Online Appendix for “Bundled Procurement for Technology Acquisition and Future Competition”

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A Proofs

Proposition 1. *The expected per-unit future profit of a player is the difference of the expected social welfare with his participation and without his participation,* $V_i(v) = E[\max_{j=0,\cdots,n}\{\bar{v}_j + \epsilon_j\}] - E[\max_{j=0,\cdots,n,j\neq i}\{\bar{v}_j + \epsilon_j\}]$*, where* $\bar{v}_0 = v$*.*

Proof. The result follows the classic auction literature. For example, see Krishna (2002). □

Lemma 1. $V_0(v)$ *is (weakly) increasing in* v *and* $V_i(v)$ $(i = 1, 2, \cdots, n)$ *is (weakly) decreasing in* v*.*

Proof. V_i is the per-unit profit for supplier i in the future market, which is the difference of the expected social welfare with his participation and without his participation as illustrated in Proposition 1. That is, $V_i(v) = E[\max_{j=0,\cdots,n}\{\bar{v}_j + \epsilon_j\}] - E[\max_{j=0,\cdots,n,j\neq i}\{\bar{v}_j + \epsilon_j\}]$, where $\bar{v}_0 = v$. As a result, $V_0(v)$ is (weakly) increasing in v. Furthermore, $V_i(v)$ is (weakly) decreasing in v for $i = 1, 2, \cdots, n$ because both the likelihood of $\bar{v}_i + \epsilon_i$ being the highest and the gap between $\bar{v}_i + \epsilon_i$ and $\bar{v}_0 + \epsilon_0$ decrease as $\bar{v}_0$ increases. □

Lemma 2. *Technology leader would drop out of the competition at an ask price (weakly) above zero, and technology follower would drop out of the competition at an ask price (weakly) below zero.*

Proof. Consider when supplier 1 drops out in the negotiation process. If supplier 1 wins the procurement project, the expected profit is $kp_1 + lV_1(v_1)$, the summation of the current profit and the expected future profit; if supplier 1 loses the procurement project, the expected profit is $lV_1(v_2)$. Therefore, supplier 1 drops out if the ask price p_1 is so low that $kp_1 + lV_1(v_1) \leq lV_1(v_2)$. By Lemma 1, $V_1(v)$ is a (weakly) decreasing function of v. The break-even profit p_1 for the current stage would be non-negative if supplier 1 offers a superior technology and non-positive if supplier 1 offers an inferior technology. Therefore, the technology leader drops out of the competition at an ask price (weakly) above zero and the technology follower drops out of the competition at an ask price (weakly) below zero. □

Theorem 1. *The supplier who provides the larger aggregate gain—i.e.,* $kU_i(v_i) + lV(v_i)$*—wins the procurement* $(i = 1, 2)$*. Furthermore, if supplier* i *wins and supplier* j *loses, supplier* i*'s total expected profit is* $(kU_i(v_i) + lV(v_i)) - (kU_j(v_j) + lV(v_j)) + lV_i(v_j)$*, and supplier* j*'s total expected profit is* $lV_j(v_i)$*.*

Proof. Without loss of generality, let us assume that supplier 1 provides the larger aggregate gain, i.e., $kU_1(v_1) + lV(v_1) \geq kU_2(v_2) + lV(v_2)$. Recall that $V(v) = V_0(v) + V_1(v) + V_2(v)$.

We argue that if the above inequality holds strictly, supplier 2 would drop out first in the negotiation process, and supplier 1 would be the winner. If supplier 1 drops out and supplier 2 wins, supplier 1's exit ask price p_1 must satisfy $lV_1(v_2) \geq kp_1 + lV_1(v_1)$, while $k(U_2(v_2) - p_2) + lV_0(v_2) \geq k(U_1(v_1) - p_1) + lV_0(v_1)$ as the buyer prefers supplier 2, and supplier 2's ask price p_2 must satisfy $kp_2 + lV_2(v_2) \geq lV_2(v_1)$ to ensure supplier 2 stays in the competition. Adding up the three inequalities, we obtain $kU_1(v_1) + lV(v_1) \leq kU_2(v_2) + lV(v_2)$ and we reach a contradiction.

Therefore, at equilibrium, supplier 2 drops out and supplier 1 is the winner. Supplier 2's exit per-unit ask price p_2 is $l(V_2(v_1) - V_2(v_2))/k$, at which supplier 2 is indifferent between winning and losing the procurement project. To win the procurement project, supplier 1 can ask for the highest p_1 such that $k(U_1(v_1) - p_1) + lV_0(v_1) \geq k(U_2(v_2) - p_2) + lV_0(v_2)$. Therefore, $p_1 = U_1(v_1) + l(V_0(v_1) + V_2(v_1))/k - [U_2(v_2) + l(V_0(v_2) + V_2(v_2))/k]$. Supplier 1's total current and future profit is $kp_1 + lV_1(v_1) = (kU_1(v_1) + lV(v_1)) - (kU_2(v_2) + lV(v_2)) + lV_1(v_2)$. Supplier 2's profit is $lV_2(v_1)$, and the buyer's total current and future profit is $kU_2(v_2) + lV(v_2) - lV_1(v_2) - lV_2(v_1)$. □

Theorem 2. *Supplier* i*'s optimal technology offer strategy* $v_i^* \in (-\infty, \bar{v}_i]$ *maximizes* $kv_i + lV(v_i)$*, or equivalently* $k(v_i + E[\epsilon_i]) + lV(v_i)$*, the expected aggregate gain.*

Proof. By the proof of Theorem 1, if $k(v_i + \epsilon_i) + lV(v_i)$ is lower than $k(v_j + \epsilon_j) + lV(v_j)$, supplier i would lose and obtain $lV_i(v_j)$; if $k(v_i + \epsilon_i) + lV(v_i)$ is higher, supplier i can capture the difference of the aggregate gain in additional to the benchmark profit $lV_i(v_j)$. Under both scenarios, we can write supplier i's total profit as $\max\{k(v_i + \epsilon_i) + lV_i(v_i) - [k(v_j + \epsilon_j) + lV_i(v_j)], 0\} + lV_i(v_j)$.

To maximize supplier i's total profit, the optimal technology offer strategy is to maximize $kv_i + lV(v_i)$, or equivalently $k(v_i + E[\epsilon_i]) + lV(v_i)$, the expected aggregate gain. □

Corollary 1. v_i^* *is a (weakly) increasing function of* α*.*

Proof. To maximize $kv + lV(v)$, it is equivalent to maximize $\alpha v + V(v)$. It suffices to show that if $\alpha v + V(v) \geq \alpha v' + V(v')$ for $v > v'$, $\alpha' v + V(v) > \alpha' v' + V(v')$ for any $\alpha < \alpha'$. This is true because $(\alpha' - \alpha)(v - v') > 0$. □

Theorem 3. *For* $\alpha \geq 1$*, offering technology value* $\bar{v}_i$ *is supplier* i*'s optimal strategy.*

Proof. By Corollary 1, it suffices to show that $v_i = \bar{v}_i$ is the supplier i's optimal technology offer strategy when $\alpha = 1$. That is, $\bar{v}_i$ maximizes $v_i + V(v_i)$ on $(-\infty, \bar{v}_i]$.

Notice that because ϵ_i are drawn independently, we can study the marginal impact of v_i on $V(v_i)$ as if all the ϵ_i $(i = 0, \cdots, n)$ have been realized according to the specified density. It suffices to show that a small unit increase in v_i would result in at most a unit decease for $V(v_i)$ under all possible ϵ_i realizations.

Case I. $\bar{v}_0 + \epsilon_0 = v_i + \epsilon_0$ is the highest among all the suppliers in the future market. Under this case, a unit increase in v_i in fact translates into a unit increase for the future aggregate gain.

Case II. $\bar{v}_0 + \epsilon_0 = v_i + \epsilon_0$ is the second highest among all the suppliers in the future market. Under this case, a unit increase in v_i translates into a unit decrease for the future aggregate gain.

Case III. Otherwise, a unit increase in v_i has no impact on the future aggregate gain.

Therefore, $V'(v) \geq -1$ and $v_i = \bar{v}_i$ is the supplier i's optimal technology offer strategy when $\alpha = 1$. Notice that the inequality reaches equality only if the selection rule is deterministic. □

Corollary 2. *When the evaluation process is deterministic, i.e., $\epsilon_i = 0$, offering $\min\{\bar{v}_i, \tilde{v}\}$ when $\alpha < 1$ and $\bar{v}_i$ when $\alpha \geq 1$ is a dominant technology offer strategy for supplier i, where $\tilde{v}$ is the highest value in $\{\bar{v}_j\}_{j=1,\cdots,n,j\neq i}$.*

Proof. Let V_1 and V_2 be the highest value and the second highest value in $\{\bar{v}_j\}_{j=1,\cdots,n}$, respectively. When the evaluation process is deterministic, i.e., $\epsilon_i = 0$, $V(v) = V(V_2) = V_1 - V_2$ when $v \leq V_2$ and $V(v) = V_1 - v$ when $v \in (V_2, V_1]$.

When $\alpha \geq 1$, offering $\bar{v}_i$ is a dominant technology offer strategy for supplier i by Theorem 3. When $\alpha < 1$, offering $\min\{\bar{v}_i, \tilde{v}\} \leq V_2$ maximizes $\alpha v + V(v)$ and is a dominant technology offer strategy for supplier i. □

Theorem 4. *Suppose that $\bar{v} = \bar{v}_1 = \bar{v}_2$ and ϵ_i $(i = 0, 1, 2)$ are continuous i.i.d. random variables, i) $V'(\bar{v}) = 0$ and ii) the suppliers' optimal technology offer v is not continuous with respect to α as long as $V(\bar{v}) < \sup\{V(v)|v \leq \bar{v}\}$.*

Proof. By Proposition 1, $V(v) = \sum_{i=0}^{2}(E[\max_{j=0}^{2}\{\bar{v}_j + \epsilon_j\}] - E[\max_{j\neq i, j=0}^{2}\{\bar{v}_j + \epsilon_j\}])$, where $\bar{v}_0 = v$. Therefore, $V'(v) = Prop(v + \epsilon_0 > \bar{v}_1 + \epsilon_1 > \bar{v}_2 + \epsilon_2) + Prop(v + \epsilon_0 > \bar{v}_2 + \epsilon_2 > \bar{v}_1 + \epsilon_1) - Prop(\bar{v}_1 + \epsilon_1 > v + \epsilon_0 > \bar{v}_2 + \epsilon_2) - Prop(\bar{v}_2 + \epsilon_2 > v + \epsilon_0 > \bar{v}_1 + \epsilon_1)$.

When $v = \bar{v}_1 = \bar{v}_2$, $Prop(v + \epsilon_0 > \bar{v}_1 + \epsilon_1 > \bar{v}_2 + \epsilon_2) = Prop(v + \epsilon_0 > \bar{v}_2 + \epsilon_2 > \bar{v}_1 + \epsilon_1) = Prop(\bar{v}_1 + \epsilon_1 > v + \epsilon_0 > \bar{v}_2 + \epsilon_2) = Prop(\bar{v}_2 + \epsilon_2 > v + \epsilon_0 > \bar{v}_1 + \epsilon_1)$ because ϵ_i $(i = 0, 1, 2)$ are continuous i.i.d. random variables. Therefore, $V'(\bar{v}) = 0$.

When $V(\bar{v}) < \sup\{V(v)|v \leq \bar{v}\}$, the suppliers' optimal technology offer $v_0^* < \bar{v}$ for some sufficiently small α_0. Because $V'(\bar{v}) = 0$, there exists a positive $\delta > 0$, such that $\alpha_0\bar{v} + V(\bar{v}) >$

$\alpha_0 v + V(v)$ for $v \in (\bar{v} - \delta, \bar{v})$. Notice that for any $\alpha > \alpha_0$, we also have $\alpha\bar{v} + V(\bar{v}) > \alpha v + V(v)$ for $v \in (\bar{v} - \delta, \bar{v})$. That is, technology offer $\bar{v}$ dominates $v \in (\bar{v} - \delta, \bar{v})$ for any $\alpha > \alpha_0$.

Theorem 3 states that when $\alpha = 1$, the optimal technology offer is $\bar{v}$. Corollary 1 indicates that as α increases from α_0 to 1, the optimal technology offer v^* increases from v_0^* to $\bar{v}$. Nevertheless, technology offer $\bar{v}$ dominates $v \in (\bar{v} - \delta, \bar{v})$ for any $\alpha > \alpha_0$. Therefore, the suppliers' optimal technology offer v is not continuous with respect to α. □

Proposition 2. *Suppose that the technology offers $v_1 = v_2 = \bar{v}_1 = \bar{v}_2$, the buyer's expected payoff in the current stage is the same under the bundled procurement mechanism and under the mechanism that procures only tangible goods despite the fact that the buyer would enjoy a future profit under the bundled procurement mechanism.*

Proof. Denote $\bar{v} \equiv \bar{v}_1 = \bar{v}_2$. The buyer's expected payoff is $E[\min\{k(\bar{v} + \epsilon_1), k(\bar{v} + \epsilon_2)\}]$ when she procures only tangible goods.

When α is sufficiently large so that both suppliers offers technology value $\bar{v}$, the buyer's expected future profit is $lV_0(\bar{v})$. Therefore, the buyer's expected payoff in the current stage is $E[\min\{k(\bar{v} + \epsilon_1) + lV(\bar{v}), k(\bar{v} + \epsilon_2) + lV(\bar{v})\}] - lV_1(\bar{v}) - lV_2(\bar{v}) - lV_0(\bar{v}) = E[\min\{k(\bar{v} + \epsilon_1), k(\bar{v} + \epsilon_2)\}]$.

Therefore, the buyer's expected payoff in the current stage is the same under both mechanisms.

□

B Private Cost Information

In the original model, costs are assumed to be zero. In this section, we allow the production cost depends on both the identity of the supplier and the technology value. We further allow the suppliers have private cost-saving information regarding the procurement project. We show that the original results continue to hold.

Let $c_i(v)$ be the nominal cost of supplier i of producing a unit of tangible goods with technology value v. Define $n_i(v) \equiv v - c_i(v)$ the net value of this technology. Let $\bar{n}_i = \max\{n_i(v) | v \leq \bar{v}_i\}$ denote the maximum net value of supplier i. We assume that supplier i can offer a technology with net value n_i if and only $n_i \leq \bar{n}_i$ and that the maximum net value of the current buyer in the future stage is the net value of the technology she acquires at the current stage. Notice that we may have $\bar{n}_i \neq n_i(\bar{v}_i)$, because the technology with the highest value may be extremely expensive. The net value of the technology reflects the social contribution of the technology.

Given a specific procurement project, the supplier i may identify additional cost-saving opportunities $\phi_i (\geq 0)$ due to his experiences and expertise. As a result, the actual per-unit cost is $c_i(v) - \phi_i$ when supplier i produces a unit of tangible goods with technology value v. Unlike valuation uncertainty ϵ_i, which is revealed to all the players after the evaluation, cost-saving uncertainty ϕ_i is supplier i's private information.

Notation	Definition	Functional Relationships
k	The size of current procurement need	
l	The discounted future market size	
α	Current weight ratio	$\alpha \equiv k/l \in [0, \infty)$
$\bar{n}_i$	Supplier i's maximum net technology value	
v_i	Supplier i's technology offer	
$c_i(v_i)$	Supplier i's technology cost	
$n_i(v_i)$	Supplier i's net value of this technology	$n_i = v_i - c_i(v_i)$, $n_i \leq \bar{n}_i$
p_i	Supplier i's per-unit ask price	
ϵ_i	Valuation uncertainty of supplier i	$\epsilon_i \sim F_i$
ϕ_i	Cost-saving uncertainty of supplier i	$\phi_i \sim G_i$, $\phi_i \geq 0$
θ_i	Total uncertainty of supplier i	$\theta_i = \epsilon_i + \phi_i$

Table 1: Summary of the Notation

We assume that the per-unit cost-saving uncertainty ϕ_i is independently drawn from some known distribution G_i and denote random variable $\theta_i \equiv \epsilon_i + \phi_i$. Index i runs from 1 to n for the current stage and 0 to n for the future stage, respectively. (The independence assumption has no bearing on our results, although it simplifies the exposition). Table 1 summarizes the notation used.

Now, we re-establish the original results in this extended setting. The key is to recognize that the net values represent the true contribution of the technologies when costs differ and show that the players only need to make decisions based on the net values instead of the original technology values.

Proposition B.1. *The expected per-unit future profit of a player is the difference of the expected social welfare with his participation and without his participation,* $\tilde{V}_i(n) = E[\max_{j=0,\cdots,n}\{\bar{n}_j + \theta_j\}] - E[\max_{j=0,\cdots,n, j\neq i}\{\bar{n}_j + \theta_j\}]$*, where* $\bar{n}_0 = n$*.*

In the future stage, originally each supplier drops out when the ask price reaches zero. Now, the suppliers drop out at their private cost levels $(c_i(v_i) - \phi_i)$. Once again, we can show that the future stage is equivalent to a second-price auction mechanism, in which the supplier who offers the highest social welfare wins. Notice that for supplier i, the per-unit social welfare is $v - (c_i(v) - \phi_i) + \epsilon_i = n_i(v) + \theta_i$. Therefore, all the suppliers will offer the technology with the highest possible net value within their technology domains. Instead of competing via technology values, now they need to take into account the costs and compete via net values. That is, the expected per-unit future profit would be defined through n instead of v while all the properties and results remain the same.

Notice that because the future profit estimations are defined through the net value of the technology and independent of the private cost-saving information ϕ_i, the current buyer is capable of creating and revealing a per-unit price adjustment term for each supplier during the evaluation process in this extended setting. The net value of the technology also plays a key role in the current stage. Define $\tilde{U}_i(n_i) \equiv U_i(v_i) - (c_i - \phi_i) = n_i + \theta_i$ as the net per-unit utility of the technology. Under a two-supplier setting, the winning supplier is determined according to the aggregate gain.

Theorem B.1. *The supplier who provides the larger aggregate gain—i.e., $k\tilde{U}_i(n_i) + l\tilde{V}(n_i)$—wins the procurement ($i = 1, 2$). Furthermore, if supplier i wins and supplier j loses, supplier i's total expected profit is $(k\tilde{U}_i(n_i) + l\tilde{V}(n_i)) - (k\tilde{U}_j(n_j) + l\tilde{V}(n_j)) + l\tilde{V}_i(n_j)$ and supplier j's total expected profit is $l\tilde{V}_j(n_i)$.*

In the original setting, supplier i drops out the negotiation process in the current stage if both suppliers' offers result the same value to the buyer (i.e., $k(U_i(v_i) - p_i) + lV_0(v_i) = k(U_j(v_j) - p_j) + lV_0(v_j)$) and the ask price p_i is so low such that $kp_i + lV_i(v_i) \leq lV_i(v_j)$. The fact that supplier j has yet to drop out implies that $lV_j(v_i) \leq kp_j + lV_j(v_j)$. Adding up the three inequalities results the finding that the supplier who provides the larger aggregate gain wins the procurement in the original setting.

In this extended setting, supplier i drops out if both suppliers' offers result the same value to the buyer (i.e., $k(U_i(v_i) - p_i) + l\tilde{V}_0(n_i) = k(U_j(v_j) - p_j) + l\tilde{V}_0(n_j)$) and the ask price p_i is so low such that $k(p_i - (c_i - \phi_i)) + l\tilde{V}_i(n_i) \leq l\tilde{V}_i(n_j)$. The fact that supplier j has yet to drop out implies that $l\tilde{V}_j(n_i) \leq k(p_j - (c_j - \phi_j)) + l\tilde{V}_j(n_j)$. Adding up the three inequalities results the finding that the supplier who provides the larger aggregate gain wins the procurement in the extended setting. This further leads to the original main finding.

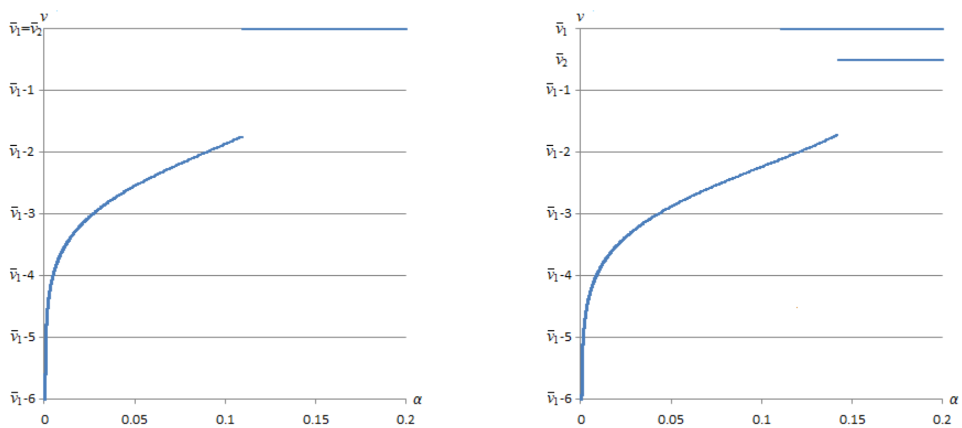
Theorem B.2. *Supplier i's optimal technology offer strategy $n_i^* \in (-\infty, \bar{n}_i]$ maximizes $kn_i + l\tilde{V}(n_i)$, or equivalently $k(n_i + E[\theta_i]) + l\tilde{V}(n_i)$, the expected aggregate gain.*

Notice that the open descending price negotiation structure ensures the private cost-saving information does not hinder the strategy-proofness of the main strategy because the future profit estimations are defined through the net value of the technology and independent of the private cost-saving information ϕ_i. As a result, a one-to-one mapping can be built between the original analysis and the general cost setting by replacing v_i with n_i, ϵ_i with θ_i, U_i with $\tilde{U}_i$, and V_i with $\tilde{V}_i$ as the players only need to make decisions based on the net values instead of the original technology values. This mapping enables us to use similar proofs to establish all the results in the original settings.

C Numerical Studies under the Multinomial Probit Model

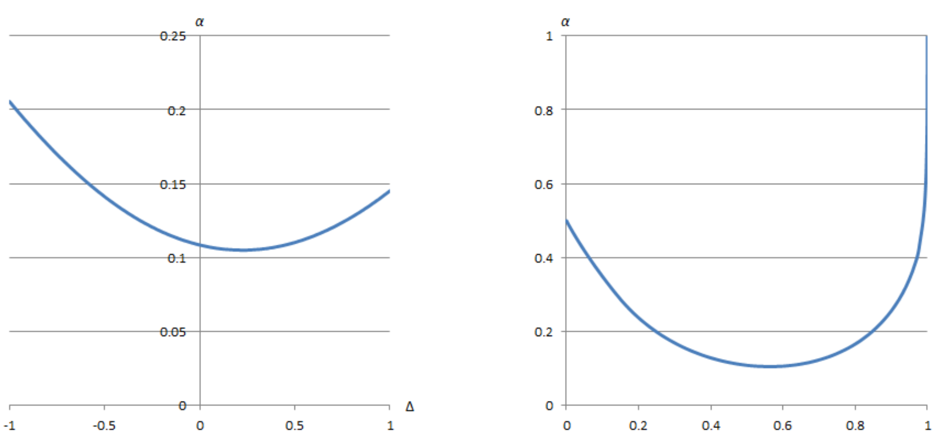
In this section, we consider an alternative discrete choice model called the multinomial probit model (hereinafter, MNP). Under MNP, ϵ_i are i.i.d. according to the normal distribution: $\epsilon_i \sim N(0, \sigma^2)$. Under MNP, we define the normalized technology gap as $\Delta \equiv \frac{\bar{v}_1 - \bar{v}_2}{\sigma}$ for the two-supplier case. The dynamic game under the MNP model is essentially defined through two parameters: α captures the relative size of the current project and Δ captures the intensity of supplier competition.

Figure 1 illustrates how the optimal technology value v^* varies as a function of α for $\Delta = 0$ and $\Delta = 0.5$. When $\Delta = 0$, $\alpha \geq 0.1086$ induces supplier 1 to offer $\bar{v}_1$. When $\Delta = 0.5$, the technology leader (i.e., supplier 1) always offers a (weakly) higher technology value because he has a large feasible region. As a result, the discontinuity of supplier 1's optimal technology offer curve occurs at a lower α value than that of supplier 2.



(a) $\Delta = 0$ (b) $\Delta = 0.5$

Figure 1: Optimal technology value v^* as a function of α (at $\mu = 1$).



(a) α as a function of Δ (b) α as a function of the market share

Figure 2: Minimum α such that $v^* = \bar{v}_1$ for supplier 1.

Figure 2(a) specifies the minimum α needed to induce supplier 1 to offer the highest technology value $\bar{v}_1$ for a given Δ. To capture the whole scope of Δ, the x-axis in Figure 2(b) is the implied market share, which varies from 0 to 1 as Δ varies from $-\infty$ to ∞. As Δ approaches ∞ (and the implied market share approaches 1), α approaches 1. When the technology leader's implied market share is at most twice as large as that of the technology follower, $\alpha = 15\%$ is sufficient to induce the suppliers to offer their highest technology values.

To quantify the effectiveness of the bundled procurement mechanism, we compare the buyer's expected profit under the bundled procurement with the profit when she procures only tangible goods. We find that similar to the MNL model, the bundled procurement is preferred when $|\Delta|$ is not too large and α is sufficiently large. We also observe that the cost for the technology acquisition (i.e., the procurement cost under the bundled procurement mechanism minus the procurement cost when the buyer only procures the tangible goods) can be negligible compared to the expected profit from the future market.

D The Procurement Practice in Three Gorges Project

The study is partly motivated by the generator procurement practice in Three Gorges project, the world's largest hydroelectric power station in generating capacity. Numerous Chinese enterprises were involved in the actual procurement process. For example, Three Gorges International Bidding Limited Corporation was set up to handle the procurement process, while Harbin Electric Machinery and Dongfang Electric Machinery were the manufacturers who received the technologies. Because all these entities are state-owned enterprises, it is natural for the national development strategy to focus on the total gain of all these firms while each individual firm aims to maximize its own profit.

The international bidding for the generators commenced in June 24th, 1996. Instead of procuring all the generators needed, the project was designed so that the dam was built in multiple phases and only the generators on the left bank was procured in the beginning, and the other half of the procurement needs were kept for the future.

To ensure the success of the technology transfer, the tender documents clearly stated "three must": tenders must agree to work jointly with the Chinese enterprises on design and production, and assume full responsibility for the technical and economic availability of equipment; tenders must fully transfer the technology to Chinese enterprises, and train Chinese technical staff; Chinese manufacturing enterprises' subcontracting share must exceed 25% of the total contract price of the 14 units, and the last two units must be manufactured by Chinese enterprises.

Responding to the call, major international hydroelectric power equipment suppliers assembled themselves into consortiums in a bid to outpower each other. Given the complexity of the project, the deadline for bid submission was set at December 18, 1996 and all six consortiums submitted the bids on the deadline. After that, an evaluation team of eighty people evaluated the bids and conducted three rounds of multilateral negotiation. The evaluation and negotiation processes took eight months and achieved a price reduction of 20%, a saving of $200 million.

On September 2, 1997, the international procurement contracts and loan agreements for the 14 generators on the left bank of the Three Gorge Project were signed. The total contract price of the 14 generators is $740 million with the price tag for technology transfer at $16.35 million, both of which were paid by installments to ensure compliance. The contracts also specified a subcontracting share of 31% ($230 million) for the Chinese enterprises.

In 2004, Alstom, Harbin Electric Machinery, and Dongfang Electric Machinery each won four units out of the 12 generators on the right bank of the Three Gorges project. The two Chinese enterprises transferred from the rim of bankruptcy to leading suppliers in the world market, and currently building 19 of the 24 largest hydropower plants worldwide (Godrey 2009).

E Estimating α for Three Gorges Project

In this section, we estimate the relative project size α for the generator procurement project. The procurement project (left bank) includes 14 generators, each with a capacity of 700 megawatts. To calculate the discounted future market, we first estimate the growth rate of the hydropower industry. Table 2 from U.S. Energy Information Administration lists the worldwide installed capacity of hydroelectricity from 1980 to 2005. We observe that the hydropower industry has enjoyed a stable growth rate of 2.0-2.1%, whether we choose the fifteen-year period (1980-1995) before the call of proposals, or the ten-year period (1995-2005) when the Three Gorges Dam (left bank) was constructed.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Capacity (GW)	462	477	493	506	522	538	552	569	583	573	573	578	588
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capacity (GW)	599	614	625	635	649	658	676	689	699	714	733	751	771

Table 2: Worldwide Installed Capacity of Hydropower

The discounted future capacity growth (GW) can be written as $\sum_{i=T+1}^{\infty} Mg(1+g)^{L-1}\frac{(1+g)^i}{(1+r)^i} = \frac{(1+g)^{L+T}}{(1+r)^T}\frac{g}{r-g}M$, where M is the worldwide capacity at the time of bidding, L is number of years it takes the generators to become operational and contribute to the worldwide capacity, T is number of years for the buyer to adopt the technology and compete with current suppliers, g is the growth rate, and r is the discount rate. The term $Mg(1+g)^L$ is the forecasted capacity growth when the generators become operational at the time of the bidding.

In the year 1996, when the proposals were solicited, $M = 638$ (GW). The generators became operational in batches over a three year span 2003-2005, and we set $L = 8$. We also set $T = 7$, as it was in June 2003 when China began to solicit international bidding for additional generators and the state-owned enterprises began to compete with the original suppliers. According to the historic trend available in 1995, the growth rate g is set at 2.0%.

During the summer of 1996, the long term (U.S.) government interest rate was slightly above 4% in real term. At a real return of 10%, the implied discounted future capacity would be 110 GW and $\alpha = 9.8/110 = 8.9\%$. At a real return of 12%, the implied discounted future capacity would be 78 GW and $\alpha = 9.8/78 = 12.6\%$. The implied α value is around 10% which is in line with the MNL and MNP models. Notice that back in 1995, China might opt to procure all the generators needed and double the α value of the procurement project; nevertheless, successful technology transfer was achieved by only procuring the generators on the left bank.

Reference

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