Cooperation on Purchasing
Modeling and Analysis of Group Purchasing Organizations

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Cooperation of independent firms allows them to benefit from an opportunity in a market that neither of the firms can exploit on its own.
Cooperation-based business models can be implemented in purchasing, production, distribution, and sales.
Cooperation-based business models can increase the competitiveness of firms.
This study extends cooperation on production, distribution, and sales to purchasing

Karabağ and Tan (2015)

Firm A
Purchasing


Firm B
Production

Ağralı, Tan, Karaesmen (EJOR 2008)

Firm C
Distribution

Tan and Akçay (POM 2008, IIE 2015)

Sales


Cooperation is a viable business model for SMEs as well as for large companies.

Project at Zer

Koç Group
82000 employees
Revenue ~$50 Billion

100 companies
Ford, Fiat, LG, B&Q, Beko, TUPRAS, Sumitome, Kagome, Caryle, Aygaz, Unicredit, …
Zer Central Services uses a cooperation-based business model

Joint indirect material and services procurement

Logistics procurement and supply chain management

Joint media procurement

Group Purchasing Organization
Zer: Logistics cooperation among different companies improves operations

Import Routes Before Cooperation
Zer: Cooperation leads to a more efficient supply chain structure

Logistics Network Using Hubs After Cooperation
Zer: Group Purchasing Organization for Indirect Material, Services, and Media

<table>
<thead>
<tr>
<th>Company</th>
<th>Work</th>
<th>Cost Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company 1</td>
<td>Industrial Gas</td>
<td>50</td>
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<tr>
<td>Company 2</td>
<td>Food and Hygiene Products</td>
<td>20</td>
</tr>
<tr>
<td>Company 3</td>
<td>Industrial Gas</td>
<td>19</td>
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<td>Company 4</td>
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<td>Company 5</td>
<td>Industrial Gas</td>
<td>12</td>
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<tr>
<td>Company 6</td>
<td>Scrap</td>
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Group Purchasing Organizations

Group purchasing organization (GPO) is an entity that is created to leverage the purchasing power of a group of businesses to obtain discounts from suppliers based on the collective buying power of the GPO members.

Vertical Group Purchasing Organization
Industrial manufacturing, Healthcare, Foodservice/grocery

Horizontal Group Purchasing Organization
Indirect, non-strategic spend
Literature

GPOs: Nollet et. al. (2003) Tella et. al. (2005)


Modelling and Analysis of the Operation of Group Purchasing Organizations

- **H suppliers** and **N retailers** in the market

- **h suppliers** and **n retailers** work with the **GPO** that offers a **quantity discounted price** to retailers and organizes an **auction** for the suppliers

- **Sales price** of the retailers is fixed

- **Purchasing price** from the suppliers in the second period is random

- **The total demand** in the market is random

- Suppliers have **fixed capacity**
Modelling and Analysis of the Operation of Group Purchasing Organizations

Price and Demand Risk

How to set the capacity for GPO?

How much to bid for the auction?

Market risk

How to set the quantity discount scheme?

Price risk

How much to purchase through GPO?

When is cooperation on procurement beneficial?

Who benefits from GPO?
Modelling and Analysis of the Operation of Group Purchasing Organizations

Second period price (random) $w_2$

Price and Demand Risk

GPO suppliers

1 $c_1$

2 $c_2$

h $c_h$

Retailers

1 $q$

2 $w_r$

n

Auction

GPO price to suppliers

GPO price to retailers

Cost (random)

Capacity for the GPO

Total Market Demand (random)

Retailer’s Sales price $p$

Price Risk

Other suppliers

h+1

H

Other retailers

n+1

N
Retailer determines how much to purchase from the GPO in the first period

\[ Q = nq \]

\[ E[\pi_r(q)] = pE[D_r] - w_rq - E[\text{Max}(D_r - q, 0)]E[w_2] \]

\[ w_r = a + \frac{b}{Q^e}, \quad be > 0 \]

\[ q^* = \begin{cases} \frac{1}{F_r^{-1}} \left( \frac{E[w_2] - a}{E[w_2]} \right) & E[w_2] \geq a > 0 \\ 0 & \text{otherwise} \end{cases} \]

If \( q^* = 0 \) GPO dissolves
Supplier determines how much of its capacity to offer to the GPO

\[ \tilde{w}_s = \tilde{a} + \frac{b}{Q^e} \]

Total number of units that can be produced

\[ \frac{1}{H} \left( \sum_{i=1}^{N} D_r - Q \right) \]

Supplier's Demand for the second period

\[ \pi^j_s(\Delta) = \begin{cases} 
\tilde{w}_s \Delta + w_2 \text{Min} \left( M - \Delta, D_s \right) + s \left( M - \Delta - D_s \right)^+ - c_j M, & \text{if } c_j \leq \tilde{w}_s \\
w_2 \text{Min} \left( M, D_s \right) + s \left( M - D_s \right)^+ - c_j M, & \text{if } c_j > \tilde{w}_s 
\end{cases} \]

Supplier's Demand for the second period

Production cost distribution of suppliers is known to all the suppliers

Other suppliers

Number of units offered to the GPO

Second period price

Salvage value

Per unit production cost
Supplier determines how much of its capacity to offer to the GPO

\[ \pi^j_s(\Delta) = \begin{cases} \tilde{w}_s \Delta + w_2 \text{Min}(M - \Delta, D_s) + s(M - \Delta - D_s)^+ - c_j M, & \text{if } c_j \leq \tilde{w}_s \\ w_2 \text{Min}(M, D_s) + s(M - D_s)^+ - c_j M, & \text{if } c_j > \tilde{w}_s \end{cases} \]

Optimal number of units to be offered to the GPO

\[ \Delta^* = \begin{cases} M & \text{if } \text{Max}\{s, E[w_2]\} \leq E[\tilde{w}_s] \\ M - F_s^{-1}\left(\frac{E[w_2] - E[\tilde{w}_s]}{E[w_2] - s}\right) & \text{if } s \leq E[\tilde{w}_s] \leq E[w_2] \\ 0 & \text{otherwise} \end{cases} \]
The GPO organizes a **uniform price reverse auction** to select the suppliers and determine the price to be paid to the suppliers.

- Each participating supplier bids its actual cost \((\Delta, c_j)\).
- \(k\) suppliers with the lowest bids are selected.
- Each winning supplier is paid the lowest losing bid \(w_s\).
- If \(k+1\) suppliers do not submit bids, GPO dissolves.

\[
E\left[ \pi_g \right] = Q \left( w_r - E\left[ w_s \right] \right)
\]
Zer: Promena Auction Platform
A supplier decides to **participate in the auction** if its maximum estimate of the auction price is lower than its cost.

\[
\text{Prob}[c_j < w_s^{\text{max}}] > 0 \quad \rightarrow \quad \text{Supplier } j \text{ submits a bid}
\]

**Distribution of the number of bidders** \(h_a\) is binomial

\[
\text{Prob}[h_a = m] = \binom{h}{m} p_a^m (1 - p_a)^{h-m}
\]

\[
p_a = \text{Prob}[c_j < w_s^{\text{max}}] = \frac{w_s^{\text{max}} - c_{\text{min}}}{c_{\text{max}} - c_{\text{min}}}.
\]
The **expected auction price** is the smallest losing bid when the required number of suppliers participate in the auction.

**Expected auction price:**

Expected value of the \((k+1)\)th smallest of \(h_a\) uniform random variables where \(h_a\) is binomially distributed and \(h_a \geq k+1\)

\[
E \left[ c_{(k+1)} \middle| c_{(1)} < \ldots < c_{(k+1)} < w_s^{\text{max}}, h_a \geq k+1 \right] = k = \left\lceil \frac{Q}{\Delta} \right\rceil
\]

\[
E \left[ w_s \right] = 1 - \frac{p_a^{k+1} (1 - p_a)^{n-k}}{(k+1) \int_0^x x^k (1-x)^{n-k-1} dx} \left( \frac{k+1}{n+1} \right) (c_{\text{max}} - c_{\text{min}}) + c_{\text{min}}
\]

\[
E \left[ \pi_g \right] = Q \left( w_r - E \left[ w_s \right] \right)
\]
Analytical Model of the GPO

- Number of suppliers, retailers, and GPO members in the market
- Demand distribution
- Second period supplier price distribution
- Retailers sales price
- GPO discount scheme
- Suppliers cost distribution
- Suppliers auction price estimate distribution
- Suppliers capacity

Retailers’ GPO ordering policy

Suppliers GPO capacity setting policy

Expected profits of suppliers, retailers, and GPO
Analytical Results on the Effects of Cooperation:
GPO is beneficial for the retailer when the following condition holds

\[ q^* \left( 1 - \frac{w_r}{E[w_2]} \right) > \int_0^{q^*} F_r(x) \, dx \]

If the expected wholesale price in the second period is greater than the wholesale discount scheme offered by GPO, GPO is always beneficial for the retailer

\[ E[w_2] > w_r \]
Analytical Results on the Effects of Cooperation: GPO is beneficial for the supplier when the following condition holds:

\[
(E[\tilde{w}_s] - E[w_2])\Delta^* + (s - E[w_2]) \int_{M-\Delta^*}^{M} F_s(x) \, dx > 0
\]

If the estimated auction price is greater than the expected wholesale price in the second period and the salvage value, GPO is always beneficial for the supplier:

\[
E[\tilde{w}_s] \geq \text{Max}\{s, E[w_2]\}
\]
Numerical Experiments

Effect of the price uncertainty with respect to GPO price
Effect of the amount of demand captured by the GPO with respect to total demand

Retailer Order Quantity
Supplier capacity offered to GPO
Realized Price
Profits
Special Case with Normal Demand Distribution leads closed form solutions

Retailer Profit and Order Quantity

\[ E[\pi_r(q)] = p\mu_r - w_rq - E[w_2]\sigma_r \eta \left(\frac{q - \mu_r}{\sigma_r}\right) \]

\[ q^* = \begin{cases} 
\mu_r + \sigma_r \Phi^{-1} \left(\frac{E[w_2] - a}{E[w_2]}\right) & E[w_2] \geq a > 0 \\
0 & \text{otherwise}
\end{cases} \]

Supplier Profit and Order Quantity

\[ E[\pi_s^j(\Delta)] = p_a \left\{ E[\tilde{w}_s] \Delta + E[w_2] \mu_s - E[w_2] \sigma_s \eta \left(\frac{M - \Delta - \mu_s}{\sigma_s}\right) + s\sigma_s \eta \left(-\frac{M - \Delta - \mu_s}{\sigma_s}\right)\right\} 
+ (1 - p_a) \left\{ E[w_2] \mu_s - E[w_2] \sigma_s \eta \left(\frac{M - \mu_s}{\sigma_s}\right) + s\sigma_s \eta \left(-\frac{M - \mu_s}{\sigma_s}\right)\right\} - c_j M \]

\[ \Delta^* = M - \frac{1}{H} (N\mu_r - Q) - \frac{1}{H} \left(\sqrt{N}\sigma_r\right) z_\alpha , \text{ where } \alpha = \frac{E[w_2] - E[\tilde{w}_s]}{E[w_2] - s} \text{ and } s \leq E[\tilde{w}_s] \leq E[w_2]. \]
Effect of the **expected second period price** on the retailer’s quantity purchased from the GPO and the supplier’s capacity offered to the GPO.
Effect of increasing **total demand** procured from the GPO on the **retailer’s profit** and the **supplier’s capacity** offered to the GPO.
Effect of **increasing total demand** procured from the GPO on the **supplier’s profit** (based on its estimate) and on the **GPO’s profit**.
Effect of increasing total demand procured from the GPO on the Expected Auction Price

- Cost distribution has lower variance ($c_{min}=25$, $c_{max}=27$)
- Cost distribution has higher variance ($c_{min}=25$, $c_{max}=100$)
- Supplier has high capacity
- Cost distribution has medium variance ($c_{min}=25$, $c_{max}=30$)
Using Group Purchasing Organizations will be beneficial for suppliers and retailers under the right conditions.

Suppliers can mitigate price and demand uncertainty by working with a GPO.

Retailers can mitigate price uncertainty by working with a GPO.

GPO can make a profit by setting the discount scheme in the right way.
Ongoing Work

Analyzing the effects of GPOs on other suppliers and retailers

Using different structures and contracts for GPO

Considering a GPO representing retailers vs a GPO representing suppliers vs a GPO as an intermediary

Comparing GPO performance with these centralized solutions
Modelling and Analysis of the Operation of Group Purchasing Organizations

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