A centralized/decentralized design of a full return contract for a risk-free manufacturer and a risk-neutral retailer under partial information sharing: A discussion

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Abstract

This paper discusses some aspects of the centralised version of the supply chain coordination method that uses the so-called Alternating Direction Method (ADM) presented by Jeong (2012, A centralized/decentralized design of a full return contract for a risk-free manufacturer and a risk-neutral retailer under partial information sharing. International Journal of Production Economics, 136(1), 110–115). We show that the method requires both from the retailer and the manufacturer to faithfully follow the proposed algorithm, without any attempt to follow their own interests in gaining higher profits. We also warn that the condition of the information privacy is violated also in partial information sharing model. Furthermore, we correct an error in one of the equations.

Keywords: Supply chain coordination, Alternating Direction Method, Information sharing

1. Introduction and problem statement

Jeong (2012) studies the newsvendor problem with a *full return contract*, where the retailer has to determine order quantity Q, while the demand Y is stochastic variable characterised by the cumulative distribution function $F(\cdot)$. The manufacturer produces the quantity Q at unit price m, and sells it

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to the retailer on wholesale price c per unit. The retailer can sell $\min\{Q, Y\}$ at retail price p and can return the remaining $\max\{Q - Y, 0\}$ at rebate price r to the manufacturer. The decision variables of the model are Q and r.

The expected profits are

$$G_{\text{RFR}}(Q, r) = (p - c)Q - (p - r)\int_0^Q F(y)dy, \tag{1}$$

$$G_{\text{MFR}}(Q, r) = (c - m)Q - r\int_0^Q F(y)dy, \text{and} \tag{2}$$

$$G_{\text{FR}}(Q, r) = G_{\text{RFR}}(Q, r) + G_{\text{MFR}}(Q, r) = (p - m)Q - p\int_0^Q F(y)dy \tag{3}$$

for the retailer, the manufacturer and the supply chain, respectively. The author assumes a *risk-free* manufacturer, that means the manufacturer should obtain profit at least as high as without the return contract. This leads to the following constraint

$$r = (c - m)\left(1 - \frac{Q^*_{\text{RNR}}}{Q}\right), \tag{4}$$

where Q^*_{RNR} is the optimal order quantity without possible returns, i.e., it maximises $G_{\text{RFR}}(Q, 0)$.

The author defines coordination as: "a supply chain is said to be coordinated if the expected profit of the supply chain is maximised". In this discussion I focus exclusively on this coordination problem, i.e., the *centralised full return contract design problem under partial information sharing* (CFRP). The solution of the presented problem is difficult, since the p price is known only by the retailer, while m is known only by the manufacturer. The demand distribution is also indicated to be private information of the retailer, although, as it is stated in Section 4.3, it must be shared truthfully. Note that truthful sharing of forecasts is a challenging task in itself, see e.g., Egri and Váncza (2012).

For the distributed solution of this problem, the author proposes the Alternating Direction Method (AMD), where the retailer and the manufacturer iteratively exchange proposals and counter-proposals (Q_1, r_1) and (Q_2, r_2), respectively. According to this method, the retailer and the manufacturer should maximise

$$L_{\text{RFR}}(Q_1, r_1) = G_{\text{RFR}}(Q_1, r_1) - L(r_1, r_2, Q_1, Q_2), \text{and} \tag{5}$$

$$L_{\mathrm{MFR}}(Q_2, r_2) = G_{\mathrm{MFR}}(Q_2, r_2) - L(r_1, r_2, Q_1, Q_2) \tag{6}$$

respectively, where

$$L(r_1, r_2, Q_1, Q_2) = u(r_1 - r_2) + v(Q_1 - Q_2) + 0.5(r_1 - r_2)^2 + 0.5(Q_1 - Q_2)^2. \tag{7}$$

I.e., they maximise their profits minus a Lagrangian term penalising $r_1 \neq r_2$ and $Q_1 \neq Q_2$. The method guarantees convergence to the optimal solution of $G_{\mathrm{FR}}(Q, r)$.

2. Discussion

Firstly, let us correct the error in Eq. (19):

$$\frac{\partial L_{\mathrm{MFR}}}{Q_2} = c - m - (c - m)\left\{\frac{Q^*_{\mathrm{RNR}}}{Q_2^2}\int_0^{Q_2} F(y)dy + (1 - \frac{Q^*_{\mathrm{RNR}}}{Q_2})F(Q_2)\right\} + v(t) + Q_1(t) - Q_2 = 0. \tag{8}$$

Since r_2 depends on Q_2, it does not vanish during the derivation, therefore the previous equation should include

$$(c - m)\left((u(t) + r_1(t+1))\frac{Q^*_{\mathrm{RNR}}}{Q_2^2} - (c - m)(1 - \frac{Q^*_{\mathrm{RNR}}}{Q_2})\frac{Q^*_{\mathrm{RNR}}}{Q_2^2}\right), \tag{9}$$

on the left hand side, c.f. Eq. (15) which correctly contains this term. There is also an error in Fig. 6. and 7.: since the definition of Q_1, r_1 and the initial parameters are the same as in Example 1, $Q_1(1)$ and $r_1(1)$ should be same as on Fig. 4. and 5., i.e., 52.5 and 0, respectively. Moreover, the curves should be similar to the curves presented on Fig. 4. and 5., but converging to $Q^* = 50$ and $r^* = 12.5$.

As for the partial information sharing, the author states that “the retailer and the manufacturer do not want to reveal complete private information”. Although in the proposed protocol they do not directly reveal their private information, after computing the optimal contract parameters, they can derive each other's price and cost parameters. When they obtain the optimal Q^* and r^* values that maximise $G_{\mathrm{FR}}(Q, r)$, the retailer can compute $m = p(1 - F(Q^*))$, while the manufacturer can determine $p = m/(1 - F(Q^*))$, thus the information privacy is violated. Furthermore, the manufacturer should know Q^*_{RNR} according to the presented ADM protocol, and therefore can obtain $p = c/(1 - F(Q^*_{\mathrm{RNR}}))$ even before the termination of the method.

Finally, we point out a weakness of an ADM-based protocol, namely that it assumes that the manufacturer and the retailer agree on maximising the total supply chain profit and they follow the prescribed steps faithfully. That means that they should not maximise their own profits, but their profits minus a Lagrangian penalty. In our opinion, this assumption is not clearly stated anywhere in Jeong (2012), thus a careless reader may think that the protocol works with a self-interested retailer and manufacturer, too. The next counterexample would like to demonstrate that this is not the case, the participants may untruthfully state that they agree on maximizing the total supply chain profit, but they cheat in order to increase their own profits.

It is possible that they do not consider the Lagrangian term, or consider it with smaller weight in order to increase their own profits. In such a case, the method does not coordinate the chain any more (in the sense of total profit maximisation). Let us show this in case of Example 2 of Jeong (2012). If the correct method is executed, it converges to the optimal $Q^* = 50$ and $r^* = 12.5$, which results in $G_{\mathrm{RFR}}(Q^*, r^*) = 156.25$ and $G_{\mathrm{MFR}}(Q^*, r^*) = 1093.75$. However, if for example, the retailer deviates from the proposed objective function and maximises

$$L'_{\mathrm{RFR}}(Q_1, r_1) = G_{\mathrm{RFR}}(Q_1, r_1) - L(r_1, r_2, Q_1, Q_2)/2 \tag{10}$$

instead of $L_{\mathrm{RFR}}(Q_1, r_1)$, this results in $Q^* = 41.07$, $r^* = 9.78$, $G_{\mathrm{RFR}}(Q^*, r^*) = 265.86$ and $G_{\mathrm{MFR}}(Q^*, r^*) = 944.27$. In such a way, the retailer can increase its expected profit, while decreases the total supply chain profit, thus corrupts coordination.

Such manipulations in distributed optimization problems are widely studied in the *distributed mechanism design* literature (for some basic definitions, see e.g., Parkes and Shneidman, 2004).

3. Conclusions

In this paper we discussed the ADM-based supply chain coordination method and pointed out that it only works with benevolent participants; a profit maximising retailer or manufacturer can distort the desirable properties of distributed optimisation algorithms. We proposed considering instruments of distributed mechanism design for supply chain coordination problems with self-interested retailer and manufacturer as possible future work.

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