Outsourcing is currently being used as an important strategy for many companies to achieve cost savings and speed up delivery time. In this research, a game theoretic model is used to design the optimal contracts between the buyer and the supplier under two types of information scenario. Under the full information case, the buyer shares her internal variable cost information with the supplier. Under the asymmetric information case, the buyer does not share her internal variable cost information with the supplier. In both cases we find the optimum outsourcing price, outsourcing time, outsourcing quality, and retail price.

**KEYWORDS:** outsourcing price, outsourcing time, outsourcing quality, contract, game theory.
ABSTRACT

Outsourcing is currently being used as an important strategy for many companies to achieve cost savings and speed up delivery time. In this research, a game theoretic model is used to design the optimal contracts between the buyer and the supplier under two types of information scenario. Under the full information case, the buyer shares her internal variable cost information with the supplier. Under the asymmetric information case, the buyer does not share her internal variable cost information with the supplier. In both cases we find the optimum outsourcing price, outsourcing time, outsourcing quality, and retail price.

KEYWORDS: Outsourcing Price, Outsourcing Time, Outsourcing Quality, Contract, Game Theory.

INTRODUCTION

With the market becoming increasingly more competitive, many companies focus on maximizing return on investments by reducing costs. Besides the cost savings, outsourcing has some other advantages, including decreasing time to market. When a company doesn’t have skills or expertise for a certain work, it may outsource that work to a supplier who can help to reduce time-to-market, like faster start-up, development and scalability for new operations. Accenture and Procter & Gamble’s (P&G) won ‘Most Innovative’ Outsourcing Excellence Award in 2013. The award recognizes Accenture’s and P&G collaboration on a commercial services program in which P&G outsources its digital marketing campaigns, e-retailer content and virtual reality centers to Accenture.

But the outsourcing is not a trouble free solution. The major concern is the quality of outsourcing work. If the outsourcers cannot get the expected quality level, the company may decide to stop outsourcing in most cases. Dell stopped routing corporate customers to a technical support call center in India because of quality issues in 2003. The quality of the particular call center was unsatisfactory leading to corporate customers’ dissatisfaction. To avoid getting hurt, Dell promptly decided to channelize those calls to a higher quality onshore center. Individual customers, on the other hand, got shifted to the lower-cost offshore centers (Huettel, 2004).

In this research, we use a game theoretic model to design the optimal contracts between the buyer who seeks outsourcing and the supplier under two types of information scenario. Under
the full information case, the buyer shares her internal variable cost information with the supplier. Under the asymmetric information case, the buyer does not share her internal variable cost information with the supplier. In both cases we find the optimum outsourcing price, outsourcing time, outsourcing quality level, and retail price.

LITERATURE REVIEW


Though outsourcing has been extensively researched in literature, relatively few have studied multiple factors in outsourcing. Most research only focus on one of the aspects of outsourcing, either cost reduction, time saving, or quality management. In contrast to any of the above research streams, our paper combines the issue of three major outsourcing benefits (cost reduction, time-saving, and quality control) and information asymmetry.

THE MODEL

As showed in Figure 1, we consider a Stackelberg game where the supplier acts as the leader and the buyer acts as a follower. First, the supplier decides the unit outsourcing price \( s \), the launch time of outsourcing product/service \( t \), and the quality of outsourcing product/service \( Q \). Then the buyer announces the retail price \( p \) to the final customers. The decision variables in our model are outsourcing price \( s \), launch time \( t \), and outsourcing quality \( Q \) for the supplier and retail price \( p \) for the buyer, each maximizing his or her own profit functions.
Demand Function

\[ d = a - bp - rt + eQ \]

(1)

where \( a > 0, \ b > 0, \ r > 0, \) and \( e > 0 \) are known parameters. As we see that the demand \( d \) is decreasing in retail price \( p \) and time to market (outsourcing time) \( t \), and increasing in the quality of outsourcing product/service \( Q \). \( a \) is the base demand. \( b \) is the retail price elasticity. \( r \) is the sensitivity of outsourced work with respect to the time to market. \( e \) is the sensitivity parameter of outsourced work with respect to the quality of outsourcing work. Including time and quality factors in the demand function is the one of major contribution for this research.

Profit Functions

The supplier’s profit function is:

\[ \pi_s = (s - c)d - \frac{L}{2} \left( \frac{T - t}{T} \right)^2 - \frac{K}{2} Q^2 \]

or

\[ \pi_s = \frac{s - c}{2} \left[ d - \frac{L}{T} \left( \frac{T - t}{T} \right)^2 - \frac{K}{2} Q^2 \right] \]

(2)

The supplier receives \( s \) from the buyer for each unit of outsourcing work. The costs for offering outsourcing work include variable cost \( c \) per unit, fixed cost related to launch time \( t \), and fixed cost related to quality \( Q \). The fix cost includes the wage for the supplier’s employees, cost of utilities and equipment, cost of training of employees, and other costs. \( T \), pessimistic estimate time, is the maximum time required for completing outsourcing work under adverse conditions. \( t \), the span of completing outsourcing work, is the decision variable for the supplier. \( T - t \) is the time saving. \( \frac{T - t}{T} \) is the ratio of time saving. \( L \) is a fixed cost parameter. \( T \) and \( L \) are common knowledge. We also assume that the quality cost is increasing in the level of...
quality offered represented by a quadratic function given by \( \frac{K}{2} Q^2 \). \( K \) is a common knowledge, a measure of the supplier quality cost efficiency. Similar fixed cost functions are extensively used in literature, including Kouvelis and Mukhopadhyay (1999), Mukhopadhyay, Zhu and Yue (2008) and Mukhopadhyay, Su and Ghose (2009), Zhu and Mukhopadhyay (2009) and etc.

The buyer’s profit function is:

\[
\pi_B = (p - s - m)d \quad \text{or} \quad \pi_{B_0}
\]

The profit margin for each outsourcing work is decided by using retail price \( p \) subtracting by outsourcing price \( s \) and buyer’s internal variable cost \( m \). We assume that \( p - s - m > 0 \). \( m \) is a private information of the buyer. In general, the supplier does not know \( m \). The buyer assumes the supplier holds a prior cumulative distribution \( F(m) \) with density function \( f(m) \), defined on \([m, \bar{m}]\), where \( 0 \leq m \leq \bar{m} \leq \infty \). The reservation profit levels of the supplier and the buyer are \( \pi_{S_0} \) and \( \pi_{B_0} \), respectively. Buyer’s profit will drop to her reservation profit for a certain value of \( m \) called \( M \), the cut-off point. At this point, the buyer will stop to trade with the buyer.

The supplier will refuse to trade with the buyer if his profit is below \( \pi_{S_0} \). Ha (2001) shows that including the cut-off point in the contract is indeed optimal.

**THE CONTRACTS**

We will study two kinds of contract: contract under full information (F), and under asymmetric information (A).

**Contracts under Full Information (F)**

In this scenario, the buyer agrees to share her private information about \( m \) to the supplier. The moves of buyer and supplier follow a Stackelberg type game. The supplier acts as the leader, announcing the \( s, t \) and \( Q \) first; the buyer acts as the follower, announcing the \( p \) after that. The solution of this game follows.

Lemma 1 gives the buyer’s best response function, as functions of \( s, t \) and \( Q \). All proofs are shown in the Appendix.

**Lemma 1:**

Buyer’s best response function in terms of the Supplier’s parameters is given as:
In stage 1 of the game, the supplier derives the optimal \( s, t \) and \( Q \) by maximizing his own profit \( \pi_s \), given in Equation (2), and substituting the optimum values of \( p \) with \( p^{BR} \) thus making it a function of \( s, t \) and \( Q \) alone. In Stage 2 of the game, the buyer uses the supplier’s policy announcement \( s_F, t_F \) and \( Q_F \), and maximizes her own profit function to obtain the optimal policies \( p_F \) in Proposition 1.1.

**Proposition 1.1:**

The equilibrium outsourcing price, outsourcing time, outsourcing quality, and retail price under full information are given by:

\[
p_F = -\frac{-a + Tr - eQ - bs - bm}{2b}
\]

\[
s_F = -\frac{-2aL + T^2 r^2 Kc + 2TrLK + 2bmLK - 2cbLK + e^2cL}{4bKL - T^2 r^2 K - e^2 L}
\]

\[
t_F = \frac{T(-TraK + TrbKm + TrcbK + 4bLk - e^2 L)}{4bKL - T^2 r^2 K - e^2 L}
\]

\[
Q_F = -\frac{L(-a + Tr + bm + bc)e}{4bKL - T^2 r^2 K - e^2 L}
\]

\[
p_F = -\frac{-3KaL + r^2 T^2 Km + r^2 T^2 Kc + 3TrKL + e^2 Lm + e^2 Lc - bKmL - bKcL}{4bKL - T^2 r^2 K - e^2 L}
\]

The corresponding profits at equilibrium are given as:

\[
\pi_{BF} = \frac{K^2 L^2 (-a + Tr + bm + bc)^2 b}{(4bKL - T^2 r^2 K - e^2 L)^2}
\]

\[
\pi_{SF} = \frac{KL(-a + Tr + bm + bc)^2}{2(4bKL - T^2 r^2 K - e^2 L)}
\]

In the next proposition, we derive insight into how these optimal values change when the parameters vary.

**Proposition 1.2:**

In the full information case,
i. The optimal outsourcing unit price \( s_F \) is increasing in \( a \) and decreasing in \( m \);

ii. The optimal outsourcing time \( t_F \) is increasing in \( m \) and \( c \), and decreasing in \( a \);

iii. The optimal outsourcing quality \( Q_F \) is increasing in \( a \) and decreasing in \( c \);

iv. The optimal retail price \( p_F \) is increasing in \( a \);

v. The buyer's profit \( \pi_{BF} \) is bigger than or equal to the supplier's profit \( \pi_{SF} \) if

\[
\frac{2KLb}{4bKL - T^2r^2K - e^2L} > 1
\]

From the Proposition, we see that outsourcing price \( s_F \), retail price \( p_F \), and outsourcing quality \( Q_F \) are all increasing in base demand \( a \). It follows intuition. It is interesting to see that outsourcing time is decreasing in \( a \).

**Contracts under Asymmetric Information (A)**

In this scenario, the supplier typically does not know the buyer's internal variable cost \( m \). The supplier acts as a leader, proposing outsourcing unit price \( s \), finish time \( t \), and quality of outsourcing level \( Q \) without knowledge of \( m \). The buyer acts as the follower, announcing retail price \( p \) after that. The supplier offers a contract to the buyer which is a menu of \( \{s, t, Q\} \) meaning that it offers a number of alternative values for this contract. The buyer has a choice of not accepting the contracts but earning her reserved profit \( \pi_{BF} \) if none of the alternatives are attractive enough to her. Or she may select one alternative from the menu and decides to accept that. In the next proposition, we derive the equilibrium outsourcing price, outsourcing time, outsourcing quality level, and retail price for the buyer and supplier under Asymmetric Information in the next proposition.

**Proposition 2.1:**

The optimal contract under asymmetric information can be found as follows. Find all contract menu \( \{s_A, t_A, Q_A\} \) that satisfy the following equations:
Proposition 2.1 gives the optimal policies of both parties when information asymmetry exists in the supply chain.

Proposition 2.2:

i. The optimal outsourcing unit price $s_A$ is increasing in $a$;

ii. The optimal outsourcing time $t_A$ is increasing in $c$, and decreasing in $a$;

iii. The optimal outsourcing quality $Q_A$ is increasing in $a$, and decreasing in $c$;

We get similar findings for the full information case.
NUMERICAL EXPERIMENTS

In this section, we will briefly report the results of our extensive numerical experimentation. The numerical values used in this experiment are given in Table 1.

<table>
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<th></th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>L</th>
<th>T</th>
<th>c</th>
<th>m</th>
<th>( \bar{m} )</th>
<th>( \pi_{S^{-}} )</th>
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<td>1</td>
<td>3</td>
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</table>

Comparing the Profit Functions in Two Cases

We assume a Uniform distribution for \( m \) with \( m \in [m, \bar{m}] \) for the asymmetric information case. In the first set of analysis, we study how the outsourcing price varies when the buyer’s internal cost \( m \) varies. The results are shown in Figure 2. We see that the outsourcing price \( F \) and \( A \) are all decreasing with \( m \). The value of information is reflected in the gap between the cases of full information (F) and asymmetric information (A). The supplier will get higher outsourcing price under (F) than under (A), \( S_F > S_A \). The finding is Figure 2 is consistent with our analysis result in Proposition 1.2 (i). The buyer prefers asymmetric information (A) to get a higher unit profit margin, like \( \pi_{S^{-}} \). She would like to keep her private cost information \( m \) as secret and don’t want to share it with the supplier. But the supplier prefers full information (F) to get a higher unit profit margin, like \( s-c \).

Figure 2: \( m \) versus the outsourcing price under full information (F) and asymmetric information (A) case.
Figures 3 illustrate the changes of retail price $p$ with various $\eta$ under full information (F) and asymmetric information (A) case. We note that the retail price is increasing with her internal cost $m$. The buyer needs to keep her profit margin by setting a higher retail price $p$ if her internal cost $m$ is high. It is interesting to see that the buyer’s unit profit margin $p-s-m$ will increase with her inner cost $m$. The buyer has a motivation to share her inner cost $m$ with the supplier when the buyer has a higher inner cost.

**Figure 3: $m$ versus the retail price $p$ under full information (F) and asymmetric information (A) case.**

From Figure 4, we see that the outsourcing time $t_A$ and $t_F$ are all increasing with the buyer’s internal cost $m$. It is also interesting to find that the outsourcing time $t$ is shorter under asymmetric information (A) than full information (F) case. So it is beneficial for the buyer to
disclose her internal cost information $m$ to the supplier, moving from the asymmetric information case to the full information case and decreasing the time to market.

Figure 4: $m$ versus the outsourcing time under full information (F) and asymmetric information (A) case.

![Graph showing $m$ versus the outsourcing time under full information (F) and asymmetric information (A) case.]

From Figure 5, we see that the outsourcing time $Q_A$ and $Q_F$ are all decreasing with the buyer’s internal cost $m$. We also find that the outsourcing quality $Q$ is higher under full information (F) than asymmetric information (A) case. The managerial insights we gain here is that the outsourcing quality will increase (like from $Q_A$ to $Q_F$) if the buyer can share her internal cost $m$ with the supplier.

Figure 5: $m$ versus the outsourcing quality under full information (F) and asymmetric information (A) case.
MANAGERIAL IMPLICATIONS AND CONCLUSION

In this paper, we consider an outsourcing scenario where a buyer outsources product or service to a supplier. We derived the equilibrium outsourcing price, outsourcing time, retail price, quality level, cut-off point, and profits under these two cases, full information and asymmetric information. We also analyzed the effect on the optimal policies of any changes in the values of market parameters and private information, by conducting sensitivity analysis, both analytically and numerically. The main conclusions of the paper are the following. The supplier’s decision variable \( s_F \), outsourcing unit price, is increasing in base demand \( a \) and decreasing in buyer’s internal cost \( m \). The supplier’s decision variable \( t_F \), optimal outsourcing time, is increasing with his own internal cost \( c \) and buyer’s internal cost \( m \), and decreasing in base demand \( a \). The other supplier’s decision variable \( Q_F \), optimal outsourcing quality, is increasing in base demand \( a \) and decreasing in his own internal cost \( c \).

Our model can be extended in many different directions. We can study supplier competition by including several suppliers in the supply chain. The game between the buyer and supplier can be modified. The buyer can act as a game leader, announcing her decision variable before the supplier’s move.

REFERENCE


