Online Appendix to "Bidding for Contracts under Uncertain Demand: Skewed Bidding and Risk Sharing"

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Appendix A

This subsection contains additinal figures, tables and results in the order they appear in the main text.

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Examples of projects that may be good Lump Sum contracting candidates:

- Bridge painting
- Bridge projects
- Fencing
- Guardrail
- Intersection improvements (with known utilities)
- Landscaping
- Lighting
- Mill/Resurface (without complex overbuild requirements)
- Minor road widening
- Sidewalks
- Signing
- Signalization

Examples of projects that may not be good Lump Sum contracting candidates:

- Urban construction/reconstruction
- Rehabilitation of movable bridges
- Projects with subsoil earthwork
- Concrete pavement rehabilitation projects
- Major bridge rehabilitation/repair projects where there are many unknown quantities.

Figure A.1: Excerpt from The FDOT Project Guidelines

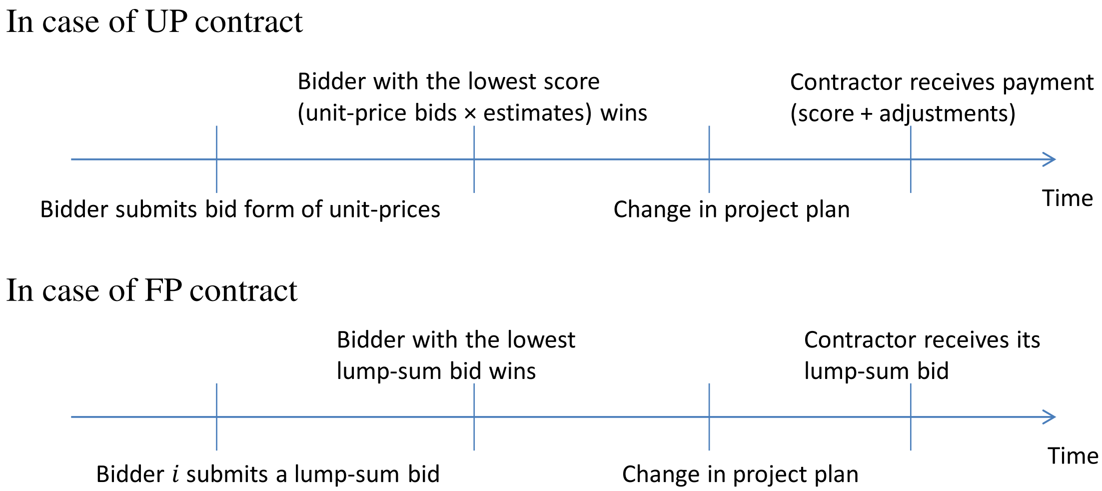

Figure A.2: Timeline of Events

Table A.1: Endogenous Switching Model: Relevance of Excluded Variables

Dependent Variable	FP (=1 if FP, =0 if UP)		
Specification	(1)	(2)	(3)
District Office Backlog	.844	.853	.884
	(.13)	(.14)	(.14)
District FE	y	y	y
Project Characteristics	y	y	y
Year Trend	y	y	y
Month FE	n	y	y
Bidder FE	n	n	y
N	1890	1890	1890

Standard errors are clustered at the district-year-month level. Project characteristics include engineer's estimate of project cost and number of plan holders. District office backlog is calculated as the total dollar value of incomplete projects at the time of project letting.

Table A.2: Endogenous Switching Model: without the Period of Stimulus Spending

Dependent Variable	$score_j$ (log)					
Specification	(1)		(2)		(3)	
Regime	FP	UP	FP	UP	FP	UP
ρ_f, ρ_u	-.759	.177	-.739	.0183	-.737	.0214
	(.11)	(.26)	(.13)	(.19)	(.13)	(.18)
σ_f, σ_u	.359	.214	.344	.210	.342	.207
	(.029	(.010)	(.027)	(.0093)	(.027)	(.0093)
Engineer's Cost Estimate (log)	.991	.991	.996	.996	.997	.997
	(.011	(.011)	(.0090)	(.0090)	(.0089)	(.0089)
Bidder Backlog	.122	.122	.0775	.0775	.843	.843
	(.19	(.19)	(.20)	(.20)	(.32)	(.32)
# of Participating Bidders	-.0142	-.0142	-.0145	-.0145	-.0155	-.0155
	(.0036	(.0036)	(.0033)	(.0033)	(.0033)	(.0033)
Month FE	n	n	y	y	y	y
Bidder FE	n	n	n	n	y	y
N	3933	3933	3933	3933	3933	3933

Standard errors are clustered at the district-year level.

District office backlog, district fixed effects, and year trends are controlled for in all specifications.

Bidders that have won less than one percent of the total value of projects are grouped together as fringe firms.

District office backlog is calculated as the total dollar value of incomplete projects at the time of project letting.

Table A.3: Test of Endogeneity of Excluded Variable

Dependent Variable	Time Overrun		
District Office Backlog	-.458	-.437	-.266
	(.37)	(.38)	(.38)
Bidder Backlog	y	y	y
Project Characteristics	y	y	y
District FE	y	y	y
Year Trend	y	y	y
Month FE	n	n	y
Bidder FE	n	n	n
N	1890	1890	1890

Standard errors are clustered at the district-year-month level.

Time overrun is defined as the log-difference in actual and expected contract days.

The test is conducted using the sample of 1,890 winning contractors.

Table A.4: Contract Type for Top 10 Items in UP contracts

Item Category	**Contractual Arrangement**	**Frequency**
Mobilization	Lumpsum	1241
Maintenance of Traffic	Lumpsum	1239
Work Zone Sign	Per Day	1217
Temporary Barricade	Per Day	1168
Advanced Warning / Arrow Board	Per Day	890
High Intensity Flashing Lights	Per Day	1200
Temporary Retro-reflective Pavement Marker	Each Unit	865
Portable Changeable Message Sign	Per Day	1004
Clearing & Grubbing	Lumpsum	1067
Painted Pavement Markings	Lumpsum	788

The means are calculated using the lowest bidder's unit-price bid from 1,341 unit-price auctions.

Quantities are estimated by FDOT prior to auction.

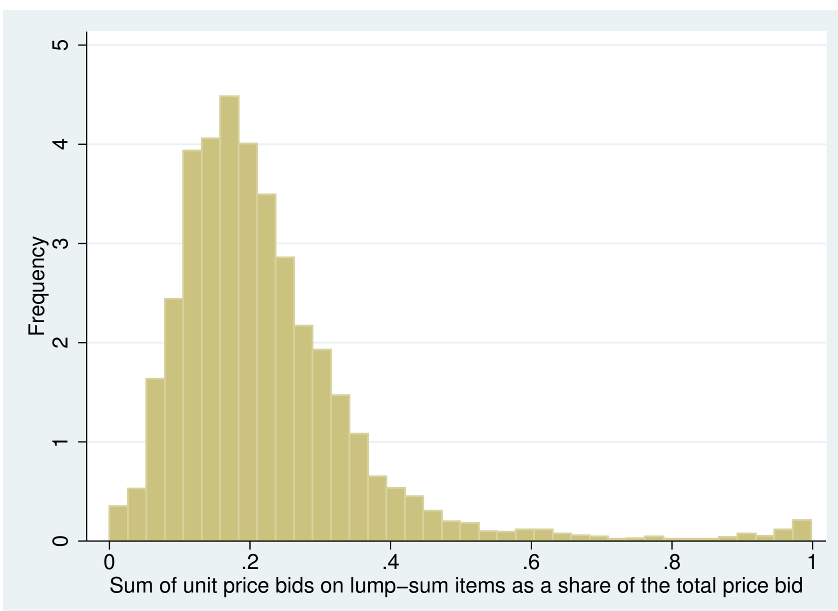

Figure A.3: Distribution of the sum of unit prices across lumpsum items as a share of bidder score

Table A.5: Variance Decomposition of Share of Non-Lumpsum Bids

	Std. Dev.	Percentage
Between-Auction	.130	70%
	(.0027)	
Within-Auction Between-Bidder	.0560	30%
	(.0005)	

Standard errors are given in parentheses.

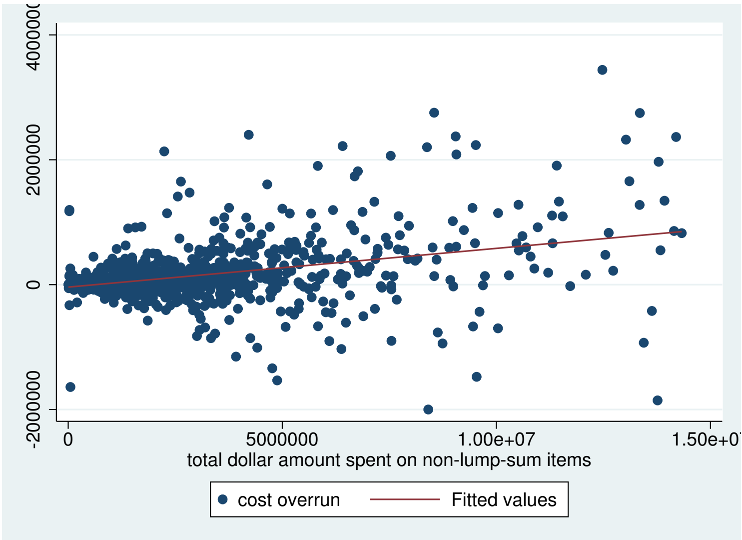

Figure A.4: Cost Overrun and Bids on Non-Lumpsum Items

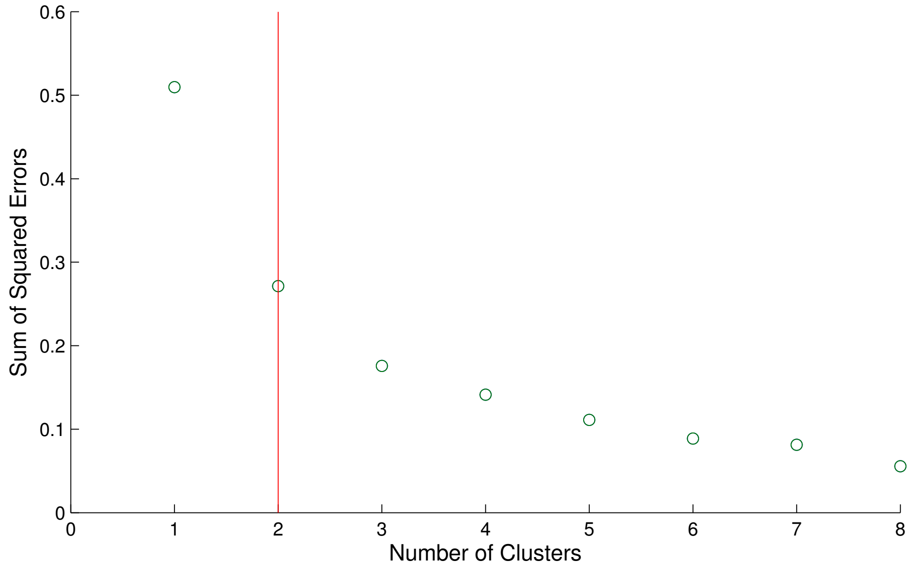

Figure A.5: Elbow Test on The Variance of Non-lumpsum Bids

Table A.6: OLS Comparison of Efficiency of Winning Bidders relative to Non-Winning Bidders

Dependent variable	e_0	e_1
Winner	-.473	-.00567
	(.033)	(.00056)

Standard errors are given in parentheses.

Appendix B: More Results on Contract Formats

There is also a large degree of heterogeneity in the use of these two contractual arrangements across FDOT district offices. Figure A.6 plots the varying levels of intensity in the use of FP relative to UP contracts for each of FDOT's seven district offices across time. As a district office procures multiple projects at a time, the intensity of FP use is measured by the share of all FP projects over the sum of FP and UP projects procured during a year.

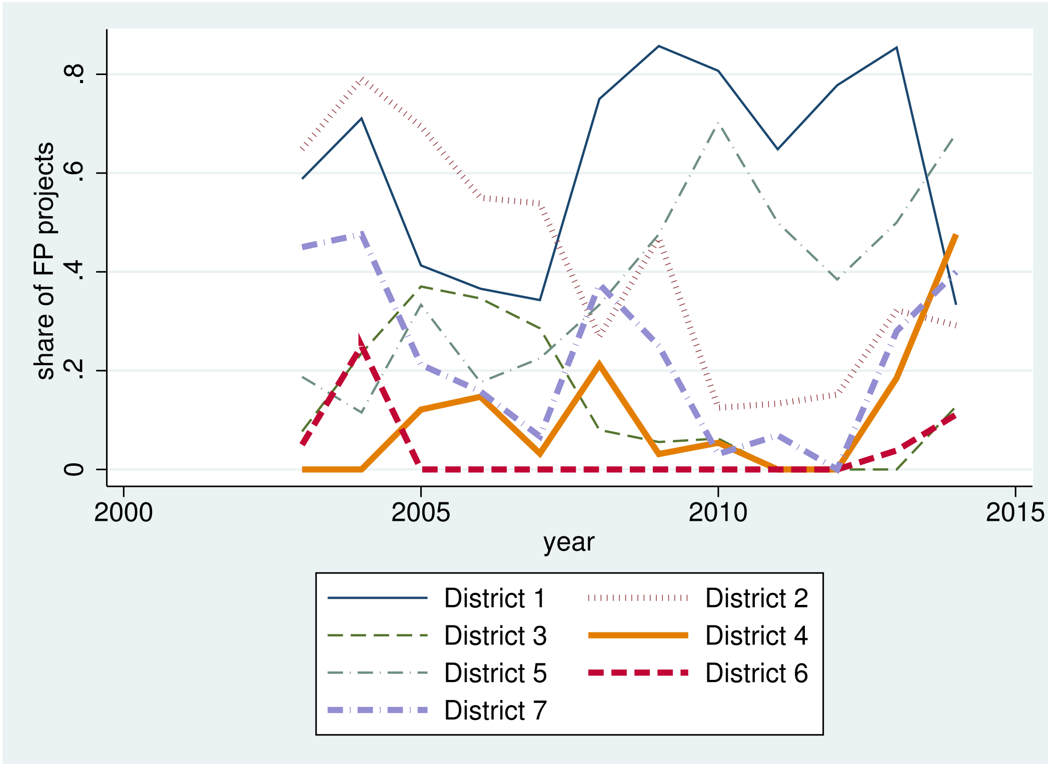

Figure A.6: Use of FP over UP at each FDOT district office

Two observations can be made from Figure A.6. First, there is state dependency in the use of FP over UP contracts while exhibiting much variation across time, which could be a product of turnover in project managers. Second, there is a common sharp increase in the use of FP over UP for the year following the financial crisis in 2008. In February 2009, the American Recovery and Reinvestment Act was signed into law. This stimulus package placed an emphasis on infrastructure investment, which raised the number of procurements significantly. If FDOT is capacity constrained, then FDOT may choose to procure those additional projects via FP. UP could involve higher transaction costs in order to estimate the quantity of each construction item, and to keep track of materials used. Indeed, FDOT engineers mention that the bulk of the administrative costs associated with UP comes from keeping track of materials used.

Table A.7: OLS Comparison of Contract Formats: Entry

Dependent Variable	Entry			
FP (=0 if UP, =1 if FP)	-.00342	-.0038	-.00427	.0151
	(.0098)	(.0097)	(.0098)	(.0085)
Engineer's Cost Estimate (log)	-.00481	-.00806	-.0058	-.0289
	(.0033)	(.0033)	(.0034)	(.003)
# of Potential Bidders	-.0109	-.0102	-.0105	-.00625
	(.00057)	(.00059)	(.00061)	(.00054)
District FE	y	y	y	y
Year Trend	n	y	y	y
Month FE	n	n	y	y
Bidder FE	n	n	n	y
R^2	.0623	.0632	.0654	.393
N	20131	20131	20131	20131

Bidders that win less than one percent of the total value of projects are grouped together as fringe firms. Standard errors are clustered at the project/auction level and presented in parentheses.

Table A.8: OLS Comparison of Contract Formats: Score

Dependent Variable	Score (log)			
FP (=0 if UP, =1 if FP)	-.0512	-.0502	-.0471	-.027
	.0083	.0083	.0083	.0081
Engineer's Cost Estimate (log)	.985	.99	.989	.975
	.0026	.0027	.0027	.003
# of Participating Bidders	-.0199	-.0196	-.0199	-.0202
	.0013	.0013	.0013	.0014
# of Potential Bidders	-.00376	-.00502	-.00459	-.00563
	.00058	.00059	.00061	.00061
District FE	y	y	y	y
Year Trend	n	y	y	y
Month FE	n	n	y	y
Bidder FE	n	n	n	y
R^2	.969	.969	.97	.975
N	8984	8984	8984	8984

Bidders that win less than one percent of the total value of projects are grouped together as fringe firms. Standard errors are clustered at the project/auction level and presented in parentheses.

Table A.9: OLS Comparison of Contract Formats: Winner's Score

Dependent Variable	Winner's Score (log)			
FP (=0 if UP, =1 if FP)	-.0489	-.0475	-.0436	-.00573
	.016	.016	.016	.017
Engineer's Cost Estimate (log)	1	1.01	1.01	.989
	.0055	.0057	.0057	.0069
# of Participating Bidders	-.0344	-.0343	-.0344	-.0336
	.0031	.0031	.0031	.0034
# of Potential Bidders	-.00585	-.00708	-.00662	-.00764
	.0013	.0013	.0013	.0014
District FE	y	y	y	y
Year Trend	n	y	y	y
Month FE	n	n	y	y
Bidder FE	n	n	n	y
R^2	.972	.972	.973	.981
N	1890	1890	1890	1890

Bidders that win less than one percent of the total value of projects are grouped together as fringe firms.
Standard errors are clustered at the project/auction level and presented in parentheses.

Table A.10: OLS Comparison of Contract Formats: Final Payment

Dependent Variable	Final Payment (log)			
FP (=0 if UP, =1 if FP)	-.0386	-.0375	-.0343	.012
	.016	.016	.017	.017
Engineer's Cost Estimate (log)	1.02	1.02	1.02	1
	.0058	.006	.006	.0071
# of Participating Bidders	-.0352	-.0351	-.0351	-.0347
	.0033	.0033	.0033	.0036
# of Potential Bidders	-.00479	-.0058	-.00525	-.00638
	.0013	.0014	.0014	.0015
District FE	y	y	y	y
Year Trend	n	y	y	y
Month FE	n	n	y	y
Bidder FE	n	n	n	y
R^2	.969	.969	.969	.979
N	1890	1890	1890	1890

Bidders that win less than one percent of the total value of projects are grouped together as fringe firms.
Standard errors are clustered at the project/auction level and presented in parentheses.

Table A.11: Top 10 Contractors for FP and UP Contracts

Top Contractors for FP	# of FP contracts	Top Contractors for UP	# of UP contracts
APAC-Southeast	73	Anderson Columbia Co.	103
Anderson Columbia Co.	70	Community Asphalt	101
AJAX Paving	47	APAC-Southeast	73
Lane Construction	33	Ranger Construction	72
Better Roads	31	Weekley Asphalt Paving	71
L-J Construction Co.	23	Hubbard Construction	51
C.W. Roberts Contracting	21	C.W. Roberts Contracting	47
Ranger Construction	19	General Asphalt Co.	38
Hubbard Construction	16	AJAX Paving	34
D.A.B. Constructors	14	P&S Paving	32

Appendix C: Derivation of (16)

Under the UP contract, a bidder's utility maximization problem with a pseudo-cost c_u is given by:

$$\max_{s_u} \qquad \left[1 - G_n(s_{u,i}|X)\right]^{n-1} u\left(s_{u,i} - c_{u,i}|X\right),$$

where $u(.)$ is CARA utility.

The first-order optimality condition gives:

$$\frac{u(s_{u,i} - c_{u,i}|X)}{u'(s_{u,i} - c_{u,i}|X)} = \frac{1 - G_n(s_{u,i}|X)}{(n-1)g_n(s_{u,i}|X)}.$$

Rewriting the left-hand side of the above equation explicitly, we have:

$$\frac{u(s_{u,i} - c_{u,i}|X)}{u'(s_{u,i} - c_{u,i}|X)} = \frac{1}{\alpha(X)}\left(\exp\left\{\alpha(s_{u,i} - c_{u,i})\right\} - 1\right).$$

Rearranging the above first-order condition, we have:

$$s_{u,i} - \frac{1}{\alpha(X)} ln \left(1 + \alpha(X) \frac{1 - G_n(s_{u,i}|X)}{(n-1)g_n(s_{u,i}|X)} \right) \quad = \quad c_{u,i}.$$

Given we know that $b_i = \theta(X) + \frac{e_i - \iota}{\alpha(X)} \Sigma^{-1}$ and $c_{u,i} = \theta_0(X) e_{0,i} + \theta(X)\iota^T - \frac{1}{2\alpha(X)}(e_i - \iota)\Sigma^{-1}(X)(e_i - \iota)^T$, we have:

$$s_{u,i} - \theta(X)\iota^T - \frac{1}{\alpha(X)} ln \left(1 + \alpha(X) \frac{1 - G_n(s_{u,i}|X)}{(n-1)g_n(s_{u,i}|X)} \right) + \frac{\alpha(X)}{2}(b_i - \theta(X))\Sigma(X)(b_i - \theta(X))^T \quad = \quad \theta_0(X) e_{0,i}.$$

Therefore, we have:

$$E \left[s_{u,i} - \theta(X)\iota^T - \frac{1}{\alpha(X)} ln \left(1 + \alpha(X) \frac{1 - G_n(s_{u,i}|X)}{(n-1)g_n(s_{u,i}|X)} \right) + \frac{\alpha(X)}{2}(b_i - \theta(X))\Sigma(X)(b_i - \theta(X))^T | b_i, X \right] \quad = \quad \theta_0(X).$$

Appendix D: Bid Homogenization

We show that the unique equilibrium bidding strategies and cost overruns are multiplicatively separable in project characteristics X given the econometric specification in (18). To see this, let us make explicit the dependency of outcome variables on the primitives.

Let $b_{1,ia} := b_1 \left(\theta_1(X_a), \sigma(X_a), \alpha(X_a), e_{1,ia} \right)$, $s_{u,ia} := s_u \left(\theta_0(X_a), \theta_1(X_a), \sigma(X_a), \alpha(X_a), e_{0,ia}, e_{1,ia}, n \right)$, and $\Delta_a := \Delta \left(\theta_1(X_a), \sigma(X_a), \alpha(X_a), e_{1,1a}, \epsilon_a \right)$. Define $b^0_{1,ia} := b_1 \left(\theta_1(0), \sigma(0), \alpha(0), e_{1,ia} \right)$, $s^0_{u,ia} := s_u \left(\theta_0(0), \theta_1(0), \sigma(0), \alpha(0), e_{0,ia}, e_{1,ia}, n \right)$, and $\Delta^0_a := \Delta \left(\theta_1(0), \sigma(0), \alpha(0), e_{1,1a}, \epsilon_a \right)$ as "normalized" non-lumpsum score, normalized score, and normalized cost overrun, respectively. This multiplicative separability of project characteristics allows for the bid-homogenization approach in a setting with CARA bidders and reduces computational burden by reducing the number of auctions the econometrician has to solve.

Proposition. *Given the econometric specification above, the unique equilibrium non-lumpsum bidding strategy, scoring strategy, and cost overrun are all multiplicatively separable in project* *characteristics, such that:*

$$\begin{aligned} b_{1,ia} &= b^0_{1,ia} \exp\left\{X_a \beta\right\}, \\ s_{u,ia} &= s^0_{u,ia} \exp\left\{X_a \beta\right\}, \\ \Delta_a &= \Delta^0_a \exp\left\{X_a \beta\right\}. \end{aligned}$$

First, consider non-lumpsum bidding strategy $b_{1,i} := b_{1,i}(\theta_1(X), \sigma(X), \alpha(X), e_{1,i})$. We know that:

$$\begin{aligned} b_{1,i}(\theta_1(X), \sigma(X), \alpha(X), e_{1,i}) &= \theta_1(X) + \frac{e_{1,i} - 1}{\alpha(X)\sigma(X)} \\ &= \left(\theta_1 + \frac{e_{1,i} - 1}{\alpha\sigma}\right) \exp\{X\beta\} \\ &= b^0_{1,i} \exp\{X\beta\}, \end{aligned}$$

where the second line follows directly from the normalization assumption (18). Therefore, the non-lumpsum bidding strategy is multiplicatively separable in X.

Second, we show that the scoring strategy is multiplicatively separable in X. To see this, let us first consider the pseudo-cost $c_{u,i} := \theta_0(X)e_{0,i} + \theta_1(X) - \frac{1}{2\alpha(X)\sigma(X)}(e_{1,i} - 1)^2$ and $c^0_{u,i} := c_{u,i}(0)$. We have:

$$\begin{aligned} c_{u,i} &= \left(\theta_0 e_{0,i} + \theta_1 - \frac{(e_{1,i} - 1)^2}{2\alpha\sigma}\right) \exp\{X\beta\} \\ &= c^0_{u,i} \exp\{X\beta\}, \end{aligned}$$

and thus, pseudo-cost is multiplicatively separable in X. Now, conjecture that $s_{u,i} := s_{u,i}(\theta_0(X), \theta_1(X), \sigma(X), \alpha(X), e_{0,i}, e_{1,i}) = s^0_{u,i} \exp\{X\beta\}$ constitutes an equilibrium scoring strategy. Consider the first-order condition with respect to score given by:

$$\begin{aligned}
s_{u,i} - \frac{1}{\alpha(X)} ln \left(1 + \alpha(X) \frac{1 - G_n(s_{u,i}|X)}{(n-1) g_n(s_{u,i}|X)} \right) &= c_{u,i}, \\
s_{u,i}^0 - \frac{1}{\alpha} ln \left(1 + \alpha \frac{1 - G_n(s_{u,i}^0|X=0)}{(n-1) g_n(s_{u,i}^0|X=0)} \right) \exp\{X\beta\} &= c_{u,i}^0 \exp\{X\beta\}, \\
s_{u,i}^0 - \frac{1}{\alpha} ln \left(1 + \alpha \frac{1 - G_n(s_{u,i}^0|X=0)}{(n-1) g_n(s_{u,i}^0|X=0)} \right) &= c_{u,i}^0,
\end{aligned}$$

where the second line follows because G_n is homogeneous of degree 0 while g_n is homogeneous of degree -1. Therefore, $s_{u,i} = s_{u,i}^0 \exp\{X\beta\}$ constitutes an equilibrium scoring strategy if $s_{u,i}^0$ is the equilibrium scoring strategy corresponding to pseudo-cost $c_{u,i}^0$. Because we know that the equilibrium is unique, $s_{u,i} = s_{u,i}^0 \exp\{X\beta\}$ is the unique equilibrium scoring strategy with $X \neq 0$.

Lastly, it is straightforward to see that $\Delta = \Delta^0 \exp\{X\beta\}$ from the cost overrun equation.

$$\begin{aligned}
\Delta &= b_{1,1}(e_{1,1} - 1 + \epsilon) \\
&= b_{1,1}^0 (e_{1,1} - 1 + \epsilon) \exp\{X\beta\} \\
&= \Delta^0 \exp\{X\beta\}.
\end{aligned}$$

This completes the proof.