A Bargaining Framework Planning for Maintenance Service Under Governmental Arms Offset Intervention

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Abstract

Most developing countries achieved necessary critical technology quickly and efficiently through the international offset program through an arms purchase. This study investigates an unexplored asymmetrical information problem for a government procurement negotiation planning between a foreign government (FG) and its third-party logistics suppliers (3PL) in country to implicate a maintenance service for the arms equipments by using offset obligations as a governmental intervention. We introduces a maintenance service contracting framework which are categorized and quantified to ascertain what contracting options are determined by a modified principal-agent model for weighting cost sharing and penalty factors with uncertainties, and to evaluate what dominant strategies are used in cooperative bargaining games to players' agendas. Additionally, numerous practical cases have indicated that the governmental intervention generates a significant effect on the relative bargaining power in negotiations.

Keywords
Maintenance service supply chain; third-party logistics; offset program; principal-agent; cooperative negotiation

1. Introduction

In today's complex economy, the international arms offset program becomes a growing interest business behavior. It involves interactions between a foreign buyer (i.e., a foreign government, FG) and a seller (i.e., the arm's original equipment manufacturer, OEM) while the FG deals an international arms trade with the government of OEM's country, such as the U.S. government (USG). The basic philosophy behind an offset agreement is to structure a commitment so that the OEM will fulfill its offset obligations to reward the FG's requirements. In practices, if the FG requests a technical capability upgrade by involving an advanced technology transfer to a given third-party logistics supplier (3PL) at the FG's site and the OEM agrees to start this transfer program to fulfill the offset obligation, and then this request becomes an arms offset program. (Tien and Yang, 2005)

Additionally, most defense systems have permanently operational life cycles and their stakeholders expect them to exhibit the necessary performance characteristics such as availability. Keeping performance characteristics result continuous requirements for logistics and maintenance services to constitute a significant part of the economy. In general, such the maintenance service requirements often generating higher profit margins than sales of the original products.(Kim et al., 2007) Therefore the systems' OEM provides maintenance services to fulfill the requirements through a traditional material contract or a performance-based logistics (PBL) contract. A material contract is traditional means of maintenance service; a buyer pays the OEM for spare parts, labor, and other service activities that are used in contract duration. A PBL contract contains a service level agreement with respect to the availability of the system(s) at the buyer's site, and concentrates on performance results rather than on material results as traditionally done. (Chiang and Wainwright, 2004; Sols et al., 2007)

However, this service relationship in most studies referred more generally to buyers awarded contract to the only OEM. (Kim et al., 2007; Nowicki et al., 2008; Oliva and Kallenberg, 2003) As a result, the concentration lacked attentions on a buyer (i.e., FG) and a third-party logistics supplier (3PL) at FG's site under intervention of an arms offset program. This restriction causes difficulties in applying results to similar partnerships on a FG awards contracts to a local 3PL. Moreover, few studies attempted to account for the maintenance service supply chain's role in the partnerships and offset program linkages among the FG, 3PL, and OEM. This limitation undoubtedly results in the buyer only awards contracts to the OEM. Therefore, the observed phenomenon of FG awards contracts to 3PL by offset program is beyond the current study's criteria. The typical paradigm occurs when an OEM is requested by an arms offset program from the FG to establish a 3PL's maintenance capacity. Hence the FG can award a maintenance service contract to a 3PL in country for economical welfare purpose. Figure 1 illustrates the relationships among the FG, 3PL in FG's site and OEM.

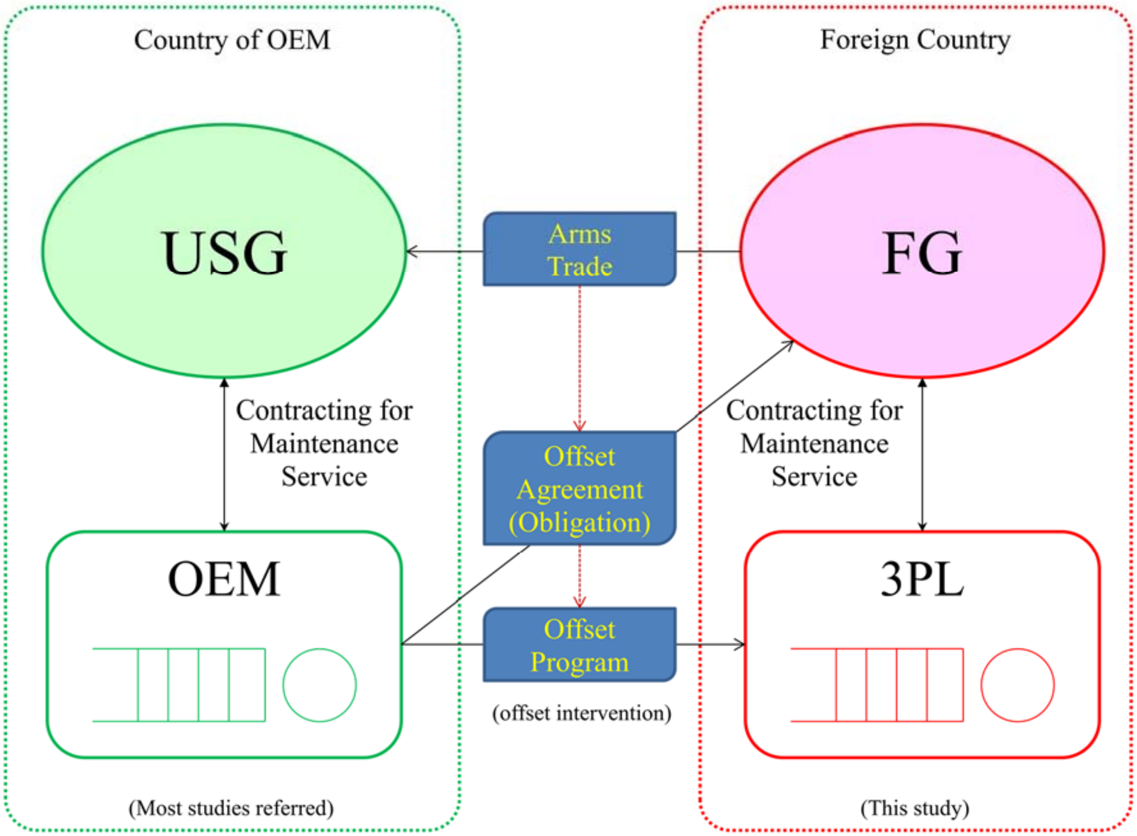

Figure 1: The arms offset and maintenance service relationships among the FG, a 3PL in country and OEM

Rooted in the conceptual framework proposed by Kim et al. (2007) and Lin et al. (2013), this study concentrates on negotiations between the FG and a specific 3PL$_i$ in maintenance service supply chain under the influence of the government procurement act (GPA) and an arms trade offset program. Specifically, this study addresses the following research questions.

(1) How do the FG and a 3PL$_i$ interact in bilateral negotiations for cooperative agreements?

(2) What are major concerns between the FG and a 3PL$_i$ in bilateral negotiations under governmental intervention, and how do they adapt to these influences while moving toward equilibrium bargaining solutions?

(3) How does bargaining power influence the negotiation decisions of dyadic players for a cooperative agreement in a maintenance service supply chain contingent on governmental financial intervention? Additionally, how do financial instruments influence various decision options of the FG and 3PL$_i$ in negotiations for maintenance service supply chain cooperation?

Compared with typical problems associated with supply chain cooperation, the issue addressed in this study has the following different features. First, this study aims at the maintenance service supply chain cooperation case by a 3PL$_i$ instead of the system's OEM. Second, this study under governmental intervention by means of GPA and financial measures from offset program.

2. Model

This section describes a total reimbursement cost by the principal-agent model to formulate the aforementioned bargaining problem in maintenance service supply chain between the FG and 3PL$_i$. The details of model formulation are presented in the following subsections.

2.1. Characteristics of maintenance service process

This study considers the FG awards an arms maintenance service contract to a 3PL$_i$ in the FG's site. The principal of maintenance service in this study is the FG acquires N identical assembled vehicles (e.g., helicopter and jet fighter etc.). Each vehicle is composed of n distinct major systems (e.g., engine or avionics) and each of them are planned to maintain by a unique 3PL$_i$ to fulfill the FG's strategies for cultivating its local industries. Failure of the system is assumed to occur at a Poisson rate λ , independently from failures of other systems. Notably, the FG maintains an inventory for spare systems and employs one-for-one base stock policy. It is a very unique but reasonable assumption for inventory. This is because in most arms trade cases, the FG also purchases spare systems in advance for uncertainties such as the FG fails bargain with a given 3PL$_i$ or the system's OEM does not release maintenance technologies to a 3PL$_i$. (Lin et al., 2013) Such inventory policy allows a immediately working system replacement while a failed one enters the 3PL$_i$'s repair facility; or occurs a backorder B_i to affect system's availability. Figure 2 illustrates this unique closed-loop cycle between the FG and 3PL$_i$ in the FG's site.

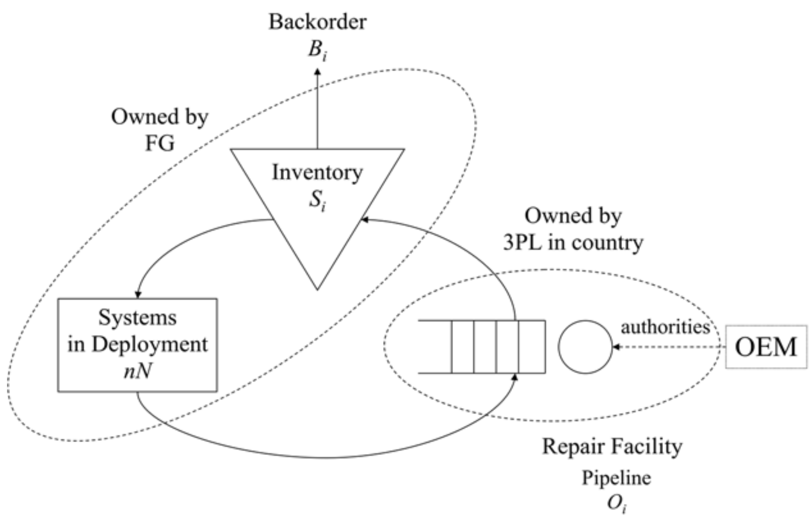

Figure 2: Closed-loop cycle for repairable systems

Additionally, the backorder B_i is a random and positive integer variable that is observed at a random point in time after steady state is reached by inventory level s_i and the repair pipeline (on-order) O_i through

$$B_i = O_i - s_i \,. \tag{1}$$

Notably, Palm's Theorem states that O_i belongs to Poisson distributed for any repair lead time distribution. (Feeney and Sherbrooke, 1966)

Proposition 2.1 The expected backorder $E\left[B_i \middle| s_i\right]$ is decreasing and convex in s_i .

Let the repair pipeline $O_i \in [0,\infty)$ is distributed continuously with cdf $F_i(0) \geq 0$ and pdf f_i. The distribution of B_i is obtained with $\Pr(B_i \leq x | s_i) = \Pr(O_i \leq x + s_i)$. Additionally, The expected backorder $E[B_i | s_i] = \int_{s_i}^{\infty} (1 - F_i(x)) dx$, therefore the differentiation $dE[B_i | s_i] / ds_i = -1 + F_i(s_i) \leq 0$ and $dE^2[B_i | s_i] / ds_i^2 = f_i(s_i) \geq 0$.

Hence the expected backorder $E[B_i | s_i]$ is decreasing and convex in s_i.

2.2. The reimbursement cost

We first set a 3PL$_i$'s fixed cost function c_i to generate a total reimbursement cost C_i. The fixed cost is composed of a building up cost (e.g. hardware section such as facility founding cost) η_f; software sections such as authorities and technical assistance (by OEM) cost η_a, and a summation cost for all maintenance actions η_m through

$$c_i = \eta_f + \eta_a + \eta_m . \tag{2}$$

Notably, the c_i can be reduced by the 3PL$_i$'s cost reduction effort a_i. By exerting effort, the 3PL$_i$'s incurs disutility $\psi_i(a_i)$ which is convex increasing ($\psi_i'(a_i) > 0$, $\psi_i''(a_i) > 0$), therefore $\psi_i(a_i)$ can be assessed by FG. Furthermore, we assume a_i is 3PL$_i$'s discretionary decision. This allows the FG does not subsidize 3PL$_i$'s internal cost to withstand the scrutiny of a possible audit, but only reimburses the undisputed direct costs of maintenance. In the sequel, Chen (2005) proposed a quadratic function $\psi(a_i) = k_i a_i^2 / 2$ with $\forall k_i > 0$ to generate compact expressions without fundamentally changes in our model. Therefore the total reimbursement is observable by FG through

$$C_i = c_i - a_i + \varepsilon_i . \tag{3}$$

The variable ε_i represents an uncertainty that is beyond the 3PL$_i$'s control and which is uncorrelated with backorder B_i, therefore $Cov[\varepsilon_i, B_i] = 0$. Additionally, Equation (3) does not consider an alternative, whereby 3PL$_i$'s efforts impact the availability or other performance characteristics of system *i,* with or without extra technical assistance from the OEM. This is a reasonable because in practice, the arms export country (e.g., USG) will not allow such performance increase by a 3PL$_i$ in the FG's site.

2.3. Expected utility solution for the FG and 3PL$_i$

To facilitate model formulation, we assume all competing 3PLs provide the same unit price for maintenance service ($p_i = p_j = p$, $\forall i \neq j$) to the FG. We infer a cooperative contract function $T(C_i, B_i)$ by Lin et al. (2013) between the FG and a specific 3PL$_i$ as

$$T(C_i, B_i) = \omega_i + \alpha_i C_i - \upsilon_i B_i . \tag{4}$$

Equation (4) represents the FG's payment (transfer) to 3PL$_i$ is comprised of three terms: (1) a fixed payment ω_i, (2) a reimbursement C_i for 3PL$_i$'s nonnegative cost without incentive, and (3) a backorder-contingent B_i. It helps the FG can determine ω_i, α_i and υ_i as contract parameters. Additionally, the variable α_i is the FG's share of 3PL$_i$'s costs, and υ_i is the penalty rate for backorders B_i incurred by 3PL$_i$. Therefore the FG can evaluate the effectiveness of the most widely used four contract forms by controlling α_i and υ_i in Equation (4) to effectively analyze decision-making with four bargaining options through

Option 1. A pure fixed price contract $T_F\left(C_i, B_i\right)$ that combines without reimbursement and penalty items. Thus the contract option $T_F\left(C_i, B_i\right)=\omega_i$, where $\alpha_i=0$ and $\upsilon_i=0$;

Option 2. A common practice $T_P\left(C_i, B_i\right)$ that combines with $T_F\left(C_i, B_i\right)$ and penalty items but without reimbursement. Thus the contract option $T_P\left(C_i, B_i\right)=\omega_i-\upsilon_i B_i$, where $\alpha_i=0$ and $\upsilon_i \in\left(0,1\right]$;

Option 3. A cost-plus contract $T_C\left(C_i, B_i\right)$ that combines with reimbursement and without penalty item. Thus the contract option $T_C\left(C_i, B_i\right)=\omega_i+\alpha_i C_i$, where $\alpha_i \in\left(0,1\right]$ and $\upsilon_i=0$; and

Option 4. A performance-based contract $T_B(C_i, B_i)$ that combines with reimbursement and penalty item. Thus the contract option $T_B\left(C_i, B_i\right)=\omega_i+\alpha_i C_i-\upsilon_i B_i$, where $\alpha_i \in\left(0,1\right]$ and $\upsilon_i \in\left(0,1\right]$.

Table 1 shows various contracting behaviors of the FG and a 3PL$_i$ under all four contract combinations, which are integrated into a typical normal form of game theory.

Table 1: Normal form for feasible contracting options.

		3PL$_i$	
		$\alpha_i=0$	$0<\alpha_i<1$
FG	$\upsilon_i=0$	$T_F\left(C_i, B_i\right)=\omega_i$	$T_C\left(C_i, B_i\right)=\omega_i+\alpha_i C_i$
	$0<\upsilon_i<1$	$T_P\left(C_i, B_i\right)=\omega_i-\upsilon_i B_i$	$T_{PB}\left(C_i, B_i\right)=\omega_i+\alpha_i C_i-\upsilon_i B_i$

Those four contracting options are demonstrated in real practices to represent both parties' perspectives (i.e., the FG and 3PL$_i$). Additionally, the 3PL$_i$ is the only maintenance service provider for system *i* in the FG's site, therefore we assume the 3PL$_i$ is risk aversion and looks for maximum profit. Scherer (1964) demonstrated the risk-averse relationship of the 3PL$_i$ to represent expected mean-variance utility through

$$E\left(U_i\left(X\right)\right)=E\left(X\right)-\gamma_i \frac{Var\left[X\right]}{2}. \tag{5}$$

The risk aversion factor γ_i is constant and $\gamma_i \geq 0$, such that the greater γ_i is, the more risk aversion 3PL$_i$ has. This expected utility function has been widely used in recent operations-management research because of its tractability. (Kim et al., 2007) Hence we derive the expected utility function $E_i\left[U_i(T(C_i, B_i)-C_i)-\psi(a_i)\middle|a_i, s_i\right]$ for 3PL$_i$ by the contract function $T\left(C_i, B_i\right)$ through Equation (4-5), where

$$E_i\left[U_i(T(C_i, B_i)-C_i)-\psi(a_i)\middle|a_i, s_i\right]=\omega_i-(1-\alpha_i)(C_i-a_i)-\upsilon_i E\left[B_i\middle|s_i\right]-\frac{ka_i^2}{2}-\gamma_i(1-\alpha_i)^2\frac{Var\left[\varepsilon_i\right]}{2}-\gamma_i\upsilon_i^2\frac{Var\left[B_i\middle|s_i\right]}{2}. \tag{6}$$

The first three terms together in Equation (6) represent the expected net income of a 3PL$_i$; whereas the fourth term is the internal disutility for exerting cost reduction efforts; and the last two terms represent risk premiums associated with cost and performance uncertainties respectively.

Similarly, the expected utility function $E_g\left[U(-T_i(C_i, B_i))\middle|\left\{a_i, s_i\right\}\right]$ of FG is derived through

$$E_g\left[U(-T_i(C_i, B_i))\middle|\left\{a_i, s_i\right\}\right]=-(\omega_i-\alpha_i(C_i-a_i)-\upsilon_i E\left[B_i\middle|s_i\right]+\gamma_i\alpha_i^2\frac{Var\left[\varepsilon_i\right]}{2}+\gamma_i\upsilon_i^2\frac{Var\left[B_i\middle|s_i\right]}{2}). \tag{7}$$

The first three terms of Equation (7) represent the expected net payment of the FG, and the last two terms represent the penalties in backorder cases B_i incurred in the maintenance service sequence. Notably, the FG's utility is a function of the total expenditure; and 3PL$_i$ is assumed to have a fixed reservation utility in one contract duration.

Hence we can normalize its value to zero without loss of generality. Therefore, we can derive the expected utility function $E\left[U\left(x\right)\right]$ of a 3PL$_i$ from Equation (6) and the FG from Equation (7) with contracting options by weighting parameters α_i and υ_i in Table 2.

Table 2: Expected utilities of various contracting options.

Option	FG	3PL$_i$
T_F	$-\omega$	$\omega-(C_s-a)-\frac{ka^2}{2}-r\frac{Var[\varepsilon]}{2}$
T_P	$-(\omega-\upsilon E[B_i\|s_i]+r\upsilon^2\frac{Var[B_i\|s_i]}{2})$	$\omega-(\mathrm{C}_s-a)-\upsilon E[B_i\|s_i]-\frac{ka^2}{2}-r\frac{Var[\varepsilon]}{2}-r\upsilon^2\frac{Var[B_i\|s_i]}{2}$
T_C	$-(\omega-\alpha(C_s-a)+r\alpha^2\frac{Var[\varepsilon]}{2})$	$\omega-(1-\alpha)(\mathrm{C}_s-a)-\frac{ka^2}{2}-r(1-\alpha)^2\frac{Var[\varepsilon]}{2}$
T_{PB}	$-(\omega-\alpha(\mathrm{C}_s-a)-\upsilon E\left[B_\mathrm{i}\|s_\mathrm{i}\right]+r\alpha^2\frac{Var\left[\varepsilon\right]}{2}+r\upsilon^2\frac{Var\left[B_\mathrm{i}\|s_\mathrm{i}\right]}{2})$	$\omega-(1-\alpha)(C_s-a)-\upsilon E[B_\mathrm{i}\|s_\mathrm{i}]-\frac{ka^2}{2}$ $-r(1-\alpha)^2\frac{Var[\varepsilon]}{2}-r\upsilon^2\frac{Var[B_\mathrm{i}\|s_\mathrm{i}]}{2}$

Our representation of the 3PL maintenance services relationship is based on a standard single-location, steady-state repairable model with a take-it-or-leave-it contract. According to Nagarajan and Bassok (2008), the order steps of play is through

(1) The FG acquired numbers of the system *i* and set the base stock levels of spares inventory s_i.
(2) The FG requests an offset program (i.e., the intervention) to system's OEM, and the OEM agrees to provide technical assistance to a local 3PL$_i$ in FG's site for establishing a maintenance service supply chain.
(3) The FG offers a take-it-or-leave-it contract, which agrees to cover the 3PL$_i$'s total cost C_i of providing maintenance service and specifying an additional price $p(C_i)$ for each cost level that 3PL$_i$ might report.
(4) The 3PL$_i$ accepts or rejects the contract.
(5) If the 3PL$_i$ accepts, it chooses effort level e, which is unobserved by the FG.
(6) The 3PL$_i$ finishes the maintenance service at a cost of C_i and a performance-based measurement (e.g., operational reliability). Hence the FG reimburses C_i and pays $p(C_i)$ under a constraint budget ω_i.

The primary purpose of imposing a constraint is to give due cognizance to certain limiting factors presented in the optimization problem under discussion. In real practices for any contracting, the best utilities in certain constrained conditions, such as locating the stationary values, are the most significant issue for each contracting party. When the constraint is complex, or when several constraints must be considered such as those shown in Table 2, we resort to a known method of the Lagrange-multiplier (Chiang and Wainwright, 2004) to convert the all four contracting options of constrained-stationary values into a form. Hence, δ is the Lagrange multiplier that observes optimization with equality constraints by using the following four theorems to specify the conditions with constraint variables (α_i, υ_i), as shown by Lin et al. (2013).

3. Numerical example analysis and result

This section generates a dominate strategy in a cost-effective manner using feasible contracting options. Based on the derived equilibrium solutions, qualitative and quantitative analyses are conducted as follows to provide additional insights into the correlations between the FG and 3PL$_i$ decision variables. We present a real defense maintenance service contracting evaluation with a 3PL$_i$ in Taiwan. This numerical example demonstrates how the proposed model can be applied in practice to support the long-term strategic commercial maintenance policies (SCMP), and bargaining conditions for an eight year contract between the Taiwanese government (i.e., the FG) and a unique 3PL$_i$ in country. The model notations show budget constraints, costs, and cost sharing and penalty parameters, which must be carefully considered. Notably, the relationship between the cost and budget constraint parameters must be reasonably specified.

A total N=100 military twin-engine helicopters are deployed in the fleet, which are powered by a type T engine system, and plus 10% for spare by Taiwan government (i.e., the FG). Table 4 shows the budget constraint considerations under a general situation, that is, without critical mission requirements, where the maintenance capability requirements of Type T series engines are shown.

Table 4: Basic considerations about model parameters

FG	$3PL_i$
Contract duration: 8 years Budget constraint ω_i =\$17M Type T engine n=200, s=20 Type T engine unit price p_u =\$0.5M Max. penalty rate υ=20% System availability=99.7%	Facility founding cost η_f : \$5M Software cost η_a : \$1M for 4 years Depreciation: Accelerated for 5 years Average unit maintenance cost: \$0.1M Profit: 10% of unit MRO cost

Table 5 shows the estimated data by the OEM of the yearly quantity of maintenance and backorders in contract durations.

Table 5: Expected maintenance/ backorder data in contract duration by OEM

Year	1st	2nd	3rd	4th	5th	6th	7th	8th	Total
Maintenance	11	11	12	12	13	13	14	15	101
Backorder	3	2	3	3	3	2	3	2	20

3.1. Determine numerical solutions for contract options

Under a selected availability target (i.e., performance characteristics), an incentive term is offered to support the software costs of $3PL_i$ by using offset program. In this example, we first derive the cost sharing weighting factor

$$a_i = \frac{\eta_a}{C_s} \approx 0.077. \tag{8}$$

The SCMP contracting value (i.e., ω_i =\$17 million) meets the threshold of the large procurement section in the GPA; thus, we can derive the penalty weighting rate as $0 \le \upsilon_i \le 0.2$. Additionally, we determine values of parameters K_i and $Var\left[\varepsilon_i\right]$ by using the following approach, where K_i is $3PL_i$'s fixed cost, such that

$$K_i = E\left[K_i\right] + \varepsilon_i. \tag{9}$$

For $3PL_i$, we knew that the expected investment $\eta_f + \eta_a \approx 15 p_u$, therefore the maximum cost reduction $a_i = 1/K_i$ is assumed to be $\left(1-1.5\sigma\right)E\left[K_i\right]$; thus,

$$k = \frac{2}{15 p_u}. \tag{10}$$

For simplicity, we also assumed the coefficient of variation to distinguish the cost uncertainties as

$$\rho = \frac{\sqrt{Var[\varepsilon_i]}}{E[K_i]}. \qquad (11)$$

We inferred the risk aversion coefficient (Kim et al., 2007) for the $3PL_i$ by using simplistic market capitalization of a representative manufacturer of the Type T engine system; for example, the manufacturer of the helicopters is chosen as the customer, and the $3PL_i$ is the supplier. Therefore we calculates the risk aversion ratio as

$$r = \frac{r_n}{r_N} \approx 98 \qquad (12)$$

Hence, we can determine the optimal expected utility values and orders for both parties, which are shown in Figure 3-4, by contracting options and cost uncertainties.

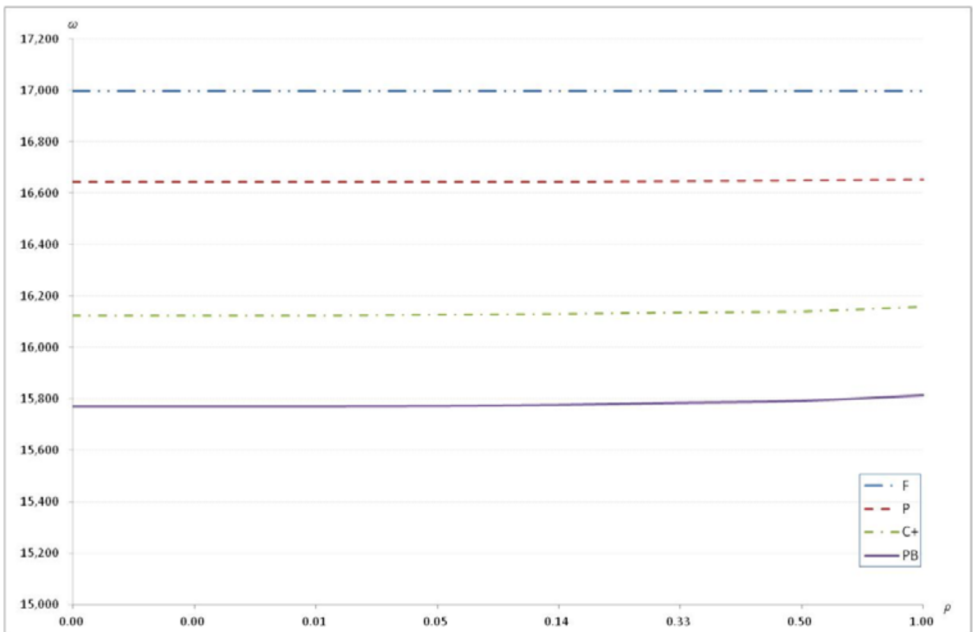

Figure 3: Expected Optimal Contract Utility Solutions for FG's budget (ω) and cost uncertainties (ρ)

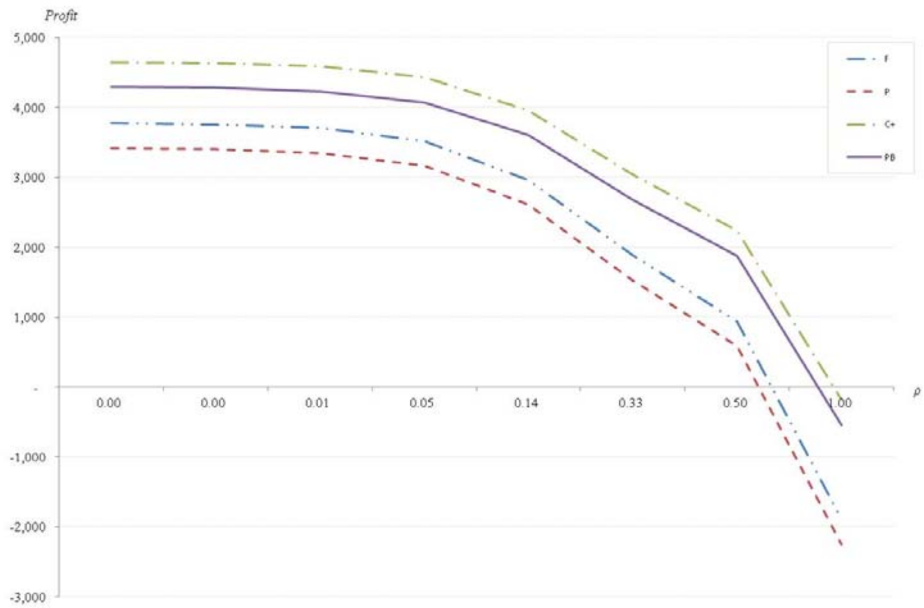

Figure 4: Expected Optimal Contract Utility Solutions for 3PL's profit and cost uncertainties (ρ)

3.2. The bargaining decision analysis for FG and 3PL

The characteristics of the solution indicate that the performance-based contract T_{PB} and cost-plus contract T_C should be the dominant maintenance strategy for this real logistics service contract because

(1) All contracting options indicate higher uncertainty results in steady expected budget spending for the FG; therefore the FG has a tendency towards risk neutral when considering a bargaining framework for this maintenance service under governmental arms offset intervention.

(2) All contracting options indicate higher uncertainty results in lower expected utility for the 3PL$_i$; therefore the 3PL$_i$ has a tendency towards risk aversion.

(3) For the FG's decision, the expected utilities (budgeting) exhibit $T_F > T_P > T_C > T_{PB}$, hence the FG's bargaining option order is $T_{PB} \succ T_C \succ T_P \succ T_F$ under a minimum budget consideration.

(4) For the 3PL$_i$, the expected utilities (profits) exhibit $T_C > T_{PB} > T_F > T_P$ with little difference in amount, hence the 3PL's bargaining option order is $T_C \succ T_{PB} \succ T_F \succ T_P$ under the maximum profit consideration.

Generally, the four contracting options combine the requirements for maximum profit for the 3PL$_i$ and minimum budget-balancing for the FG. Consequently, our proposed framework concludes that the FG is capable of performing a role for dominating the budget-balancing consideration as the first-priority criterion in contracting because the FG provides the offset program from system's OEM as an incentive and offers a take-it-or-leave-it contract to the 3PL$_i$ in country. Thus, the performance-based contracting (T_{PB}) should be the first priority for bargaining option between the FG and 3PL$_i$.

4. Conclusion

This study develops a cooperative-bargaining game model to determine a 3PL's maintenance service contract design and optimization under governmental arms offset intervention by principal-agent theory. The present findings contribute to the maintenance service supply chain field of understanding among the various forces acting on PBC bargaining options and dominant strategy. One such force is the impact between the FG, the 3PL$_i$, and the relationships with the OEM by the international arms offset program. It also constructs incentives for four commonly used contracting options to generate the dominant strategy for the FG and 3PL$_i$.

Additionally, performance-based contracting in maintenance service supply chains offers fertile ground for research where economics and classical inventory theory converge naturally. The numerical analysis demonstrate that the proposed framework is not only capable of generating performance-based contract (T_{PB}) option as the best contracting optimization by providing the arms offset program from the system's OEM as an incentive advantage to the $3PL_i$, but also demonstrate the maximum expected utilities for the $3PL_i$ and minimum budget-balance for the FG when dominating T_{PB} option. The innovation is in explicitly modeling to discover the incentive and penalty terms in the exhibit complementarily; that is, the most concerning issue for both parties is in the same direction as cost uncertainty influences. It also allows them to make normative predictions to evolve a dominant strategy, which prior research has seldom attempted.

Further research should investigate the following: First, the impact of some preventive maintenance actions rather than inspections, such as greasing and cleaning, can be considered, which may alter the rate of arrival of defects. Furthermore, real practices indicate that non-perfect maintenance may be unable to restore equipment to its original state. The constant rate of the arrival of defects can be relaxed, at the expense of more tedious mathematical manipulations. Second, the maintenance supply chain parties' bargaining using asymmetric/incomplete information is an important consideration because using negotiations with asymmetric agents may help formalizes notions, such as inventory and information being substitutable.

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Biography

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