Advances in Economics, Business and Management Research (AEBMR), volume 54
2018 5th International Conference on Management Science and Management Innovation (MSMI 2018)

Supply Chain's "Free-riding Effect" Based on Online Transaction Advantage of Backwardness

Pei-Qin LI*

Business School, East China University of Political Science and Law, Shanghai 201620, China

lipeiqin@ecupl.edu.cn

*Corresponding author

Keywords: Supply chain, Free-riding effect, Online transaction, Advantage of backwardness.

Abstract. This paper is concerned with supply chain competition and "Free-riding effect" under the assumptions that consumer demands in both online and offline markets are relative to each other. It focuses on "leader-follower" game model under supply chain framework of "one traditional manufacturer leader and one weakest traditional retailer , one online manufacturer is an up-rising star, and the traditional manufacturer leader competes with the online manufacturer in online markets". After that the paper analyses supply chain partners' optimal decisions and "Free-riding effect" by numerical analysis, especially about the coping strategies of the strong manufacturer. Some conclusions could be found out as follows: Firstly,when the strong traditional manufacturer improves its online promotion effort level, if its promotion level is low, the weakest retailer could achieve "free ride effect" , if it is high, the online manufacturer could achieve "free ride effect" obviously. Secondly, when online market demands become bigger, the retailer's "free ride effect" disappears after come first, however the online manufacturer retailer's "free ride effect" is obvious. As online manufacturer's competitiveness becomes bigger, the strong traditional manufacturer's predominance couldn't be maintained by increasing offline market's capacity.

Introduction

Today E-Commerce and Internet Technology tide have permeate all aspects of lifes, and they infused into kinds of industry supply chain channels, such as online and offline channels have no longer been a stranger for everyone. About the conflict and coordination of online market research, there are a large number of domestic and foreign literature foundation. Such as, Balasubramanian (1998) ,Lee H(2002) , Chhajed, Hess(2003) , etc. Some traditional manufacturers whose channel status were strongest have enter into online markets when e-commerce came out firstly, such as Lenovo, Nike, Uniqlo, etc. All of this kind of manufacturers have met some new online manufacturers especially in clothing industry, on the other hand, Still some of them keep their traditional retailor channels. Then various "Free-riding effect" come out that give the traditional manufacturers much pressures to compete and change. In Zhou Jiangheng,etc.(2016) had explained two types of Free-riding effects, which are "Final end free-riding effect" and "Wholesale price free-riding effect". However, in this paper it will discuss the retailor's free-riding effect and the up-rising star's free-riding effect.

Model Description and Analysis

It supposes that the manufacturer $j\left(j=1,2\right)$ sells homogeneous product $i\left(i=1,2\right)$, both of them compete on the internet at the same time. Because of its excellent choice marching into Internet when online market comes out firstly, the traditional strongest manufacturer M_1 have got major power on the Internet such as brand, online consumers, etc. And still the traditional strongest manufacturer M_1 has a traditional retailer r whose status is weakest with e-commerce's invasion deeper and deeper today. Being a up-rising star, the online manufacturer M_2 can have more power than before in competition on the Internet through improving its promotion levels. On the other hand, the traditional retailer r has to provde better services such as more comfortable shopping environments, closer places, etc. to keep its market share. The demands functions are decided not only by two manufacturers' pricing mechanisms, but also by their promotion effort levels, which are divided by two dimensions: channel promotion effort level e_d and brand promotion effort level e_b. Channel promotion competition happens on the Internet between manufacturer M_1 leader and the online manufacturer M_2, which are indicated by e_{d1} and e_{d2} respectively, and their brand sale effort e_{b1} and e_{b2} respectively. To simplify the analysis, we assume that two kind coefficients of sale effort are same $\kappa(\kappa > 0)$, and their promotion costs are $g(e_{di}) = \kappa e_{di}\,(e_{di} \geq 0)$, $g(e_{bi}) = \kappa e_{bi}\,(e_{bi} \geq 0)$ $(i = 1, 2)$. On the other hand, the traditional retailer r provides additional service $e_r\,(e_r > 0)$, and its service cost is $\eta e_r^{\,2}/2$, η is the coefficient of service cost. Respectively, the parameter μ is the marginal demand of retailer r 's additional service. Besides, the retailer r has to pay $F(F > 0)$ for its store rents, facility wages, etc. It comes out three partners' demand functions as follows:

$$D_1(p_1, w, e_{d1}, e_{b1}) = \left[a_e - mp_1 + np_2 + \theta(p_r - p_1) + \gamma e_{d1} - \lambda e_{d2} - \varphi(e_r - e_{d1})\right] e_{b1}$$

$$D_2(p_2, e_{d2}, e_{b2}) = \left[a_e - mp_2 + np_1 + \theta(p_r - p_2) + \gamma e_{d2} - \lambda e_{d1} - \varphi(e_r - e_{d2})\right] e_{b2}$$

$$D_r(p_r, e_r) = a_r - mp_r + \theta(p_1 - p_r) + \theta(p_2 - p_r) + \gamma e_r + \varphi(e_r - e_{d1}) + \varphi(e_r - e_{d2})$$

The parameter $\theta(\theta > 0)$ is price demand pervasion level between dual markets, and the parameter $\varphi(\varphi > 0)$ represents sale effort demand pervasion level between dual markets. The parameter $c_j\,(j = 1, 2)$ is manufacturer j 's product cost, $p_j\,(j = 1, 2)$ is its Internet sale price, which has that $p_j > c_j\,(j = 1, 2)$. The parameter p_r is the retailer r 's sale price, and w is its wholesale price. The relationships $p_1 > w > c_1$ must exist. The parameter a_e means product $i\,(i = 1, 2)$'s "comprehensive market demand base". Similarly, The parameter a_r is customer demand in traditional market. And m is the product demand's reaction level to itself. The parameter n is products' differentiation effects. $m > n > 0$ .The parameter γ is the product's sale effort demand reaction level to itself. The parameter λ represents products' sale effort differentiation effects, $\gamma > \lambda > 0$ .The timing of decisions is captured in a two-period framework. Firstly manufacturer M_1 and online manufacturer M_2 play a leader-follower game to decide optimal variables. Secondly, being a weakest supply chain partner, the traditional retailer participates in dual market competition.

By backward induction, All of the optimal variables and revenues can be calculated in Table 1. Accordingly, it can find out some theorems and corollaries as follows:

Optimal Strategies for the Traditional Retailer r

The traditional retailer r 's revenue function is $\pi_r = (p_r - w - c_r) D_r(p_r, e_r) - f(e_r) - F$. By derivation it concludes that,

$$\begin{cases} p_r^{\,*} = -\dfrac{1}{\hat{H}}\left[\hat{M} + \theta(p_1 + p_2)\right] \\ e_r^{\,*} = \dfrac{(\gamma + 2\varphi)}{\eta}\left(p_r^{\,*} - w\right) = -\dfrac{1}{\eta \hat{H}}(\gamma + 2\varphi)\left[\hat{M} + \theta(p_1 + p_2) + \hat{H}w\right] \end{cases}, \quad \pi_r^{\,*} = -\frac{\eta^2 \hat{H} e_r^{\,*2}}{2(\gamma + 2\varphi)^2} - F$$

And some theorems could be found to tell us basic principles, which are showed as follows:

Theorems 1 Under dual market competition, the condition that the traditional retailer r could exist is $\hat{H} < 0$, that is, $2\eta(m + 2\theta) > (\gamma + 2\varphi)^2$

Corollary 1 When Manufacturer M_2 is in second-rate predominance status, the higher the offline retailer's channel promotion level, the bigger its optimal revenues.

Corollary 2 When Manufacturer M_2 is in second-rate predominance status, the greater the sales promotion effort level's difference between online and offline markets, the lower the offline retailer's optimal revenues.

Optimal Strategies for Online Manufacturer M_2

Being a secondary leader to the traditional retailer r, the online manufacturer M_2's revenue function is, $\pi_2 = (p_2 - c_2) D_2(p_2, e_{d2}, e_{b2}) - f(e_{d2}) - f(e_{b2})$. By derivation it concludes that (all letters involved here will be showed later),

$$p_2^* = \widehat{N} p_1 + \widehat{P} w + \frac{\widehat{L} + \widehat{K}\widehat{M}}{2(m+\theta) - \theta\widehat{K}}, \pi_2^* = e_{b2}(m+\theta)(p_2 - c_2)^2 - f(e_{d2}) - f(e_{b2})$$

And some theorems could be found to tell us basic principles, which are showed as follows:

Theorems 2 Under dual market competition, the condition that online manufacturer 2 could get optimally maximal revenues is $p_2^* > c_2$.

Corollary 3 When Manufacturer M_2 is in second-rate predominance status, if $\frac{\partial \pi_2}{\partial e_{d2}} \geq 0$, the revenue of online manufacturer M_2 is positive correlation of channel promotion effort level, on the contrary it is negative correlation; If $\frac{\partial \pi_2}{\partial e_{b2}} \geq 0$, the revenue of online manufacturer M_2 is positive correlation of brand promotion effort level, on the contrary it is negative correlation.

Optimal Strategies for Manufacturer M_1

Being a supply chain leader among three partners, the manufacturer M_1's revenue function is, $\pi_1 = (p_1 - c_1) D_1(p_1, w, e_{d1}, e_{b1}) + (w - c_1) D_r(p_r, e_r) - f(e_{d1}) - f(e_{b1})$ And p_1^*, w^* can be found by the equations above. Because of complex expresses, they are not listed here. The condition in which manufacturer M_1 get optimal revenues could be found in theorems 4.

Theorems 4 Under dual markets competition, the condition that manufacturer 1 could get optimally maximal revenues is, $\begin{cases} \widehat{Q} < 0 \\ 4\widehat{Q}\widehat{R} e_{b1} - (\widehat{S} e_{b1} + \widehat{T})^2 > 0 \end{cases}$

Corollary 4 When $w > c$, the strongest leader manufacturer M_1 would like to join in the dual market competition.

Supply Chain Coordination

In the literatures Peiqin Li (2016) they have given conditions that this "Two-to-One" supply chain coordination exists, which is showed in theorems 5:

Theorems 5 if $\left[-(m+\theta) + n\frac{n}{2(m+\theta)} \right] < 0$, $\left[-(m+2\theta) + \theta\left[\frac{\theta}{2(m+\theta)} \right] \right] < 0$, and $p_r^* = p_{rT}^*$, $e_r^* = e_{rT}^*$, $p_1^* = p_{1T}^*$, the supply chain coordination exists.

By the way, all of the optimal variables are listed below in Table 1.

Numerical Simulation Analysis

What this paper cares about is that, do the online manufacturer M_2 or the traditional retailer can get a "free-riding effect" from the strongest manufacturer M_1 or not? How can the manufacturer M_1 get more benefits based on the other two's free-riding activities? How "Online market capacity rate g " and "offline market capacity a_r" influence the supply chain optimization decision? Basic parameter assumptions are as follows, $c_1 = 0.0002(K - 250)^2 + 4$, $c_2 = 0.7c_1$, $m = 19, n = 10$, $e_{b1} = h_1 e_{d1}$, $F = 100$, $\theta = 3, \eta = 2, \kappa = 1, \gamma = 0.5, \lambda = 0.3, \varphi = 0.2$, $a_e = g a_r\ (g > 0)$, $e_{b2} = h_2 e_{b1} = h_1 h_2 e_{d1}$, $e_{d2} = h_3 e_{d1}$, $a_r = 500$, $e_{d1} = 0.5$, $h_2 = 1.2$, $g = 0.8$.

When industry e-commerce development level is certain, offline market capacity a_r's change will affect some key variables, which gives out several kinds of states as follows, such as in Table 2, Table 3 and Figure 1.

Free-riding Effect Based on Promotion Effort Levels

Firstly, the key variables are h_1, h_3. Online market capacity rate g reflects the development level of e-commerce . as the variable h_1 increasing, the traditional manufacturer M_1's optimal quantity descends slightly, which means that increasing the online manufacturer M_2's channel promotion effort level couldn't shake the manufacturer M_1's status. Besides, as the variable h_3 increasing, both the traditional manufacturer M_2 optimal quantity and revenue improve at the same time, however, the traditional manufacturer M_1 has to provide a reduced price to slow down the competition pressure, and the retailer reduces its price too.

Table 1 Optimal variables of the model

p_2^*	$\hat{N}p_1+\hat{P}w+\frac{\hat{L}+\hat{K}\hat{M}}{2(m+\theta)-\theta\hat{K}}$	π_2^*	$e_{b2}(m+\theta)(p_2-c_2)^2-f(e_{d2})-f(e_{b2})$
p_r^*	$-\frac{1}{\hat{H}}\left[\hat{M}+\theta(p_1+p_2)+\hat{I}w\right]$	D_2^*	$(p_2-c_2)e_{b2}(m+\theta)$
e_r^*	$-\frac{1}{\eta\hat{H}}(\gamma+2\varphi)\left[\hat{M}+\theta(p_1+p_2)+(\hat{H}+\hat{I})w\right]$	π_r^*	$-\frac{1}{2\hat{H}}\left[\hat{M}+\theta(p_1+p_2)+(\hat{H}+\hat{I})w\right]^2$
D_r	$-(p_1-c_1)\hat{S}e_{b1}-(w-c_1)\hat{R}$ or $(m+2\theta)(p_r-w)$	D_1^*	$-(p_1-c_1)\hat{Q}e_{b1}-(w-c_1)\hat{T}$
p_1^*、w^*	$\begin{cases}\frac{\partial\pi_1}{\partial p_1}=\left[a_e-mp_1+np_2+\theta(p_r-p_1)+\gamma e_{d1}-\lambda e_{d2}-\varphi(e_r-e_{d1})\right]e_{b1}+(p_1-c_1)\hat{Q}e_{b1}+(w-c_1)\hat{T}=0\\ \frac{\partial\pi_1}{\partial w}=\left[a_r-(m+2\theta)p_r+\theta(p_1+p_2)+\gamma e_r+\varphi(e_r-e_{d1})+\varphi(e_r-e_{d2})\right]+(p_1-c_1)\hat{S}e_{b1}+(w-c_1)\hat{R}=0\end{cases}$		
π_1^*	$-(p_1-c_1)^2\hat{Q}e_{b1}-(w-c_1)^2\hat{R}-(p_1-c_1)(w-c_1)(\hat{T}+\hat{S}e_{b1})-f(e_{d1})-f(e_{b1})$		
APPENDIXES	$\tilde{H}=\frac{(\gamma+2\varphi)^2}{\eta}-2(m+2\theta),\tilde{I}=(m+2\theta)-\frac{(\gamma+2\varphi)^2}{\eta},\tilde{J}=(m+2\theta)-\frac{1}{2\eta}(\gamma+2\varphi)^2,\tilde{M}=a_r-\varphi(e_{d1}+e_{d2}),\tilde{K}=\frac{1}{\tilde{H}}\left[\frac{\varphi}{\eta}(\gamma+2\varphi)-\theta\right],$ $\tilde{L}=a_e+2(m+\theta)c_2+(\gamma+\varphi)e_{d2}-\lambda e_{d1},\frac{n+\theta\tilde{K}}{2(m+\theta)-\theta\tilde{K}}=\tilde{N},\frac{\lambda-\varphi\tilde{K}}{2(m+\theta)-\theta\tilde{K}}=\tilde{O},\frac{\frac{\varphi}{\eta}(\gamma+2\varphi)+\tilde{I}\tilde{K}}{2(m+\theta)-\theta\tilde{K}}=\tilde{P},\left[-(m+\theta)+n\tilde{N}-\frac{\theta^2(1+\tilde{N})}{\tilde{H}}+\frac{\varphi\theta}{\eta\tilde{H}}(\gamma+2\varphi)(1+\tilde{N})\right]=\tilde{Q},$ $(m+2\theta)\frac{(\theta\tilde{P}+\tilde{I})}{\tilde{H}}+\theta\tilde{P}-\frac{1}{\eta\tilde{H}}(\gamma+2\varphi)^2(\theta\tilde{P}+\tilde{H}+\tilde{I})=\tilde{R},\left[n\tilde{P}-\frac{\theta(\theta\tilde{P}+\tilde{I})}{\tilde{H}}+\frac{\varphi(\gamma+2\varphi)}{\eta\tilde{H}}(\theta\tilde{P}+\tilde{H}+\tilde{I})\right]=\tilde{S},\left[\frac{\theta(m+2\theta)(1+\tilde{N})}{\tilde{H}}+\theta(1+\tilde{N})-\frac{(\gamma+2\varphi)^2\theta}{\eta\tilde{H}}(1+\tilde{N})\right.$ $\tilde{F}=4\tilde{Q}\tilde{R}e_{b1}-(\tilde{S}e_{b1}+\tilde{T})^2$		

Table 2 Capacity optimization's numerical simulation analysis

	g	e_{d1}	h_1	h_2	h_3	c_1	c_2	p_r	p_1	w	p_2	e_r
	0.8	0.5	1	1.2	0.8	4.0626	2.8438	19.340	17.720	14.580	15.850	2.144
1	0.8	0.5	1	1.2	1.5	4.0628	2.8440	19.335	17.716	14.574	15.860	2.143
	0.8	0.5	1	1.2	2.5	4.0631	2.8442	19.333	17.714	14.573	15.864	2.142
	0.8	0.5	1	1.2	4.0	4.0636	2.8448	19.329	17.710	14.570	15.875	2.141
	0.8	0.5	0.5	1.2	1.5	5.4314	3.8020	19.784	19.411	15.163	16.752	2.079
2	0.8	0.5	1	1.2	1.5	4.0628	2.8440	19.335	17.716	14.574	15.860	2.143
	0.8	0.5	1.5	1.2	1.5	4.2905	3.0034	19.496	17.539	14.914	15.907	2.062
	0.8	0.5	2	1.2	1.5	5.3782	3.7647	19.959	18.039	15.723	16.434	1.906
	0.5	0.5	1	1.2	1.5	5.2291	3.6604	18.786	13.530	14.464	11.867	1.945
3	0.8	0.5	1	1.2	1.5	4.0628	2.8440	19.335	17.716	14.574	15.860	2.143
	1.2	0.5	1	1.2	1.5	4.4355	3.1048	20.717	24.406	15.778	22.147	2.223
	1.6	0.5	1	1.2	1.5	6.0251	4.2176	22.509	31.796	17.649	29.050	2.187

Table 3 Capacity optimization's numerical simulation analysis (Cont'd)

	π_r	π_1	π_2	K^*	D_r	D_1	D_2	D_1/D_r	$\frac{D_1+D_2}{D_r}$	$\frac{D_1+D_r}{D_2}$
	462.15	2797.06	2232.28	232.306	119.032	113.274	171.695	0.950	2.390	1.350
1	462.01	2796.38	2233.66	232.277	119.016	113.260	171.762	0.952	2.394	1.352
	461.80	2795.39	2235.64	232.240	118.994	113.242	171.857	0.952	2.396	1.351
	461.49	2793.92	2238.62	232.175	118.962	113.213	172.000	0.952	2.398	1.350
	429.46	1820.76	1105.70	165.401	115.519	49.882	85.467	0.432	1.172	1.935
2	462.01	2796.38	2233.66	232.277	119.016	113.260	171.762	0.952	2.394	1.352
	420.58	3515.04	3295.13	288.114	114.546	173.568	255.492	1.515	3.746	1.128
	344.98	3969.34	4235.30	333.012	105.903	227.109	334.460	2.145	5.303	0.996
	363.19	1524.36	887.74	171.607	108.048	63.559	108.333	0.588	1.590	1.584
3	462.01	2796.38	2233.66	232.277	119.016	113.260	171.762	0.952	2.394	1.352
	504.93	4858.11	4784.77	296.663	123.477	173.185	251.350	1.403	3.438	1.180
	485.92	7315.69	8138.58	350.626	121.522	229.104	327.791	1.885	4.583	1.069

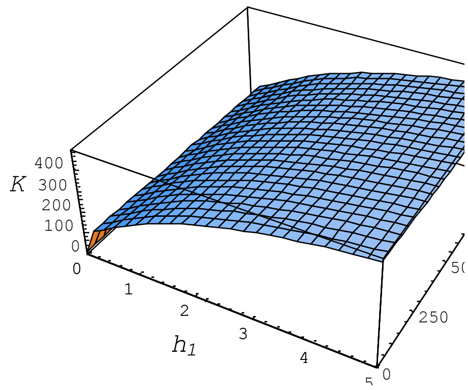

Fig. 1 The traditional manufacturer M_1's optimal revenue

Secondly, as the variable h_1 increasing, both the demand quantity and revenue curves of traditional retailer first rise then descend. On the contrary, the product cost and price strategy of both the traditional manufacturer M_1 and M_2 take on the feature of going up after dropping.all of which mean that, when the online promotion effort level h_1 of the manufacturer M_1 is lower such as $h_1 = 0.5$, the retailer can acquire the obvious "Free-riding effect" from the traditional manufacturer M_1, and both of its demand quantity and revenue rise significantly. Of course, the manufacturer M_1 can solve its overcapacity problem by improving its online promotion level at this time. And at $h_1 = 1$ the retailor gets the manimum revenue, with the manufacturer M_1 realizes its optimal capacity decision too.It can conclude that, being a supply chain leader, the manufacturer M_1 has to take more responsity online or offline, especially when its capacity is too much and it has great pressure to recoup inventory funds. However, with the online promotion effort level h_1 becoming bigger, the retailor's "Free-riding effect" disappears little by little. It comes out that, the weakest traditional retailor will exit market finally if online promotion competition keeps up, which conforms to the reality that many physical store close down today. So, this kind of "Free-riding effect" is temporary, and the whole supply chain have not realize "Win-win" cooperation, People need to find out better methods to solve this reality conflict.

Thirdly, with the variable h_1 increasing, the demand quantity and revenue of both the traditional manufacturer M_1 and M_2 become bigger significantly, the traditional manufacturer M_1 's online promotion effort brings the online manufacturer M_2 more revenue, which means that the manufacturer M_2 acquires "Free-riding effect". To some degree online promotion will help the whole industry demand quantity becomes bigger. Here the traditonal manufacturer leader M_1 takes more industry responsity, and its production allocation tends to online market more,from 0.432 to 2.145.

Finally, with online market capacity rate g improving, both the ratailor and online manufacturer M_2 have “Free-riding effect”, just as with the variable h_1 increasing their free-riding effect shows. What the difference is that, with the variable h_1 increasing, the consumer can achieve much more welfare than the latter, but the online market capacity rate g improving has more influence on industry market size, so in the latter the retailor’s”Free-riding effect”is more outstanding than the before.

In the end, the coping strategies of traditional manufacturer M_1 are the key questions in next research of this paper. It should focus on contract design, the role shift of traditional retailor, etc. to try to improve supply chain efficiency.

Acknowledgement

This research was financially supported by the Fourty Years of the Reform and Opening-up Project of East China University Political and Law (PN: 401-B-6001-16-0022409-20).

References

[1] Brynjolfossn E, Smith M D. Frictionless Commerce: A Comparison of Internet and Traditional Retailers[J]. Management Science, 2000, 46(4): 563-585.

[2] Cattani K, Gilland W, Swanrninathan JM. Boiling Frogs: Pricing Strategies for a Manufacturer Adding a Direct Channel that Competes with Traditional Channel [J]. Production and Operation Management, 2006, 15(l):40-56.

[3] Choi TM, Li D, Yan H. Optimal Returns Policy for Supply Chain with E-Marketplace [J]. Int. J. Production Economics, 2004, 88: 205–227.

[4] Collinger T. Lines Seperating Sales Channels Blur: Manufacturers, Direct Sellers, Retailers Invade Each Other [J]. Turf. Advertising Age, 1998(30):34.

[5] Ding Zhengping, Liu Yezheng. Revenue sharing contract in dual channel supply chain in case of free riding. Journal of Systems Engineering. 2013, 28(3):370-376

[6] Kevin Zhu. Information Transparency of Business-to-Business Electronic Markets: A Game-Theoretic Analysis. Management Science, 2004, 50(5): 670–685.

[7] Lee H, Whang S. The Impact of the Secondary Market on the Supply Chain[J]. Management Science, 2002, 48(6): 719-731.

[8] Zhou Jiangheng, Zhao Ruijuan. Quality disclosure strategy in a dual-channel supply chain based

On free-riding effect. Systems Engineering--Theory & Practice, 2016, 36(11):2839-2852.