified in this report.

From our simulation exercises, we show that the implementation of price adjustments would make bidders bid more aggressively. This is associated with the reduction in contractor's risk which can affect more severely small competitors. Each state has different fuel usage factors and numbers of eligible items. Furthermore, there are different levels of trigger values from 5% to 25% for a fuel price adjustment. Note that some states, such as New York, Iowa, and Montana, use a dollar value instead of a percentage as the trigger value. The state of Vermont employs the 5% trigger values, which is relatively low compared to other states. Appendix B provides more detailed description of price adjustment implementation across the country.

The implementation of a fuel price adjustment clause seems to have helped the state government reduce its costs. The question of whether the threshold should be relaxed or not can be answered with more conviction until we complete the next step of our analysis. This is an area that could benefit from future investigation. A future research project could design pilot projects and experiments that could help the Agency calibrate the parameters of its price adjustment mechanisms for maximum desired effect.

We show that the more complex a project is, the more frequently it will be renegotiated. A complex project often consists of a higher number of tasks and requires a higher number of working days to be completed. Whenever feasible the state should split larger projects into smaller ones.[7] It is often hard for the engineers to provide the complete design and specification on the complex project in the design stage. A possible recommendation for very complex projects would be to employ the design-build (D-B) contracting technique. This contract mechanism allows a contractor more flexibility for innovation, which leads a lower cost to taxpayers. There are many practical examples of design-build contracts: Utah I-15, State Route 288, Virginia, Route 3 North, Massachusetts, and New Mexico State Route 44[8]. However, if a firm's performance is easy to verify, meaning that the state government can easily monitor any deviations from the specifications and plans, it should invest more in design and specification with the current auction mechanism.

More established ("top") firms are submitting change orders more frequently even if you control for project size and complexity. We observe that (relative) bids are much higher on the most frequently renegotiated items than on the least frequently renegotiated items. There is an obvious strategic manipulation of bids that can help firms win a contract at a competitive low bid and increase the payments it receives later on. Awareness of this can help the state agency to establish stricter negotiation rules, such as the aforementioned reserve price rule.

The economic and statistical significance of the unemployment rate in the regression analysis suggests that, to the extent possible, the Agency should execute its construction program countercyclically. There are potentially large savings from concentrating expensive, non urgent projects during economic slack times. We

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[7] Caution should be exercised here. Sometimes it is relevant to split large projects and sometimes it is recommended to join smaller projects together when there are complementarities - economies of scale or scope. The recommendation depends on the nature of work and potential synergies.

[8] For more detailed descriptions and examples, see "Report to Congress on Public –Private Partnerships" (2004).

recommend that future research investigate the prioritization and funding mechanisms necessary to carry out successfully such a countercyclical program.

Lastly, the geographic dispersion of change orders and projects suggests that future research should investigate why certain parts of the highway system seem more susceptible to large ex post renegotiations. There may be systematic firm-level, project-specific or topographic effects that we could not detect with the database at our disposal for this project.

APPENDICES

Appendix 1A: The most frequently renegotiated item list (top 30)

Item No.	Frequency	Item Description
630.15	55	FLAGGERS
490.3	47	SUPERPAVE BITUMINOUS CONCRETE PAVEMENT
406.5	41	PRICE ADJUSTMENT, ASPHALT CEMENT (N.A.B.I.)
406.25	37	BITUMINOUS CONCRETE PAVEMENT
404.65	32	EMULSIFIED ASPHALT
630.1	32	UNIFORMED TRAFFIC OFFICERS
690.5	28	PRICE ADJUSTMENT, FUEL
507.15	28	REINFORCING STEEL
641.1	27	TRAFFIC CONTROL
210.1	27	COLD PLANING, BITUMINOUS PAVEMENT
501.34	24	CONCRETE, HIGH PERFORMANCE CLASS B
635.11	22	MOBILIZATION/DEMOBILIZATION
204.3	21	GRANULAR BACKFILL FOR STRUCTURES
301.35	20	SUBBASE OF DENSE GRADED CRUSHED STONE
203.15	19	COMMON EXCAVATION
621.2	18	STEEL BEAM GUARD RAIL
608.25	18	ALL PURPOSE EXCAVATOR RENTAL, TYPE I
613.11	18	STONE FILL, TYPE II
649.31	18	GEOTEXTILE UNDER STONE FILL
675.2	17	TRAFFIC SIGNS, TYPE A
621.9	17	TEMPORARY TRAFFIC BARRIER
613.1	17	STONE FILL, TYPE I
646.41	16	DURABLE 100 mm YELLOW LINE
204.2	16	TRENCH EXCAVATION OF EARTH
514.1	14	WATER REPELLENT
646.4	14	WHITE LINE
506.6	14	STRUCTURAL STEEL
646.21	13	100 mm (4 INCH) YELLOW LINE
646.85	13	REMOVAL OF EXISTING PAVEMENT MARKINGS
675.5	13	REMOVING SIGNS
631.1	13	FIELD OFFICE, ENGINEERS

Note: The list contains supplemental agreement items only to the extent they were identified from the existing list of unique items (456 in total) in the spec book.

Appendix 1B: Items that have never been renegotiated (256 items)

Item No.	Frequency	Item Description
619.17	97	YIELDING MARKER POSTS
609.1	89	DUST CONTROL WITH WATER
646.682	49	TEMPORARY 24 INCH STOP BAR, PAINT
651.26	38	HAY BALES FOR EROSION CONTROL
201.31	36	THINNING AND TRIMMING FOR SIGNS
525.1	36	REMOVAL OF EXISTING RAILING
621.81	30	REMOVAL AND DISPOSAL OF GUIDE POSTS
527.1	28	MAINTENANCE OF STRUCTURES AND APPROACHES
653.4	28	INLET PROTECTION DEVICE, TYPE I
653.5	24	BARRIER FENCE
646.71	23	TEMPORARY CROSSWALK MARKING W/DIAGONAL LINES
646.702	22	TEMPORARY CROSSWALK MARKING, PAINT
525.33	19	BRIDGE RAILING, GALVANIZED NETC 2 RAIL
601.7015	18	18" CPEPES
621.53	18	TERMINAL CONNECTOR FOR STEEL BEAM GUARDRAIL
617.12	16	RELOCATE MAILBOX, MULTIPLE SUPPORT
646.632	14	TEMPORARY 6 INCH YELLOW LINE, PAINT
629.42	13	TRANSFER TO NEW SYSTEM, WATER SYSTEM
651.27	12	CEDAR BARK MULCH
501.22	11	CONCRETE, CLASS A
646.662	11	TEMPORARY 12 INCH WHITE LINE, PAINT
646.712	11	TEMPORARY RAILROAD CROSSING SYMBOL, PAINT
675.31	11	W-SHAPE STEEL SIGN POST
675.41	11	FOUNDATION FOR W-SHAPE STEEL POST, 600 MM (24 INCH) DIAMETER
646.466	10	DURABLE 12 INCH WHITE LINE, RECESSED POLYUREA
649.515	10	GEOTEXTILE FOR SILT FENCE, WOVEN WIRE REINFORCED
201.3	9	THINNING AND TRIMMING
516.11	9	BRIDGE EXPANSION JOINT, VERMONT
531.11	9	BEARING DEVICE ASSEMBLY, ELASTOMERIC PAD
619.2	9	REMOVING AND RESETTING PROPERTY MARKERS
656.25	9	EVERGREEN SHRUBS
656.5	9	TRANSPLANTING SHRUBS
678.24	9	ELECTRICAL WIRING
525.5	8	CAST-IN-PLACE CONCRETE BRIDGE RAIL
580.12	8	REPAIR OF CONCRETE SUPERSTRUCTURE SURFACE, CLASS III
621.3	8	BOX BEAM GUARDRAIL
646.512	8	DURABLE RAILROAD CROSSING SYMBOL, THERMOPLASTIC

Item No.	Frequency	Item Description
656.4	8	GROUND COVERS AND VINES
524.21	7	JOINT SEALER, POLYURETHANE
525.23	7	BRIDGE RAILING - ALUMINUM/PEDESTRIAN
601.99	7	RELAYING PIPE CULVERTS
646.32	7	RAILROAD CROSSING SYMBOL
646.49	7	DURABLE LETTER OR SYMBOL
646.491	7	DURABLE LETTER OR SYMBOL, TYPE I TAPE
505.17	6	STEEL PILING, HP 360 × 108 (HP 14 × 73)
510.22	6	PRESTRESSED CONCRETE VOIDED SLABS
525.43	6	BRIDGE RAILING, GALVANIZED HDSB/FASCIA MOUNTED/HAND RAIL
605.11	6	200 MM (8 INCHES)
616.305	6	BITUMINOUS CONCRETE CURB, TYPE A
619.1	6	BOUNDARY MARKERS
646.25	6	300 MM (12 INCH) YELLOW LINE
646.481	6	DURABLE 24 INCH STOP BAR, TYPE I TAPE
653.45	6	FILTER BAG
406.3	5	SURFACE TOLERANCE PAY ADJUSTMENT
505.265	5	STEEL PILING FOR INTEGRAL ABUTMENTS, HP 310 X 125
525.22	5	BRIDGE RAILING - 3 RAIL ALUM
601.2625	5	30" CPEP(SL)
605.21	5	200 MM (8 INCHES)
614.1	5	TEMPORARY RELOCATION OF STREAM
646.52	5	DURABLE RAILROAD CROSSING SYMBOL
656.85	5	TREE PROTECTION
678.16	5	FLASHING BEACON, GROUND MOUNTED
402.1	4	AGGREGATE SHOULDERS, IN PLACE
522.35	4	NONSTRUCTURAL LUMBER, TREATED
529.5	4	REMOVE EXISTING PIPE 12" THROUGH 24" DIAMETER
619.14	4	BOLLARDS
620.3	4	DRIVE GATE FOR WOVEN WIRE FENCE
621.206	4	STEEL BEAM GUARDRAIL, GALVANIZED/NESTED
621.85	4	GUIDE POSTS
629.44	4	PIPE INSULATION
646.401	4	DURABLE 4 INCH WHITE LINE, TYPE I TAPE
646.661	4	TEMPORARY 12 INCH WHITE LINE, TYPE II TAPE
646.75	4	RAISED PAVEMENT MARKERS, TYPE II
653.15	4	HAY BALES
680.2	4	TRAVEL INFORMATION SIGN
203.25	3	CHANNEL EXCAVATION OF EARTH
415.2	3	COLD MIXED RECYCLED BITUMINOUS PAVEMENT
415.25	3	EMULSIFIED ASPHALT, COLD MIX

Item No.	Frequency	Item Description
506.8	3	DRAIN TROUGH
524.2	3	JOINT SEALER, POLYURETHANE
601.081	3	15" RCP CLASS III
601.0905	3	300 MM CPEP
604.11	3	CONCRETE MANHOLE WITH CAST IRON COVER
604.43	3	REHABILITATION OF SEWER MANHOLES
616.22	3	GRANITE BRIDGE CURB
620.15	3	GATE FOR CHAIN-LINK FENCE, 1.2 M (4 FEET)
621.18	3	STEEL BACKED TIMBER GUARDRAIL
646.476	3	DURABLE 12 INCH YELLOW LINE, RECESSED POLYUREA
646.65	3	TEMPORARY 300 MM YELLOW LINE
646.72	3	TEMPORARY RAILROAD CROSSING SYMBOL
649.21	3	GEOTEXTILE UNDER RAILROAD BALLAST
656.41	3	PERENNIALS
656.8	3	LANDSCAPE BACKFILL, TRUCK MEASUREMENT
658.2	3	REST AREA BENCH
660.1	3	TIMBER PAINTING, ENVIRONMENTAL PROTECTION
660.2	3	TIMBER PAINTING, FIRE RETARDANT
660.3	3	TIMBER PAINTING, INSECTICIDE/FUNGICIDE
677.13	3	OVERHEAD TRAFFIC SIGN SUPPORT, MULTI-SUPPORT
678.2	3	INTERCONNECTING CABLE
678.27	3	PULL BOX, DOUBLE
854.07	3	AIRCRAFT TIE DOWN ANCHOR,TYPE A
864.05	3	L-108, 1/C #8, L-824, TYPE C, 5KV
864.06	3	L-108, #8 COUNTERPOISE WIRE
201.11	2	CLEARING AND GRUBBING, INCLUDING INDIVIDUAL TREES AND STUMPS
501.221	2	CONCRETE, CLASS A QC/QA
525.11	2	RESETTING RAILING
525.3	2	BRIDGE RAILING - 1 RAIL GALV. BOX BEAM
526.3	2	MECHANICALLY STABILIZED EARTH (MSE) WALL
527.11	2	TRAFFIC PROTECTION FOR BRIDGE PROJECTS
528.12	2	TEMPORARY PEDESTRIAN BRIDGE
529.26	2	REMOVAL OF CONCRETE OR MASONRY
531.12	2	BEARING DEVICE ASSEMBLY, POT
555.2	2	ACCESS TO BRIDGE
601.0246	2	36" CAAP .075 (2-2/3 X 1/2)
601.0405	2	12" PCCSP .064 (2-2/3 X 1/2)
601.0816	2	18" RCP CLASS IV
601.5814	2	450 MM CPEP ELBOW
604.6	2	CAPPING EXISTING DROP INLETS
612.1	2	GABION RETAINING WALL

Item No.	Frequency	Item Description
619.15	2	WOOD MARKER POSTS
621.16	2	CEDAR LOG RAIL
621.17	2	CABLE GUARDRAIL
621.216	2	HD STEEL BEAM GUARDRAIL, GALVANIZED/NESTED
621.54	2	MODIFIED ECCENTRIC LOADER TERMINAL
621.78	2	REPLACE GUARD RAIL CABLE
623.3	2	INCLINOMETER
628.6	2	SEWER MAIN ON BRIDGE
629.3	2	REMOVE HYDRANT
629.31	2	METER PIT
629.38	2	DUCTILE IRON FITTINGS
646.411	2	DURABLE 4 INCH YELLOW LINE, TYPE I TAPE
646.432	2	DURABLE 150 MM YELLOW LINE, THERMOPLASTIC
646.511	2	DURABLE RAILROAD CROSSING SYMBOL, TYPE I TAPE
649.1	2	GEOTEXTILE FABRIC FOR FILTERS
651.3	2	SODDING
653.3	2	PREFABRICATED CHECK DAM
656.65	2	LANDSCAPE WATERING
676.15	2	REMOVE AND REPLACE REFLECTOR UNIT
864.04	2	L-108, CABLE TRENCH
864.14	2	L-125, TAXIWAY GUIDANCE SIGN
901.1	2	REMOVAL AND REPLACEMENT OF CROSS TIES
960.11	2	MAINTENANCE OF RAIL TRAFFIC
203.26	1	CHANNEL EXCAVATION OF ROCK
203.35	1	GRAVEL BACKFILL FOR SLOPE STABILIZATION
404.45	1	TAR EMULSION
407.01	1	PAVER PLACED SURFACE TREATMENT, TYPE C
407.02	1	QUICK SET SLURRY, TYPE II
505.165	1	STEEL PILING, HP 12 X 84
505.2	1	STEEL PILING, HP 360 × 174 (HP 14 × 117)
505.255	1	STEEL PILING FOR INTEGRAL ABUTMENTS, HP 310 X 93
505.3	1	STEEL PILING FOR INTEGRAL ABUTMENTS, HP 14 X 117
510.23	1	PRESTRESSED CONCRETE GIRDERS
524.12	1	JOINT SEALER, COLD POURED
525.21	1	BRIDGE RAILING - 2 RAIL ALUM
525.31	1	BRIDGE RAILING, GALVANIZED 2 RAIL BOX BEAM
525.32	1	BRIDGE RAILING - GALV. BOX BEAM /PEDESTRIAN
525.42	1	BRIDGE RAILING, GALVANIZED HDSB/CURB MOUNTED/HAND RAIL
526.15	1	TREATED TIMBER BIN - TYPE RETAINING WALL
531.13	1	BEARING DEVICE ASSEMBLY, STEEL
541.21	1	CONCRETE, CLASS AA

Item No.	Frequency	Item Description
541.31	1	CONCRETE, CLASS D
541.4	1	CONCRETE, CLASS LW
541.58	1	MORTAR, TYPE IV
545.2	1	PREFABRICATED MULTI-MODAL BRIDGE
580.19	1	CONCRETE, CLASS AA OVERLAY
580.4	1	FIBER REINFORCED POLYMER WRAP
601.0046	1	36" CSP .079 (2-2/3 X 1/2)
601.0052	1	42" CSP .109 (2-2/3 X 1/2)
601.0068	1	1500 CSP 3.51 (68 X 12)
601.0205	1	12" CAAP .060 (2-2/3 X 1/2)
601.0225	1	24" CAAP .060 (2-2/3 X 1/2)
601.0227	1	24" CAAP .105 (2-2/3X1/2)
601.0237	1	30" CAAP .105 (2-2/3 X 1/2)
601.0257	1	48" CAAP .105 (2-2/3 X 1/2)
601.041	1	375 MM PCCSP 1.63 MM (68 MM X 12 MM)
601.0416	1	450 MM PCCSP 2.01 MM (68 MM X 12 MM)
601.0426	1	600 MM PCCSP 2.01 MM (68 MM X 12 MM)
601.0436	1	30" PCCSP .079 (2-2/3 X 1/2)
601.0446	1	900 MM PCCSP 2.01 MM (68 MM X 12 MM)
601.0457	1	48" PCCSP .109 (2-2/3 X 1/2)
601.0527	1	54" PCCSP .109 (3X1)
601.0542	1	1800 MM PCCSP 2.77 MM (75 MM X 25 MM)
601.0805	1	12" RCP CLASS III
601.0826	1	24" RCP CLASS IV
601.0827	1	600 MM RCP CLASS V
601.0845	1	36" RCP CLASS III
601.0855	1	48" RCP CLASS III
601.0925	1	30" CPEP
601.5415	1	450 MM PCCSP ELBOW 1.63 MM (68 MM X 12 MM)
601.6046	1	900 CSPES 2.01 (68 X 12)
601.6061	1	54" CSPES .109 (2-2/3 X 1/2)
601.621	1	375 MM CAAPES 1.52 MM (68 MM X 12 MM)
601.6215	1	18"CAAPES .060 (2-2/3 X 1/2)
601.7005	1	12" CPEPES
605.9	1	UNDERDRAIN RISER
608.11	1	BULLDOZER RENTAL, TYPE II
608.2	1	DRAGLINE RENTAL, TYPE I
616.25	1	PRECAST REINFORCED CONCRETE CURB, TYPE A
616.315	1	BITUMINOUS CONCRETE CURB, TYPE B
618.21	1	REMOVE AND REPLACE BRICK PAVING
621.217	1	HD STEEL BEAM GUARDRAIL, GALVANIZED/NESTED W/8 FEET POSTS

Item No.	Frequency	Item Description
621.35	1	STEEL BEAM MEDIAN BARRIER
621.66	1	ANCHOR FOR CABLE RAIL AT OPENINGS
623.5	1	GROUND WATER OBSERVATION WELL
623.6	1	EARTH PRESSURE CELL
624.25	1	DUCTS, DIRECT BURIAL (PVC)
624.39	1	PAD FOR 3 PHASE TRANSFORMER
624.4	1	PAD FOR SERVICE AREA INTERFACE
624.51	1	HANDHOLE - LARGE
624.52	1	HANDHOLE - SMALL
628.27	1	VITRIFIED CLAY PIPE, EXTRA STRENGTH
628.3	1	RELAYING SEWER PIPE
628.5	1	ADJUST ELEVATION OF SEWER CLEANOUT
629.26	1	GATE VALVE
629.32	1	PLASTIC WATER PIPE, FLEXIBLE
629.45	1	IRRIGATION SYSTEM
636.15	1	UTILITY SYSTEM
646.403	1	DURABLE 4 INCH WHITE LINE, EPOXY PAINT
646.407	1	DURABLE 4 INCH WHITE LINE, RECESSED TYPE I TAPE
646.413	1	DURABLE 4 INCH YELLOW LINE, EPOXY PAINT
646.417	1	DURABLE 4 INCH YELLOW LINE, RECESSED TYPE I TAPE
646.421	1	DURABLE 6 INCH WHITE LINE, TYPE I TAPE
646.427	1	DURABLE 6 INCH WHITE LINE, RECESSED TYPE I TAPE
646.428	1	DURABLE 6 INCH WHITE LINE, RECESSED THERMOPLASTIC
646.431	1	DURABLE 6 INCH YELLOW LINE, TYPE I TAPE
646.437	1	DURABLE 6 INCH YELLOW LINE, RECESSED TYPE I TAPE
646.438	1	DURABLE 6 INCH YELLOW LINE, RECESSED THERMOPLASTIC
646.441	1	DURABLE 8 INCH WHITE LINE, TYPE I TAPE
646.447	1	DURABLE 8 INCH WHITE LINE, RECESSED TYPE I TAPE
646.451	1	DURABLE 8 INCH YELLOW LINE, TYPE I TAPE
646.457	1	DURABLE 8 INCH YELLOW LINE, RECESSED TYPE I TAPE
646.467	1	DURABLE 12 INCH WHITE LINE, RECESSED TYPE I TAPE
646.487	1	DURABLE 24 INCH STOP BAR, RECESSED TYPE I TAPE
646.507	1	DURABLE CROSSWALK MARKING, RECESSED TYPE I TAPE
646.672	1	TEMPORARY 12 INCH YELLOW LINE, PAINT
646.8	1	RAISED PAVEMENT MARKERS, TYPE I
648.1	1	PAINTED CURB
653.26	1	TEMPORARY STONE CHECK DAM, TYPE II
653.41	1	INLET PROTECTION DEVICE, TYPE II
653.65	1	LIVE FASCINE
658.1	1	ROADSIDE REST FACILITY (BUILDING)
661.1	1	METAL ROOFING

Item No.	Frequency	Item Description
675.4	1	FOUNDATION FOR W-SHAPE STEEL POST, 450 MM (18 INCH) DIAMETER
676.2	1	DELINEATOR WITH FLEXIBLE POST
677.11	1	OVERHEAD TRAFFIC SIGN SUPPORT, TUBULAR BEAM
677.12	1	OVERHEAD TRAFFIC SIGN SUPPORT, CANTILEVER
678.41	1	TEMPORARY FLASHING BEACON
680.4	1	RELOCATE INFORMATION PLAZA
681.1	1	COLLECTION & DISPOSAL OF BULKY METALLIC WASTE
854.01	1	P-602 BITUMINOUS PRIME COAT
864.08	1	L-110, 2-WAY X 4" DIA. U.G. ELECTRICAL DUCT
864.11	1	L-125, MEDIUM INTENS TAXIWAY LTS, BASE MTD
904.15	1	REMOVAL AND REPLACEMENT OF INDIVIDUAL RAILS
910.1	1	BALLAST
930.31	1	WOOD PLATFORM
995.11	1	NO EXCUSE BONUS (N.A.B.I.)

Regression Variables (Tables 1 and 2 of Part Two)

Dependent Variable	Descriptions and construction of the variable
Log of Bid	The weighted sum of unit prices and quantities on the original contract. The logarithm of bidding amount of each bidder on the original contract is used in the empirical analysis.
Relative bid	Bidding amount for each bidder on the original contract divided by engineer's cost estimate
Independent Variable	**Auction specific characteristics**
Proportion of price adjustment	Ex post total price adjustment amount divided by engineer's cost estimate in the project. The price adjustment amount is the reimbursed amount according to the price adjustment clauses for fuel and asphalt.
Proportion of positive quantity adjustment	Ex post total positive quantity adjustment amount divided by engineer's cost estimate in the project.
Proportion of negative quantity adjustment	Ex post total negative quantity adjustment amount divided by engineer's cost estimate in the project.
New item amount	The total value of new added items divided by bidding amount in the project.
Quantity Adjustment	The dummy variable that takes the value one if there was a quantity adjustment in the project.
Price Adjustment	The dummy variable that takes the value one if there was a price adjustment in the project.
Price & Quantity Adjustment	The dummy variable that takes the value one if there were a quantity adjustment and a price adjustment in the project.
Log of Engineer's Estimate	The logarithm of engineering cost estimates on the original contract.
Log of Calendar days	The number of calendar days that are required to complete the project. The logarithm of the number of calendar days is used in the empirical analysis.

Independent Variable	Auction specific characteristics
Expected number of Bidders	It is calculated using past 12 month information for each bidder and plan holder list. We construct the probability of submitting bids conditional on being a plan holder. For an auction at time t, the expected number of bidders is the summation of the participation probabilities. Then, we multiply dummy variable to the expected number of bidders to identify an auction, in which the qualified plan holders are more than 3 on the plan holder list. The 3 qualified plan holders are the threshold to release the information on plan holders' identities.
Asphalt Project	The dummy variable that takes the value one if a project is the asphalt paving project.
Bridge Project	The dummy variable that takes the value one if a project is the bridge project.
	Bidder specific characteristics
Log of Firm's Backlog	We assume that a project is completed in a uniform fashion over the length of the contract. A contract backlog is constructed by summing the remaining values of a firm's ongoing projects. However, if projects are completed, the backlog of the firm goes to zero. The logarithm of the amount of a bidder's current backlog is used in the empirical analysis.
Distance to the project locations	The logarithm of distance between the firm's location and the location of work sites. If a project is needed to perform statewide, we consider its location as the center of the state. Moreover, if a project has multiple sub-projects, we take the average of the distances to each work site.
Rival's minimum distance	The logarithm of the minimum of all rivals' distances between work sites and their locations in an auction
Rival's minimum backlog	The logarithm of the minimum of all rivals' backlog amounts in an auction
A top firm	A firm is assigned as a top firm if its annual revenue value is greater than 20 percent of the total value of all firms' revenues each year during the sample period.
Debt to Asset Ratio	A firm's total debt is the sum of current liabilities, long-term debt and other liabilities. We construct the ratio as a firm's total debt divided by its total asset every year.
D-A Ratio*Top Firm	The interaction term as multiplying dummy variable of a top firm to Debt to Asset Ratio.
Log of Asset	The logarithm of a bidder's asset amount each year
Local Market	The total remaining value of a firm's ongoing projects in a county divided

Power	by the total remaining value of all firms' ongoing projects in that county at time t.
Utilization Rate	It is a firm's current backlog divided by its maximum backlog during the sample period. It is set to zero if a firm never won during the sample period.
	Variables on general economic conditions
Unemployment Rate	The monthly unemployment rate in Vermont from the Bureau of Labor Statistics (BLS)
Real Volume of Projects	Monthly volume of contracted projects is measured by the logarithm of the amount of all awarded projects at a given month; deflated by the monthly index of producer's prices published by BLS.
Gas price index	The three month moving average of the monthly posted gas price index in Vermont from the Vermont Agency of Transportation
Log of Number of Building Permits	The logarithm of the three month moving average of monthly building permits issued for Vermont from the Bureau of Economic Analysis.

Regression Variables (Tables 3 and 4 of Part Two)

Dependent Variable	**Descriptions and construction of the variable**
Number of change orders	The frequency that the renegotiation occurs in an auction. It equals the total number of change order numbers in an auction
Change orders	A dummy variable that identifies whether an auction was renegotiated
Independent Variable	**Auction specific characteristics**
Log of Engineer's Estimate	The logarithm of engineering cost estimates on the original contract.
Expected number of Bidders	It is calculated using past 12 month information for each bidder and plan holder list. We construct the probability of submitting bids conditional on being a plan holder. For an auction at time t, the expected number of bidders is the summation of the participation probabilities. Then, we multiply dummy variable to the expected number of bidders to identify an auction, in which the qualified plan holders are more than 3 on the plan holder list. The 3 qualified plan holders are the threshold to release the information on plan holders' identities.
Log of Calendar days	The number of calendar days that are required to complete the project. The logarithm of the number of calendar days is used in the empirical analysis.
Asphalt Project	The dummy variable that takes the value one if a project is the asphalt paving project.
Bridge Project	The dummy variable that takes the value one if a project is the bridge project.
	Bidder specific characteristics
Distance to the project locations	The logarithm of distance between the firm's location and the location of work sites. If a project is needed to perform statewide, we consider its location as the center of the state. Moreover, if a project has multiple sub-projects, we take the average of the distances to each work site.
A top firm	A firm is assigned as a top firm if its annual revenue value is greater than 20 percent of the total value of all firms' revenues each year during the sample period.
Debt to Asset Ratio	A firm's total debt is the sum of current liabilities, long-term debt and other liabilities. We construct the ratio as a firm's total debt divided by its total asset every year.
D-A Ratio*Top Firm	The interaction term as multiplying dummy variable of a top firm to Debt to Asset Ratio.

Log of Asset	The logarithm of a bidder's asset amount each year
Local Market Power	The total remaining value of a firm's ongoing projects in a county divided by the total remaining value of all firms' ongoing projects in that county at time t.
MLT	It is the proportional difference between the winning and the second lowest bid when there are multiple bidders. In the case of a single bidder, it is constructed as the proportional difference between the winning bidder and the engineering cost estimate.
Deviation	The proportional difference between the winning bid and the engineer cost estimates.
	Variables on general economic conditions
Average Unemployment Rate	The average value of the monthly unemployment rate during completing a project. The monthly unemployment rate in Vermont is from the Bureau of Labor Statistics (BLS)
Average Gas price index	The average value of gas price index during completing a project. The monthly posted gas price index in Vermont is from the Vermont Agency of Transportation.
Log of Number of Building Permits	The logarithm of the three month moving average of monthly building permits issued for Vermont from the Bureau of Economic Analysis.

Regression Variables (Tables 5 and 6 of Part Two)

Dependent Variable	Descriptions and construction of the variable
Amounts of Change Orders(Ratio relative to engineer's cost estimate)	The dollar amounts of Change Orders relative to the engineer's cost estimate
Log of RMSD	The logarithm of Root Mean Square Deviation. We calculate the sum of the squared differences between engineering cost estimates and bidders' bids on an item divided by the number of tasks. Then, we take the square root of the value and take a logarithm value of each bidder in an auction.
Independent Variable	**Auction specific characteristics**
Log of Engineer's Estimate	The logarithm of engineering cost estimates on the original contract.
Expected number of Bidders	It is calculated using past 12 month information for each bidder and plan holder list. We construct the probability of submitting bids conditional on being a plan holder. For an auction at time t, the expected number of bidders is the summation of the participation probabilities. Then, we multiply dummy variable to the expected number of bidders to identify an auction, in which the qualified plan holders are more than 3 on the plan holder list. The 3 qualified plan holders are the threshold to release the information on plan holders' identities.
Log of Calendar days	The number of calendar days that are required to complete the project. The logarithm of the number of calendar days is used in the empirical analysis.
Asphalt Project	The dummy variable that takes the value one if a project is the asphalt paving project.
Bridge Project	The dummy variable that takes the value one if a project is the bridge project.
	Bidder specific characteristics
Distance to the project locations	The logarithm of distance between the firm's location and the location of work sites. If a project is needed to perform statewide, we consider its location as the center of the state. Moreover, if a project has multiple sub-projects, we take the average of the distances to each work site.
A top firm	A firm is assigned as a top firm if its annual revenue value is greater than 20 percent of the total value of all firms' revenues each year during the sample period.

Debt to Asset Ratio	A firm's total debt is the sum of current liabilities, long-term debt and other liabilities. We construct the ratio as a firm's total debt divided by its total asset every year.
D-A Ratio*Top Firm	The interaction term as multiplying dummy variable of a top firm to Debt to Asset Ratio.
Log of Asset	The logarithm of a bidder's asset amount each year
Local Market Power	The total remaining value of a firm's ongoing projects in a county divided by the total remaining value of all firms' ongoing projects in that county at time t.
MLT	It is the proportional difference between the winning and the second lowest bid when there are multiple bidders. In the case of a single bidder, it is constructed as the proportional difference between the winning bidder and the engineering cost estimate.
Deviation	The proportional difference between the winning bid and the engineer cost estimates.
	Variables on general economic conditions
Average Unemployment Rate	The average value of the monthly unemployment rate during completing a project. The monthly unemployment rate in Vermont is from the Bureau of Labor Statistics (BLS)
Average Gas price index	The average value of gas price index during completing a project. The monthly posted gas price index in Vermont is from the Vermont Agency of Transportation.
Log of Number of Building Permits	The logarithm of the three month moving average of monthly building permits issued for Vermont from the Bureau of Economic Analysis.

Regression Variables (Tables 7 and 8 of Part Two)

Dependent Variable	Descriptions and construction of the variable
Itemized Bid	The logarithm of bids of each bidder at item level.
Itemized relative bid	Bids at item level divided by engineer's cost estimate of that item
Independent Variable	**Auction specific characteristics**
Positive Quantity Adjustment	The dollar amount of ex post total positive quantity adjustment divided by $10,000 at item level.
Negative Quantity Adjustment	The dollar amount of ex post total negative quantity adjustment divided by $100,000 at item level.
Less Frequently Renegotiated Item	The dummy variable that takes the value one if an item has been less frequently renegotiated during the sample period. More specifically, The dummy variable that takes the value one if the frequency of renegotiation for an item is below median of the frequency distribution.
More Frequently Renegotiated Item	The dummy variable that takes the value one if an item has been more frequently renegotiated during the sample period. More specifically, The dummy variable that takes the value one if the frequency of renegotiation for an item is above median of the frequency distribution.
Log of Engineer's Item Estimate	The logarithm of engineering cost estimates on an item.
Expected number of Bidders	It is calculated using past 12 month information for each bidder and plan holder list. We construct the probability of submitting bids conditional on being a plan holder. For an auction at time t, the expected number of bidders is the summation of the participation probabilities. Then, we multiply dummy variable to the expected number of bidders to identify an auction, in which the qualified plan holders are more than 3 on the plan holder list. The 3 qualified plan holders are the threshold to release the information on plan holders' identities.
Asphalt Project	The dummy variable that takes the value one if a project is the asphalt paving project.
Bridge Project	The dummy variable that takes the value one if a project is the bridge project.
	Bidder specific characteristics
Log of Firm's Backlog	We assume that a project is completed in a uniform fashion over the length of the contract. A contract backlog is constructed by summing the remaining values of a firm's ongoing projects. However, if projects are completed, the backlog of the firm goes to zero. The logarithm of the

	amount of a bidder's current backlog is used in the empirical analysis.
Distance to the project locations	The logarithm of distance between the firm's location and the location of work sites. If a project is needed to perform statewide, we consider its location as the center of the state. Moreover, if a project has multiple sub-projects, we take the average of the distances to each work site.
Rival's minimum distance	The logarithm of the minimum of all rivals' distances between work sites and their locations in an auction
Rival's minimum backlog	The logarithm of the minimum of all rivals' backlog amounts in an auction
A top firm	A firm is assigned as a top firm if its annual revenue value is greater than 20 percent of the total value of all firms' revenues each year during the sample period.
Debt to Asset Ratio	A firm's total debt is the sum of current liabilities, long-term debt and other liabilities. We construct the ratio as a firm's total debt divided by its total asset every year.
D-A Ratio*Top Firm	The interaction term as multiplying dummy variable of a top firm to Debt to Asset Ratio.
Log of Asset	The logarithm of a bidder's asset amount each year
Local Market Power	The total remaining value of a firm's ongoing projects in a county divided by the total remaining value of all firms' ongoing projects in that county at time t.
	Variables on general economic conditions
Unemployment Rate	The monthly unemployment rate in Vermont from the Bureau of Labor Statistics (BLS)
Log of Number of Building Permits	The logarithm of the three month moving average of monthly building permits issued for Vermont from the Bureau of Economic Analysis.

Summary Statistics for Tables 1 and 2 of Part Two

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of Bid amount	1028	13.885	1.041	10.125	17.272
Relative Bid	1028	1.083	0.248	0.436	1.919
Proportion of Price Adjustment	1028	0.006	0.024	0.000	0.236
Proportion of Positive Quantity Adjustment	1028	0.045	0.080	0.000	0.825
Proportion of Negative Quantity Adjustment	1028	-0.049	0.130	-1.353	0.000
Top Firm	1028	0.082	0.274	0.000	1.000
New Item Amount	1028	0.050	0.098	-0.008	0.777
Quantity Adjustment	1028	0.738	0.440	0.000	1.000
Price Adjustment	1028	0.006	0.076	0.000	1.000
Price & Quantity Adjustment	1028	0.088	0.283	0.000	1.000
Log of Engineer's Estimate	1028	13.831	1.060	10.174	17.016
Debt to Asset Ratio	957	0.452	0.243	0.000	1.070
D-A Ratio*Top Firm	957	0.022	0.116	0.000	0.783
Log of Asset	985	15.862	1.777	12.528	19.689
Local Market Power	1028	0.100	0.197	0.000	1.000
Log of Calendar Days	1028	5.423	0.777	2.639	7.107
Log of Firm's Backlog	957	9.575	7.108	0.000	17.516
Expected Number of Bidders	927	3.760	3.021	0.000	11.524
Gas Price Index	1006	2.584	0.527	1.807	4.033
Log of Number of Building Permits	1006	10.102	0.933	7.361	11.192
Distance to the Project Location	1028	3.757	0.811	0.449	6.969
Rival's Minimum Backlog	1011	3.335	6.049	0.000	17.440
Rival's Minimum Distance	1027	2.802	1.111	-0.713	5.791
Real Volume of Projects	1006	12.512	0.324	11.564	13.184
Utilization	946	0.248	0.266	0.000	0.947
Unemployment Rate	1028	4.715	1.430	3.300	7.300
Asphalt Project	1028	0.418	0.494	0.000	1.000
Bridge Project	1028	0.475	0.500	0.000	1.000

Summary statistics for table 3 and 4 of Part Two

Variable	Obs	Mean	Std. Dev.	Min	Max
The Number of Change Orders	312	3.628	4.256	0.000	35.000
Change Orders	312	0.824	0.382	0.000	1.000
Log of Engineer's Estimate	312	13.883	1.163	10.174	17.016
Expected Number of Bidders	281	2.516	2.743	0.000	11.524
Top Firm	312	0.647	0.479	0.000	1.000
Proportion of Deviation	312	-0.076	0.225	-1.293	0.433
Debt to Asset Ratio	299	0.427	0.247	0.000	1.070
D-A Ratio*Top Firm	299	0.259	0.277	0.000	0.869
Log of Assets	303	16.264	2.034	12.528	19.689
Local Market Power	312	0.320	0.310	0.002	1.000
MLT	312	0.111	0.151	-0.238	0.920
Log of Calendar Days	312	5.295	0.769	2.639	7.107
Distance to the Project Location	312	3.769	0.786	1.136	6.969
Average of Gas Price Index	312	2.724	0.383	2.080	4.030
Average of Unemployment Rate	312	4.815	1.393	3.300	7.270
Log of Number of Building Permits	304	10.146	0.901	7.361	11.192
Asphalt Project Dummy	312	0.526	0.500	0.000	1.000
Bridge Project Dummy	312	0.375	0.485	0.000	1.000

Summary statistics for table 5 of Part Two

Variable	Obs	Mean	Std. Dev.	Min	Max
Amounts of Change Orders (Ratio relative to engineer's cost estimate)	312	0.064	0.102	-0.173	0.769
Expected Number of Bidders	281	2.516	2.743	0.000	11.524
Top Firm	312	0.647	0.479	0.000	1.000
Proportion of Deviation	312	-0.076	0.225	-1.293	0.433
Local Market Power	312	0.320	0.310	0.002	1.000
Log of Calendar Days	312	5.295	0.769	2.639	7.107
Debt to Asset Ratio	299	0.427	0.247	0.000	1.070
D-A Ratio*Top Firm	299	0.259	0.277	0.000	0.869
Log of Assets	303	16.264	2.034	12.528	19.689
Distance to the Project Location	312	3.769	0.786	1.136	6.969
Average of Gas Price Index	312	2.724	0.383	2.080	4.030
Average of Unemployment Rate	312	4.815	1.393	3.300	7.270
Log of Number of Building Permits	304	10.146	0.901	7.361	11.192
Asphalt Project Dummy	312	0.526	0.500	0.000	1.000
Bridge Project Dummy	312	0.375	0.485	0.000	1.000

Summary statistics for table 6 of Part Two

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of RMSE	1028	9.823	0.828	6.187	12.311
Dummy of Change Orders	1028	0.831	0.375	0.000	1.000
Amounts of Change Orders (Ratio)	1028	0.058	0.118	-0.800	0.869
Log of Engineer's Estimate	1028	13.831	1.060	10.174	17.016
Top Firm	1028	0.082	0.274	0.000	1.000
Debt to Asset Ratio	957	0.452	0.243	0.000	1.070
D-A Ratio*Top Firm	957	0.022	0.116	0.000	0.783
Log of Assets	985	15.862	1.777	12.528	19.689
Local Market Power	1028	0.100	0.197	0.000	1.000
Log of Calendar Days	1028	5.423	0.777	2.639	7.107
Expected Number of Bidders	927	3.760	3.021	0.000	11.524
Distance to the Project Location	1028	3.757	0.811	0.449	6.969
Log of Firm's Backlog	957	9.575	7.108	0.000	17.516
Rival's Minimum Backlog	1011	3.335	6.049	0.000	17.440
Rival's Minimum Distance	1027	2.802	1.111	-0.713	5.791
Unemployment Rate	1028	4.715	1.430	3.300	7.300
Asphalt Project	1028	0.418	0.494	0.000	1.000
Bridge Project	1028	0.475	0.500	0.000	1.000

Summary statistics for table 7 and 8 of Part Two

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of Itemized Bid	57324	8.263	2.152	0.000	15.559
Itemized Relative Bid	57324	1.080	0.487	0.200	2.500
Positive Quantity Adjustment	57324	0.101	1.692	0.000	212.960
Negative Quantity Adjustment	57324	-0.014	0.292	-27.608	0.000
Less Frequently Renegotiated Item	57313	0.281	0.450	0.000	1.000
More Frequently Renegotiated Item	57313	0.572	0.495	0.000	1.000
Top Firm	57324	0.078	0.269	0.000	1.000
Log of Engineer's Item Estimate	57324	8.296	2.138	0.000	15.400
Debt to Asset Ratio	54097	0.442	0.243	0.000	1.070
D-A Ratio*Top Firm	54097	0.024	0.121	0.000	0.783
Log of Assets	55482	16.004	1.762	12.528	19.689
Local Market Power	57324	0.141	0.257	0.000	1.000
Expected Number of Bidders	50614	4.005	2.891	0.000	11.524
Distance to the Project Location	57314	3.538	1.001	0.131	6.481
Log of Firm's Backlog	54289	9.951	7.044	0.000	17.516
Rival's Minimum Backlog	56681	3.393	6.130	0.000	17.440
Rival's Minimum Distance	57314	2.656	1.151	-0.713	5.791
Unemployment Rate	57324	4.588	1.370	3.300	7.300
Asphalt Project Dummy	57324	0.432	0.495	0.000	1.000
Bridge Project Dummy	57324	0.498	0.500	0.000	1.000

Appendix B

Summary of Use of Price Adjustment Clauses, Fall 2008

AASHTO Subcommittee on Construction, Contract Administration Technical Section

Of 52 member departments (includes the 50 states plus DC and PR):

- 40 (77%) states use a fuel price adjustment clause
- 42 (81%) states use an asphalt cement price adjustment clause
- 15 (29%) states use a steel price adjustment clause
- 3 (6%) states use a Portland cement price adjustment clause

The following use "Opt-in/Opt-out" clauses for:

- Fuel (9 states): CO, KS, LA, MO, MT, ND, SD, VA, WY
- Asphalt cement (4 states): IL, KS, LA, MO
- Steel (5 states): IL, NE, OR, PA, VA

REFERENCES

AASHTO Subcommittee on Construction. "Price/Supply Issues, Alternate Bidding Issues, Practices for Increasing Competition."
http://construction.transportation.org/Pages/Surveys.aspx

Bajari, P., S. Houghton, and S. Tadelis (2011): Bidding for Incomplete Contracts: An Empirical Analysis of Adaptation Costs, Working Paper (earlier version NBER working paper #12051).

Bajari, P., S. Tadelis (2006): Incentives and award procedures: competitive tendering versus negotiations in procurement in the Handbook of Procurement Cambridge University press.

Bajari, P., R. McMillan, and S. Tadelis (2009): Auctions versus Negotiations in Procurement: an Empirical Analysis, Journal of Law, Economics, and Organization, 25(2), 372-399.

Chong, E., C. Staropoli, and A. Yvrande-Billon (2010): Auction versus Negotiation in Public Procurement: Looking for Empirical Evidence, Working paper

De Silva, D. G., T. Dunne, A. Kankanamge, and G. Kosmopoulou (2008): The Impact of Public Information on Bidding in Highway Procurement Auctions, European Economic Review, 52, 150-181.

De Silva, D. G., T. Dunne, and G. Kosmopoulou (2003): An Empirical Analysis of Entrant and Incumbent Bidding in Road Construction Auctions, Journal of Industrial Economics, 51(3), 295-316.

Holmgren, M., E. Jessup, K. Casavant, and J. Lazarus (2010): Improving Fuel Price Adjustment for State Departments of Transportation: A National Survey of Practice, Transportation Research Forum.

Kosmopoulou, G., and X. Zhou (2012): Price Adjustment Policies in Procurement Contracting: An Analysis of Bidding Behavior, Working paper

United States Department of Transportation. "Report to Congress on Public-Private Partnerships"
http://www.fhwa.dot.gov/reports/pppdec2004/