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Research on Medical Supply Chain Based on Disqualification Rate and Service Level

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ABSTRACT. *The disqualification rate and service level of medical devices have an influence on consumer's choice. High qualification rate and service level mean expensive costs to supply chain companies, which affects the profits of all companies in the supply chain eventually. The centralized decision-making is taken in this paper to guide the companies make appropriate decisions. The purpose of the former is to maximize the total utility of the society, while the latter is to maximize the profits of each enterprise. To our surprise, there is a saddle point, which means that the supply chain system reaches equilibrium at this point. Given the disqualification rate, we establish the function of profit to supplier and manufacturer. There is no maximum total profits of the society in the supply chain. However, the supply chain system reaches equilibrium at saddle point. The equilibrium point also plays an important role on decisions of companies in the supply chain. Additionally, we find that the relationship between selling price and disqualification rate is non-monotonic and complicated. The service level and disqualification rate are also non-linear. The total social profits can be obtained based on selling price and service level decided by manufacturer. Moreover, the service level is negative to punishment costs of disqualification rate. When the disqualification rate is small enough or large enough, the selling price is positive to the punishment costs due to unqualified products. Otherwise, the selling price is negative to the punishment costs. Eventually, some managerial implications are proposed to the companies and government in the supply chain.*

KEYWORDS: *disqualification rate, service level, medical devices, centralized decision-making*

1. Introduction

With the rapid development of medical industry, a large number of enterprises choose to invest in the medical equipment industry. The medical device industry all over the world not only reaches a considerable scale but has been maintaining a fast growth rate. However, although the technology for producing and testing medical devices has improved a lot, it is hard that each equipment produced is qualified and

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even some of the disqualified medical devices come into the market. According to the survey of Kaiser Health News, in the past 20 years, 2.4 million reports have been related to the failure of blood glucose meters for diabetics, many of which have malfunctions before customers began to use them. Therefore, the service to the failed machine is inevitable. In addition, in China, Guangdong Food and Drug Administration found three batches of samples of ultrasound Doppler fetal heart rate meter unqualified in March, 2018. According to the relevant legal and regulations, these enterprises had to investigate the causes, recall products, formulate rectification measures and make rectification within a limited time. These punishments can cause huge costs to the enterprises. In February, 2020, a mask factory in Shaodong County, Hunan Province, China was reported to have produced and sold unqualified masks. After investigation and testing, government found that the company's manufacturing environment and masks it produced were far from meeting the standard, which had broken the law. As a result, the company was fined 100,000RMB. All these cases show that medical equipment unqualified is a common phenomenon and can cause great losses to companies and society.

It is well known that the medical devices play a vital role on the disease diagnosis. Once the diagnosis goes wrong, both the hospital and the medical equipment enterprise suffer more. Meanwhile, it is a huge disaster to consumers. With the purpose of guiding companies' decisions based on selling price and service level, we established the mathematical model and solved it. Therefore, both the disqualification rate and service level are considered in this paper. We consider a two-stage supply chain including a supplier and a manufacturer. Through constructing a mathematical model and making centralized decision, we obtain a solution of selling price and a service level for manufacturer to make supply chain reach equilibrium, which is also named saddle point. Further, the relationship between selling price and disqualification level is discussed. We find that the selling price and disqualification rate are nonlinear and unanalyzable. To our surprise, the relationship between service level and disqualification rate is also complicated and nonlinear. According to the disqualification rate and punishment costs, the manufacturer can choose appropriate selling price and service level to make the supply chain system reach equilibrium. Moreover, the service level is negative to punishment costs of disqualification rate. When the disqualification rate is small enough or large enough, the selling price is positive to the punishment costs due to unqualified products. Otherwise, the selling price is negative to the punishment costs. More importantly, the appropriate value of disqualification rate is proposed to supplier. What's more, we also have suggestions about what the level of punishment costs should the government sets.

The model setup is described and analyzed in section 2 and section 3. In section 4, we conclude this paper and propose some managerial implications to companies and government. Meanwhile, some limitations about this paper are discussed for further study in section4.

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2. Signals and model

2.1 Signals and assumptions

P_m: Selling price per product for manufacturer.

Ps: Selling price per product for supplier.

S : Service level provided by manufacturer.

Π_m: The profits of manufacturer.

Πs: The profits of supplier.

α : Disqualification rate decided by supplier. $\alpha\epsilon(0,1)$

p : Punishment costs of per unit disqualified product decided by government.

β: The percentage of penalties borne by the manufacturer because of disqualified product. $\beta\epsilon(0,1)$

a : The basic demand.

b : The coefficient of selling price.

c : The coefficient of disqualification rate.

d : The coefficient of service level.

D : The total market demand.

2.2 Related assumptions

Assuming that the market demand is affected by the selling price, disqualification rate and the service level. Meanwhile, we assume that the relationship between the total market demand and service level is linear. Total market demand and disqualification rate are also linear. The market demand is represented by the following expression.

$$D=a-bP_m-c\alpha + dS \ (a, b, c, d > 0) \tag{1}$$

In this paper, we assume that the service cost per unit product is one. For convenience, we only consider the condition that the disqualification rate is a determined value. Besides, the information in the medical devices supply chain is symmetric. We also assume that the price changes have a greater impact on total demand than changes in service level and in disqualification rate. Additionally, the disqualification rate changes have a greater impact on total demand than changes in service level(b>c>d). For the convenience of analysis, we assume $b > 3a$.

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2.3 Model

The problem we discuss in this paper is what is the appropriate decision about selling price and service level for manufacturer. Further, we give some wisdom suggestions to supplier about how to decide the disqualification rate. The determination of penalty costs due to disqualification rate also be discussed in our study. The ultimate goal of this study is to make the supply chain reach equilibrium. The model is established as follows.

1. In the basis of service level, selling price, disqualification rate and punishment costs, we formulate the profit function of the manufacturer supplier respectively.

2. Given the appropriate disqualification rate, the manufacturer decide the optimal selling price and service level to maximize the overall profits.

$$\pi_m (P_m, S) = (P_m - P_s - S\alpha)D - \beta p\alpha D$$
$$\pi_s (P_s) = P_s D - (1-\beta)p\alpha D$$
$$\max \pi_m + \pi_s(P_m, S) = (P_m - S\alpha - p\alpha)D \tag{2}$$

3. Solutions and analysis

Firstly, adding equation(1) to equation(2), we obtain equation(3).

$$\max \pi_m + \pi_s(P_m, S) = -bP_m^2 + (a - c\alpha + dS + b\alpha S + pb\alpha)P_m - \alpha dS^2 + (c\alpha^2 - a\alpha - pd\alpha)S - pa\alpha + pc\alpha^2 \tag{3}$$

Next, we take the first partial derivatives of equation (3) with respect to the selling price and service level. We obtain equation(4) and equation(5).

$$\frac{\partial \pi_m + \pi_S}{\partial P_m} = -2bP_m + a - c\alpha + dS + b\alpha S + pb\alpha = 0 \tag{4}$$

$$\frac{\partial \pi_m + \pi_S}{\partial S} = -2\alpha dS + c\alpha^2 - a\alpha - pd\alpha + dP_m + b\alpha P_m = 0 \tag{5}$$

Simultaneous equations, we get the solution about selling price and service level. That is:

$$\begin{cases} S^* = \dfrac{-(b^2+cb)\alpha^2 + (ab - 3pdb + cd)\alpha - ad}{(d-b\alpha)^2} & (6) \\ P_m^* = \dfrac{(b^3p - b^3 - 2cb^2)\alpha^3 + (2ab^2 - b^2d + 2bcd - 3pabd - 2b^2pd)\alpha^2 + (bpd^2 - 3pad^2 - 2abd)\alpha}{(d-b\alpha)^2} & (7) \end{cases}$$

Through the analysis of the hessian matrix , this point is not an extreme point. In other words, there exists no maximum value of total social profits. However, the supply chain system reach equilibrium at this point, which means that the supply chain will eventually reach a steady state. According to the expression of selling price and service level, we can clearly find the complex relationship between selling price and disqualification rate. Additionally, there is also no evidence of a positive

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or negative relationship between service level and disqualification rate. However, what makes sense is that we obtain an expression of the selling price and service level. Eventually, the total social profits can be solved based on the solution of selling price and service level.

Further, we take first partial derivatives of equation (6) with respect to the punishment costs. We obtain equation(8).

$$\frac{\partial S^*}{\partial p} = \frac{-3db}{(d-b\alpha)^2} < 0 \tag{8}$$

According to equation(8), the service level decreases with punishment costs of disqualification rate. When the cost due to unqualified products is high, the manufacturer chooses low level service to make up for a loss. In order to ensure a certain level of service, the punishment costs should not be so high. For ensuring the quality of the products, the costs also should not be too low. Therefore, an appropriate costs should be decided by government .

In a similar way, we take first partial derivatives of equation (7) with respect to the punishment costs. We obtain equation (9).

$$\frac{\partial P_m^*}{\partial p} = \frac{b^3\alpha^3-(3abd+2b^2d)\alpha^2+(bd^2-3ad^2)\alpha}{(d-b\alpha)^2} \qquad (\alpha \neq \frac{d}{b}) \tag{9}$$

$$\begin{cases} \dfrac{\partial P_m^*}{\partial p} > 0 \quad if\ \alpha \in \left(0, \dfrac{(3a+2b)d - d\sqrt{9a^2+24ab}}{2b^2}\right) or\ (\dfrac{(3a+2b)d + d\sqrt{9a^2+24ab}}{2b^2}, 1) \\ \dfrac{\partial P_m^*}{\partial p} < 0 \qquad else\ \alpha \in (\dfrac{(3a+2b)d - d\sqrt{9a^2+24ab}}{2b^2}, \dfrac{(3a+2b)d + d\sqrt{9a^2+24ab}}{2b^2}) \end{cases}$$

When the disqualification rate is small enough or large enough, the selling price increases with the punishment costs due to unqualified products. Otherwise, the selling price is negative to the punishment costs. The supplier should better keep the disqualification rate in range two, which is $\alpha \in (\frac{(3a+2b)d-d\sqrt{9a^2+24ab}}{2b^2}, \frac{(3a+2b)d+d\sqrt{9a^2+24ab}}{2b^2})$. Considering the negative relationship between service level and punishment costs, the appropriate punishment costs due to unqualified products should be chosen by government.

4. Conclusion and prospect

According to our study, there is a saddle point, which makes the supply chain system reaches equilibrium. First, the value of total social profits can be obtained based on the solution of selling price and service level. Second, the relationship between selling price and disqualification rate is non-monotonic and complicated. The service level and disqualification rate are also non-linear. Moreover, the service level is negative to punishment costs of disqualification rate. Therefore, the punishment costs due to disqualification rate should not be too high or too low. Besides, when the disqualification rate is small enough or large enough, the selling price is positive to the punishment costs due to unqualified products. Otherwise, the selling price is negative to the punishment costs. In order to balance selling price, punishment costs of unqualified products and service level, the government should keep the disqualification rate in range two.

However, there are some limitations about our study. First, we assume the relationship between market demand and service level or disqualification rate is linear. In the future study, we can take some further assumptions. Second, there is no numerical analysis in our study. Therefore, numerical analysis can be performed in further study. Additionally, the decentralized decision making can be used to solve the model in the further study to maximize the profits of every company in the supply chain. In the end, we can assume that the disqualification rate obeys some distribution to bring the study closer to reality.

References

[1] Tinglong Zhang, Liang Liang. Research on single-cycle product supply chain decision considering pass rate [J]. Operations and management, 2007 (05): 142-146.
[2] Wei Zhao, Yan Wen , Na Feng. Study on the differential game model of supply chain considering the influence of service level on demand [J]. Journal of Qingdao university (natural science edition), 2019, 32 (03): 102-109+122.
[3] Xumei Zhang , Jinzhong Leng, etc. Optimization strategy of manufacturers and service providers under the influence of pre-sales service on product demand [J]. Systems engineering, 2016, 34 (01): 102-107.
[4] Chen M S, Chuang C C. An extended newsboy problem with shortage-level constraints [J]. International Journal of Production Economics, 2000, 67: 269-277.
[5] Yan Ruiliang, Pei Zhi, Retail services and firm profit in a dual-channel market [J]. Journal of Retailing and Consumer Services. 2009 (16): 306-314.
[6] Luj-c, tsaoy-c, Charoensiriwath C.Competition Under manufacturer service and retail price [J]. Economic Modelling, 2011, 28 (3): 1256 ~ 126
[7] https://www.toutiao.com/a6789809258834690574/
[8] https://ql1d.com/newsjin/show/source/rss/type/1/id/9850779.html? tt_group_id= 6661192592685793799
[9] https://www.chashebao.com/yiliaobaoxian/18785.html#z5
[10] http://www.sohu.com/a/328861036_120067548
[11] https://www.xzbu.com/6/view-146860