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Research on Game of Manufacturer and Retailer Under Government's Subsidy

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Abstract
Considering demand influenced by government's subsidy, retail price, random factor, objective functions of maximizing expected profit are suggested to supplier and retailer, equilibrium solutions of supplier's wholesale price, retailer's retail price and order quantity are available based on Stackelberg game model, following conclusions are drawn by theoretical and numerical analysis, wholesale price, retail price, average demand, order quantity, profit increase with government's subsidy; consumer's expense price decreases with government's subsidy. which means subsidy can boost demand, increase enterprise's profit, reduce consumer's cost, therefore, subsidy policy is favorable to government, enterprises and consumer.

Key words: Government's subsidy; Manufacturer; Retailer; Stackelberg game

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INTRODUCTION

America and other developed countries have been influenced by international financial crisis since 2009, these countries formulated various policies for stimulating economic recovery. China also took the positive fiscal policies according to domestic conditions, for example, government conducted kinds of subsidy activities of exchanging new electric appliance, auto and other products with old ones in partial cities. in this context, the game of firms has great change in supply chain, what decisions should manufacturer and retailer make for optimal profit? how to influence on price, order quantity, profit and other variables by government's subsidy? the series of problems are worth to study.

Many scholars investigate longitudinal game of enterprises in supply chain. Such as, Esmaeili etc[1] established Stackelberg and cooperative game of buyer and seller, optimal solutions were available. Leng and Parlar[2] considered supply chain consists of manufacturer, distributor and retailer, cooperative game theory models were established based on demand information sharing, the exclusive cost allocation plan was concluded. Cai etc[3]] evaluated impact on competition of supplier and retailer by price discount contract and pricing strategy, proved that price discount contract was better than non contract, the fixed pricing strategy could bring more benefits to retailers, dominant party must not guarantee advantage. Zhu etc[4] researched on retailer's order game problem by the way of dispersion and concentration under uncertain demand, it was concluded that demand information sharing could improve supply chain's performance. Chiang[5] investigated effect on supply chain's efficiency by alternative products, results showed that alternative could increase or decrease efficiency of centralized supply chain, supplier and retailer could gain more profits if they were cooperative, but supply chain was difficult to reach optimization because of competition. Zhou etc[6] assumed that retailer was leader, manufacturer was follower, Stackelberg model was established; if retailer offered contract terms in the symmetric game, proved that existing the sole optimal production for manufacturer, verified influence on supply chain's performance by contractual parameters and fungible products. Ge and Hu[7] studied strategies and effects of bargaining power and knowledge spillovers at firm level when cooperation and competition coexist in aligned R&D within supply chains. results showed that horizontal collaboration, a higher level of R&D investment and production could be achieved in aligned R&D although spillovers are low, it was optimal to collaborate with such firms whose bargaining power was close to his own. the alliance could enhance technological share only when it had a high ablity to coordinate its members. Wu etc[8] constructed optimal compensate contract within double moral hazard from the supplier. in this contract, the optimal rate of both sides marginal profit was the rate of each effort efficiency. Liu and Cetinkaya[9] considered a buyer-driven channel and two specific cases were analyzed where the buyer had: (i) full information; and (ii) incomplete information about the supplier's cost structure under three general contract types. it was shown that, from the system's perspective, the buyer-driven channel was more efficient than the supplier-driven channel under an optimal one-part linear contract. under conditions of information asymmetry, it was demonstrated that the leadership was not necessarily beneficial for either party. Amaldoss and Staelin[10] aimed at new product investment, studied the game of enterprise alliance under summation and product utility functions. Whang[11] researched on "free-rider " problem of downstream enterprise, studied game of upstream and downstream firms for RFID decisions. Cachon and Kök[12] investigated game problem of a retailer and multiple manufacturers for different types of contracts. Zhang etc[13] argued dynamic game between a manufacturer with a retailer in asymmetric information situation. Iida and Zipkin[14] studied games of series of supply chain which is consists of a manufacturer and a retailer, results showed that unless transfer payment was consistent, otherwise information sharing was meaningless. Bandyopadhyay and Paul[15] researched on game equilibrium problems of two rival manufacturers and a retailer based on return strategy.

Judging from the existing research literatures, longitudinal game of enterprises under the background of government's subsidy policy, especially literatures of impact on longitudinal game by government's subsidy are scarce. in this paper, considering demand is uncertain, non-cooperative game of manufacturer and retailer under the background of government's subsidy is analyzed, investigating manufacturer's pricing strategy, retailer's ordering strategy and their interactive relationships, studying effect on price, quantity, enterprise's profits and consumer by government's subsidy, providing decision support for government formulating subsidy policy.

2. BASIC MODELS AND ASSUMPTIONS

This paper analysis non-cooperative game relationships between manufacturer and retailer in the context of government implementing subsidy policy, supposing demand is influenced by retail price, government's subsidy and random factor. subsidy is paid for consumer, so, demand function is

$$\begin{aligned} Q &= a - b(P - S) + \varepsilon \\ &= a - bP + bS + \varepsilon \qquad (a > 0,\ b > 0) \end{aligned} \tag{1}$$

Where Q is demand, a is basic demand, b is factor of effect on demand by price, P is retail price, S is government's subsidy, $P - S$ is consumer's expense price, ε is random factor, its mean is $\mu = 0$ and variance is σ^2, demand Q is a nonnegative random variable with probability density function $f(\bullet)$, and cumulative distribution function $F(\bullet)$, mean equals to $\mu = a - bP + bS$ and variance is σ^2, average demand is $\overline{Q} = a - bP + bS$.

Retailer orders quantities of product from manufacturer, and pays purchase cost; meanwhile, retailer sells product to customer, customer get government's subsidy after he buys product; when demand is less than order quantity, retailer receives salvage value of remaining product; when demand is greater than order quantity, retailer undertakes opportunity loss. therefore, retailer's profit function is

$$\begin{aligned} \Pi_r = {} & P\int_0^q xf(x)dx + P\int_q^{+\infty} qf(x)dx + v\int_0^q (q-x)f(x)dx \\ & - m\int_q^{+\infty}(x-q)f(x)dx - Wq \end{aligned} \tag{2}$$

where $\prod_r$ is retailer's profit, q is retailer's order quantity, v is unit salvage value, m is unit opportunity loss, W is manufacturer's wholesale price. therefore, $P\int_0^q xf(x)dx + P\int_q^{+\infty} qf(x)dx$ is retailer's sale when order quantity just meets demand, is $v\int_0^q (q-x)f(x)dx$ retailer's salvage value when demand is less than order quantity, $m\int_q^{+\infty}(x-q)f(x)dx$ is retailer's opportunity cost when demand is more than order quantity, W_q is retailer's purchase cost, retailer's decision variables are P and q.

Manufacturer organizes production after receiving order, then delivers product to retailer and gains profit from retailer. therefore, manufacturer's profit function is

$$\Pi_m = (W - C)q \tag{3}$$

Where $\prod_m$ is manufacturer's profit, C is unit production cost, manufacturer's decision variable is W.

3. GAME ANALYSIS

Assuming unit opportunity loss and unit salvage value are common knowledge, firstly, manufacturer determines wholesale price, retailer determines retail price and order quantity according to wholesale price, both parties form Stackelberg game relations. so, the equilibrium of game may be available according to reverse inductive method.

Simplify formula (2), we can get retailer's profit function

$$\Pi_r = (P-v+m)[\int_0^q xf(x)dx - q\int_0^q f(x)dx] + q(P+m-W) - m(a-bP+bS) \tag{4}$$

Without loss of generality, assuming demand follows normal distribution, let $\frac{x-\mu}{\sigma}=t$, so, $\chi = \mu + \sigma t$, $d\chi = \sigma dt$, we can get

$$\int_0^q f(x)dx = \int_{-\infty}^{\frac{q-\mu}{\sigma}} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt = \int_{-\infty}^{\frac{q-\mu}{\sigma}} \varphi(t)dt = \Phi\left(\frac{q-\mu}{\sigma}\right)$$

$$\int_0^q xf(x)dx = \mu\Phi(\frac{q-\mu}{\sigma}) + \sigma\int_{-\infty}^{\frac{(q-\mu)}{\sigma}} t\varphi(t)dt$$

Where $\varphi(\bullet)$ is probability density function of standard normal distribution, $\Phi(\bullet)$ is distribution function of standard normal distribution.

Take above formulas into (4), we can get retailer's profit

$$\Pi_r = (P-v+m)[\sigma\int_{-\infty}^{\frac{q-\mu}{\sigma}} t\varphi(t)dt - (q-\mu)\Phi(\frac{q-\mu}{\sigma})] + q(P+m-W) - m(a-bP+bS) \tag{5}$$

Firstly, retailer optimizes the order quantity q for maximizing his profit $\max_q \Pi_r$, taking the first derivative of formula (5) with respect to q, we can get

$$\frac{\partial\Pi_r}{\partial q} = (P+m-W) - (P+m-v)\Phi(\frac{q-\mu}{\sigma})$$

Let $\frac{\partial\Pi_r}{\partial q}=0$, we can get $\Phi(\frac{q-\mu}{\sigma}) = \frac{P+m-W}{P+m-v}$, therefore, the optimal order quantity q^* satisfies the following equation

$$q^* = \mu + \sigma\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right) = a-bP+bS+\sigma\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right) \tag{6}$$

Secondly, retailer optimizes retail price p for maximizing his profit $\max_q \Pi_r$, taking the first derivative of formula (5) with respect to p, notice that $\mu = a - bP + bS$, we can get

$$\frac{\partial\Pi_r}{\partial P} = \sigma\int_{-\infty}^{\frac{q-\mu}{\sigma}} t\varphi(t)dt - (q-\mu)\Phi\left(\frac{q-\mu}{\sigma}\right) (-p-v+m)b\Phi\left(\frac{q-\mu}{\sigma}\right) + q + mb = 0 \tag{7}$$

Integrate (6) with (7), the optimal retail price p^* satisfies the following first-order equation

$$\frac{\partial\Pi_r}{\partial P} = a-2bP+bW+bS+\sigma\int_0^{\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right)} t\varphi(t)dt (+\sigma\frac{W-v}{P+m-v})\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right) = 0 \tag{8}$$

Assuming information is symmetrical, manufacturer realizes reflection from retailer, adjusts wholesale price W for maximizing his profit; manufacturer and retailer finally achieve equilibrium based on Stackelberg game, integrate (6) with (3), we can get manufacturer's profit function

$$\Pi_m = (W-C)q^* = (W-C)\left[a-bP+bS+\sigma\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right)\right] \tag{9}$$

Taking the first derivative of formula (9) with respect to W, let $\frac{\partial\Pi_m}{\partial W}=0$, the optimal wholesale price W^* satisfies the following first-order equation

$$\frac{\partial\Pi_m}{\partial W} = \left[a-bP+bS+\sigma\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right)\right] + \left[\frac{(C-W)\sigma}{(P+m-v)\varphi\left[\Phi^{-1}\left(\frac{P+m-W}{P+m-v}\right)\right]}\right] = 0 \tag{10}$$

The optimal wholesale price W^* and retail price P^* can be calculated by solving equations (8) and (10), inserting W^* and P^* into formula (6), the optimal order quantity q^* is available, then, plug W^*, P^* and q^* into formulas (2) and (3), we can get manufacturer's profit $\prod_m^*$ and retailer's profit $\prod_r^*$ based on Stackelberg game.

4. COMPUTATIONAL RESULTS

There are a television manufacturer and a television retailer in the market, government takes subsidy policy for exchanging new televisions with old ones, relevant parameters are a = 7000, b = 5, C = 100, m = 100, v= 50, σ = 1000, market random factor follows normal distribution, its mean is $E\varepsilon = 0$ and variance is σ^2, demand Q follows normal distribution, its mean is $\mu = a - bP + bS$ and variance is σ^2, when S is changed, other parameters are constant, they are calculated by Mathematica software based on game model, the optimal results are shown in Table 1.

Table 1
Effect of Variation of Government's Subsidy on the Relative Variables

S	Q	q^*	W^*	P^*	$P^* - S$	$\prod_r^*$	$\prod_m^*$
10	1416	1202	738	1127	1117	435039	767162
50	1451	1219	766	1160	1110	444136	811597
90	1491	1246	791	1192	1102	460307	860907
130	1536	1282	814	1223	1093	483287	915206
170	1585	1327	834	1253	1083	512810	974415
210	1640	1380	853	1282	1072	548626	1038330

Figure 1~3 are obtained from Table 1.

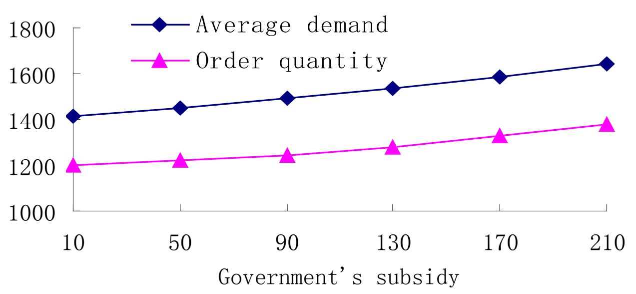

Figure 1
Influence on Average Demand and Order Quantity by Government'S Subsidy

From Figure 1, we can draw that average demand and retailer's order quantity increase with government's subsidy, and their increasing rates have growing tendency gradually. that is, view from government's perspective, subsidy policy can enlarge demand. because of financial crisis, many domestic manufacturers suddenly face decreasing order from overseas in 2009, especially to coastal factories, under this unfavorable situation, government immediately implemented the subsidy policy for exchanging new electrical appliance and automobile with old ones, which has brought massive order to those enterprises, and achieved the purpose of stimulating demand.

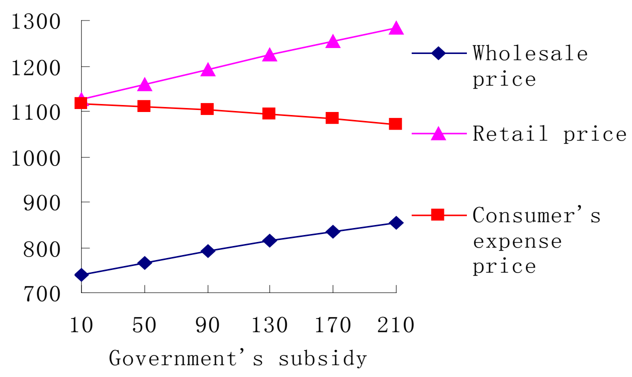

Figure 2
Influence on Wholesale Price, Retail Price and Consumer's Expense Price by Government'S Subsidy

From Figure 2, we can draw that wholesale price, retail price increase with government's subsidy, consumer's expense price decreases with government's subsidy. that is to say, although government's subsidy leads price to increase, consumer pays the less than ever actually. view from consumer's perspective, government's subsidy may reduce the extraneous cost for consumer, and subsidy is bigger, consumer's cost is smaller. but government's subsidy is possible to cause the inflation because of increasing price, therefore, government should moderate subsidy policy.

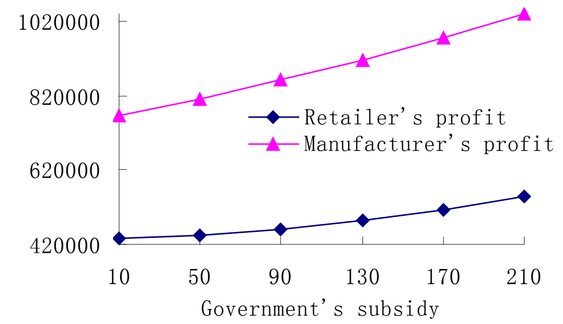

Figure 3
Influence on Manufacturer'S Profit and Retailer'S Profit by Government'S Subsidy

From Figure 3, we can draw that retailer's profit and manufacturer's profit increase with government's subsidy. view from enterprise's perspective, government's subsidy may bring extra profit to enterprise, and subsidy is bigger, profits are larger, especially, subsidy is more advantageous to manufacturer's profit, which shows that government's subsidy especially plays an imortant role in manufacturer.

CONCLUSION

Under the background of government's subsidy, considering demand is influenced by subsidy, price and random factor, Stackelberg game models of manufacturer and retailer are established, through theoretical and numerical analysis, the following main conclusions are drawn: average demand, order quantity, wholesale price, retail price, profit increase with government's subsidy; consumer's expense price decreases with government's subsidy. therefore, government's subsidy can stimulate demand, increase enterprise's profit, reduce consumer's cost, thus, subsidy is advantageous to government, enterprise and consumer.

Demand is considered indefinite in this article, under the background of government implementing subsidy, investigating longitudinal game problem of upstream and downstream enterprises in supply chain, as well as the influence on price, demand, enterprise's profit and consumer by government's subsidy. future research should consider influence on horizontal game of enterprises by government's subsidy, game relationships between government and enterprise, and influence on government's subsidy policy by cooperation of enterprises.

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