CHEMICAL ENGINEERING TRANSACTIONS
VOL. 66, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866233

Game Analysis of Market Entry of Small and Medium-sized Chemical Companies

Ting Yang, Ming Liu*

School of Economics and Management, Weifang University, Weifang 261061, China
liumingswjtu@163.com

In the chemical industry market, large chemical companies are usually the earlier market entrants, and small and medium-sized chemical companies are latter entrants to the market. Therefore, the question of how small and medium-sized chemical companies enter the market and survive in competition is worth studying in depth. This paper uses the game theory of Stackelberg oligopolistic competition to construct a market entry game model for small and medium-sized chemical companies. Through the model derivation, it is found that the decisive factor for whether small and medium-sized chemical companies enter the chemical industry market or not is the fixed cost they need to pay for entering the market, its market share after they entering the market and whether they can increase consumer surplus determine whether the government will provide support.

1. Introduction

Under the social background of economic development, social progress and encouragement of entrepreneurship, Chinese small and medium-sized companies have been developing vigorously, among which, a certain number of small and medium-sized chemical companies are included. However, as latter market entrants and market followers, small and medium-sized chemical companies have limited economic strength and insufficient competitive strength. Whether they can successfully enter the chemical industry market and survive and develop is a problem worthy of in-depth research. This paper will use game theory to intensively analyze this issue.

Game Theory studies when a subject's choice is affected by other subject choices, and at the same time, it in turn affects the decisions of other subject's choices and the balance issue of the decision. In other words, unlike traditional microeconomics, in the game theory, a subject's individual utility function not only depends on his own choice of behavior, but also depends on the choice of other subject's behavior, which means the individual's optimal choice is a function of the behavior of others. Therefore, what game theory studies is a decision-making problem, namely the individual optimal choice when there is an external mutual economy. Oligopoly market, for example, it’s an exception in traditional microeconomics, but an important application field of game theory, such as the Stackelberg oligopolistic competition model.

In 1934, H.Von.Stackelberg proposed the Stackelberg equilibrium theory, which is considered to be the earliest version of Selten’s "Subgame Perfect Nash equilibrium" (1965).

In the real market, the market position of competitor manufacturers is different, which results in that their decision-making has the feature of time-series. It is usually the case that large companies make decisions first, while small companies observe first, and then according to their abilities and the goal they want to achieve, they formulate their own countermeasures. It is based on this asymmetric competition situation that Stackelberg established the oligopolistic competition model.

The Stackelberg oligopolistic competition theory classifies oligopolistic competition manufacturers as "leaders" and "followers" for analysis. Unlike in Cournot oligopolistic model, the oligopolies are evenly matched and following each other, in Stackelberg oligopolistic competition model, one side is a leader who is dominant, and the other is a follower whose strength is weaker, and each manufacturer must make decision on its production output and choose the optimal production output decision to maximize its profits.

In the chemical industry market, large chemical companies represented by state-owned chemical companies occupy a dominant position as “leaders.” Small and medium-sized chemical companies are disadvantaged

Please cite this article as: Yang T., Liu M., 2018, Game analysis of market entry of small and medium-sized chemical companies, Chemical Engineering Transactions, 66, 1393-1398 DOI:10.3303/CET1866233

both in capital amount and market appeal and are “followers”. Both provide chemical products for the demanding market, and both are considered as indispensable forces in the development of the chemical industry. However, there is also a competition game between the two, and for the game problems between the two, the Stackelberg oligopolistic competition model can be applied for analysis and explanation.

2. Basic assumptions

Assumption 1: There are two main players in the chemical industry market – large chemical companies and small and medium-sized chemical companies. As market leaders and first entrants, the large chemical companies need to maintain their vested interests, and they must set economic barriers for the market entry.
Assumption 2: The cost function of the large chemical companies is $C_1(q)$, and the cost function of small and medium-sized chemical companies is $C_2(q)$.
Assumption 3: In order to overcome the economic barriers to entry in the chemical industry market, the small and medium-sized chemical companies need to pay the corresponding costs, set the cost as ω, ω includes the minimum capital requirements for setting up chemical companies and the minimum cost required to achieve economies of scale in the future business process.
Assumption 4: The demand function of the chemical industry market is:
$P(q)=1-q$
The total supply of chemical products in the chemical industry market is:
$q=q_1+q_2$
The remaining demand in the market is:

$$S(q) = V(q) - q \times P(q), \quad V(q) = \int_0^q P(\alpha)d\alpha$$

Where, q_1 is the quantity of chemical products provided by large chemical companies, q_2 is the quantity of chemical products provided by small and medium-sized chemical companies in the chemical industry market, and $V(q)$ represents the utility obtained by product demanders.
Assumption 5: The target profit function is $\pi(q_1, q_2)$, where the profits of large chemical companies are $\pi_1(q_1, q_2)$, and the profits of small and medium-sized chemical companies are $\pi_2(q_1, q_2)$.

3. Entry game between large chemical companies and small and medium-sized chemical companies

Basing on above assumptions, construct the Stackelberg model. In an open chemical industry market, both sides of the game have complete information. Small and medium-sized chemical companies as potential entrants can observe that the product supply of large chemical companies in the chemical industry market is q_1, so their product supply is $q_2(q_1)$ units. Because large chemical companies have set up economic barriers for market entry, small and medium-sized chemical companies need to pay ω more units to enter the market. Using the reverse-order derivation to solve the Perfect Nash equilibrium, the target profit function expected by small and medium-sized chemical companies is:

$$\max_{q_2 \geq 0} \pi_2(q_1, q_2) = (1 - q_1 - q_2)q_2 - \omega \tag{1}$$

Finding the first derivative of q_2 for formula 1 yields:

$$q_2^*(q_1) = \frac{1 - q_1}{2} \tag{2}$$

$$\pi_2^*(q_1, q_2) = \frac{(1 - q_1)^2}{4} - \omega \tag{3}$$

Considering that large chemical companies have predicted that small and medium-sized chemical companies will choose q_2 according to $q_2^*(q_1)$, the expected target profit function of large chemical companies is:

$$\max_{q_1 \geq 0} \pi_1(q_1, q_2) = (1 - q_1 - q_2)q_1 \tag{4}$$

Substituting formula 2 into the expected target profit function (formula 4) of large chemical companies, we can obtain:

$$\pi_1^*\left(q_1, q_2^*(q_1)\right) = \frac{(1-q_1)q_1}{2} \tag{5}$$

Assume ω=0 (which does not exist in reality), that is when small and medium-sized chemical companies have zero entry cost, they will certainly enter the chemical industry market. Find the first derivative of q_1 for formula 5, then the Stackelberg game result is:

$$q_1^* = \frac{1}{2},\ q_2^* = \frac{1}{4},\ \pi_1^* = \frac{1}{8},\ \pi_2^* = \frac{1}{16}$$

However, in real life, the cost of small and medium-sized chemical companies for entering the chemical industry market is ω>0, at this time, the Stackelberg game result is:

$$q_1^* = \frac{1}{2},\ q_2^* = \frac{1}{4},\ \pi_1^* = \frac{1}{8},\ \pi_2^* = \frac{1}{16} - \omega$$

Therefore, under the condition of ω>0, only when $\pi_2^* = \frac{1}{16} - \omega > 0$, namely $\omega < 1/16$, can the small and medium-sized chemical companies gain profits, and can they enter the chemical industry market.

At this time, vested interests (large chemical companies) will adjust the supply of products to the entire market (which will result in economies of scale) when they are taking into account the market entry threats of small and medium-sized chemical companies, thus making the profits of small and medium-sized chemical companies negative, impeding the entry of small and medium-sized chemical companies.

At this time:

$$\pi_2^*\left(\bar{q}_1, q_2\right) = \frac{\left(1-\bar{q}_1\right)^2}{4} - \omega \le 0,$$

namely

$$q_1 \ge \bar{q}_1 = 1 - 2\sqrt{\omega}$$

Where, $\bar{q}_1$ is the minimum amount of capital invested by large chemical companies to establish economic barriers. Substituting $\bar{q}_1 = 1 - 2\sqrt{\omega}$ into formula 5 can obtain the profit of large chemical companies:

$$\bar{\pi}_1 = \bar{q}_1\left(1 - \bar{q}_1\right) = 2\sqrt{\omega}\left(1 - 2\sqrt{\omega}\right) \tag{6}$$

Whether large chemical companies increase invested capital and increase supply to impede the entry of small and medium-sized chemical companies depends entirely on ω, that is the cost of setting up economic barriers, if and only if the profit obtained by impeding the small and medium-sized chemical companies is more than the profit obtained by the capital investment in the Stackelberg game, will the large chemical companies choose to increase the capital supply to impede the entry of small and medium-sized chemical companies into the chemical industry market.

Order

$$\bar{\pi}_1 = \bar{q}_1\left(1 - \bar{q}_1\right) = 2\sqrt{\omega}\left(1 - 2\sqrt{\omega}\right) = \frac{1}{8},$$

then we can get:

$$\sqrt{\omega_1} = \frac{\left(2 - \sqrt{2}\right)}{8},\quad \sqrt{\omega_2} = \frac{\left(2 + \sqrt{2}\right)}{8}$$

Based on the above analysis, when ω>0, there are three situations in which small and medium-sized chemical companies enter the chemical industry market or not:

Case 1: When the fixed cost ω>1/16, the profits of small and medium-sized chemical companies for entering the chemical industry market are negative, so they will not enter the market; large chemical companies will not increase market capital investment, they will choose the amount of capital that provides the best profit, that is $k_2^* = 1/2$, obtain the maximum profit 1/4.

Case 2: When the fixed cost $\omega \in (\omega_1, 1/16)$, $q_1 < \bar{q}_1$, the profit obtained by impeding the small and medium-sized chemical companies is more than the profit obtained by the capital investment in the Stackelberg game, the large chemical companies will increase $\bar{q}_1 = 1 - 2\sqrt{\omega}$ capital investment, so as to impede the entry of the small and medium-sized chemical companies into the chemical industry market.

Case 3: When the fixed cost $\omega \in (0, \omega_1)$, the profit obtained by impeding the small and medium-sized chemical companies is less than the profit (1/8) obtained by the capital investment in the Stackelberg game, at this time, the large chemical companies will not impede the entry of the small and medium-sized chemical companies into the chemical industry market.

According to the derivation, the conditions for determining whether small and medium-sized chemical companies can enter the chemical industry market or not are: potential entrants (small and medium-sized chemical companies) overcome the cost ω of vested interests (large chemical companies) for setting up the obstacles, the higher the entry cost ω set by the large chemical companies, the more difficult it is for small and medium-sized chemical companies to enter the chemical industry market. Therefore, the best strategy to impede the entry of small and medium-sized chemical companies into the market is to set higher market entry barriers.

4. Market entry game participated by the government, the large chemical companies, the small and medium-sized chemical companies

The chemical industry plays an important role in economic and social development. In order to achieve the goal of optimizing local economic and social welfare, local government would encourage small and medium-sized chemical companies to enter the chemical industry market. Due to the existence of certain policy factors in the chemical industry market, the entry of small and medium-sized chemical companies is not merely a game between vested interests and potential entrants, but it is a game between three sectors including the local government.

After the local government joins the game, considering that the chemical industry institutions will bring certain benefits to local economic development and social employment, chemical companies, especially chemical companies whose products are related to national economy and people's livelihood, may receive certain policy support, such as financial subsidies $\mu_i(i=1,2;\ \mu_1\neq\mu_2)$. The benefit that chemical companies bring to the local society and the economy is $\phi_i(i=1,2;\ \phi_1\neq\phi_2)$, at this time, the profit expectations of both the large chemical companies and the small and medium-sized chemical companies will change. Assume q^t_1 is the product quantity of the large chemical companies before the entry of small and medium-sized chemical companies, then before the small and medium-sized chemical companies enter the market, the profit function of large chemical companies is:

$$\pi_1^t = \left(1 + \mu_1^t\right)\left[P\left(q_1^t\right) \times q_1^t - C_1\left(q_1^t\right)\right]$$

After the entry of small and medium-sized chemical companies, the profit function of large chemical companies is:

$$\pi_1 = \left(1 + \mu_1\right)\left[P\left(q_1\right) \times q_1 - C_1\left(q_1\right)\right]$$

At this time, the profit function of small and medium-sized chemical companies is:

$$\pi_2 = \gamma\left(1 + \mu_2\right)\left[P\left(q_2\right) \times q_2 - C_2\left(q_2\right)\right]$$

(γ is the entry probability of small and medium-sized chemical companies)

After the entry of small and medium-sized chemical companies, the social welfare function of the local government is:

$$\max(V) = S(q) + \pi_1 + F + \phi_1 \times \pi_1 + \rho\left(1 + \phi_2\right)\pi_2 \quad (\rho=0,1)$$

Where, F is the financial compensation of the local government obtained from the central government to support chemical industry development, $\rho=0$ represents that the small and medium-sized chemical companies do not enter the chemical industry market, $\rho=1$ represents that the small and medium-sized chemical companies enter the chemical industry market.

Before the small and medium-sized chemical companies enter the chemical industry market, the social welfare function of the local government is:

$$V = S\left(q_1^t\right) + \pi_1^t + F + \phi_1 \times \pi_1^t$$

After the entry of small and medium-sized chemical companies, the social welfare function of local governments becomes:

$$V^* = S\left(q_1 + q_2\right) + \pi_1 + F + \phi_1 \times \pi_1 + \pi_2 + \phi_2 \times \pi_2$$

If and only if *V*-V⩾0* would local governments encourage small and medium-sized chemical companies to enter, that is:

$$S(q_1+q_2)-S(q_1^t)+(\pi_1-\pi_1^t)+(\phi_1\pi_1-\varphi_1^t\pi_1^t)+(1+\phi_2)\pi_2\geq 0$$

Since $S(q_1+q_2)-S(q_1^t)>0$, $(1+\phi_2)\pi_2>0$, then *V*-V⩾0* depends on the influence of small and medium-sized chemical companies on the profits $(\pi_1-\pi_1^t)$ of vested interests (large chemical companies) and the change in the influence $(\phi_1\pi_1-\varphi_1^t\pi_1^t)$ of the vested interests on the local welfare.
We further assume that, there is no restriction on the entry of small and medium-sized chemical companies into the chemical industry market, $C_1(q)=C_2(q)$, their products and the products provided by large chemical companies are substitutable, then after the small and medium-sized chemical companies obtained the market access, the chemical industry market becomes a duopoly market, and their profits respectively are: $\pi_1=\frac{\pi_1^t}{2}$, $\pi_2=\frac{\pi_1^t}{2}$, at this time, *V*-V⩾0*, there is:

$$S(q_1+q_2)-S(q_1^t)+\left(\frac{\pi_1^t}{2}-\pi_1^t\right)+\left(\phi_1\frac{\pi_1^t}{2}-\varphi_1^t\pi_1^t\right)+(1+\phi_2)\frac{\pi_1^t}{2}\geq 0$$

After simplification we can get:

$$S(q_1+q_2)-S(q_1^t)+\frac{\pi_1^t}{2}(\phi_1-2\phi_1^t+\phi_2)\geq 0 \tag{7}$$

Derived from formula 7 we can get, since $S(q_1+q_2)-S(q_1^t)>0$, therefore only if $(\phi_1-2\phi_1^t+\phi_2)>0$, namely that the traditional and the new type of chemical industry institutions bring enough welfare benefits to the local society and economy, then *V*-V⩾0*, at this time, the small and medium-sized chemical companies can get more than half of the market share when they enter the chemical industry market.
By organizing and converting formula 7, we can get:

$$S(q_1+q_2)-S(q_1^t)\geq\frac{\pi_1^t}{2}(2\phi_1^t-\phi_1-\phi_2) \tag{8}$$

From formula 8, it can be deduced that if $S(q_1+q_2)-S(q_1^t)$ is large enough to offset the loss of large chemical companies after the entry of small and medium-sized chemical companies (including the loss of profits of large chemical companies and the loss of social welfare of local governments), then the local government would allow small and medium-sized chemical companies to enter the market.

5. Conclusion of market entry game

Conclusion 1: The decisive factor for whether small and medium-sized chemical companies enter the chemical industry market or not is the entry cost ω they need to pay for entering the market. The critical value of ω is 1/16, that is, when ω>1/16, the potential entrants (small and medium-sized chemical companies) will not enter the chemical industry market, when ω<1/16, it will enter the chemical industry market.
Conclusion 2: The higher the entry cost ω set by the vested interests (large chemical companies), the more difficult it is for the small and medium-sized chemical companies to enter the chemical industry market. Therefore, in order to impede the entry of small and medium-sized chemical companies, large chemical companies will increase the amount of capital supply to reduce the profits of potential entrants (small and medium-sized chemical companies).
Conclusion 3: The decisive factor on whether local government encourages small and medium-sized chemical companies to enter the chemical industry market is whether the entry of small and medium-sized chemical companies into the chemical industry market will increase local social welfare levels and whether they can provide greater social utility.
Conclusion 4: There are two types of choices for small and medium-sized chemical companies to obtain government support: first, they can occupy more than half of the chemical industry market share after they enter the chemical industry market; second, their increased consumer surplus $S(q1+q2)-S(q_1^t)$ can supplement the potential loss of vested interests and the loss of local initial social welfare brought by their entry.

References

Avci N., Geldermann J., Renta O., Hubert F.,2003, Internet-based information exchange network between EU member states, the European Commission, and small and medium-sized enterprises (SME) in relation to the EU Solvent Directive, Surface Coatings International Part B: Coatings Transactions, 86, 231-235, DOI: 10.1007/BF02699658

Baltz K., 2004, Colin Camerer: Behavioral game theory, experiments in strategic interaction, Politische Vierteljahresschrift, Berlin, Germany, 45, 446-449, DOI: 10.1007/s11615-004-0067-y

Chen Y.P., Caldwell M., Dickerhoof E., Hall A., Odakura B., Morelli K., Fanchiang H.C., 2014, Game Analysis, Validation, and Potential Application of EyeToy Play and Play 2 to Upper-Extremity Rehabilitation, Rehabilitation Research and Practice, London, UK, 13-25, DOI: 10.1155/2014/279609

Fleischer M., 2003, Regulation and innovation in the chemical industry: A comparison of the EU, Japan and the USA, Surface Coatings International Part B: Coatings Transactions, Springer US, 86, 21-29, DOI: 10.1007/BF02699589

Huang K.N., 2009, Evolutionary Games and Evolutionary Economics, Economic Research Journal, 2, Beijing, China, 132-145.

Li X.Y., Chen W.M., 2008, Evolutionary Game Model of Knowledge Sharing within an Organization, Statistics and Decision, Vol 12, Wuhan, China, 170-171.

Lin Q.L., Meng Y., 2013, Research on Evaluation of Core Competitiveness of Small and Medium-sized Chemical Enterprises Based on Factor Analysis, Guild to Business, 11, Wuhan, China, 31-32.

Wang D.Z., Lang M.X., Sun Y., 2014, Evolutionary Game Analysis of Co-opetition Relationship between Regional Logistics Nodes, Journal of Applied Research and Technology, Mexico City, Mexico, 12, 251-260, DOI: 10.1016/S1665-6423(14)72341-7

Wang X.Q., Sun X.Y., 2018, Evolutionary game analysis on supervision governance of chemical enterprises based on public participation behavior, Journal of Safety Science and Technology, Beijing, China, 3, 180-186, DOI: 10.11731/j.issn.1673-193x.2018.03.027

Xu G.X., Wu J.B., Deng X.H., Xu X.Y., 2008, On the Development Strategy for Medium-Size Chemical Enterprises in China, Reformation & Strategy, Nanning, China, 24, 138-140, DOI: 10.3969/j.issn.1002-736X.2008.05. 042

Yang Z.K., 2007, Research on Countermeasures for Small and Medium-sized Chemical Enterprises Developing Circular Economy, Morden Management Science, Beijing, China, 9, 8-10. DOI: 10.3969/j.issn.1007-368X. 2007.01.005

Zhang H., Sun X.M., Sun B.L., 2015, Game Analysis and Conflict Analysis of Market Entry, Commercial Times, Beijing, China, 23, DOI: 10.3969/j.issn.1002-5863.2015.23.014

Zhang W.Y., 2012, Game Theory and Information Economics, Shanghai People's Publishing House, Shanghai, China.

Zhang W.Y., 2014, Game Theory, Peking University Press, Beijing, China.

Zhao H.P., Feng Y.C., Jiang J.D., 2006, Market entry game in supply chain based on evolutionary game, Computer integrated manufacturing systems, Beijing, China, 10, 1703-1707, DOI: 10.3969/j.issn.1006-5911.2006.10.029

Zhou X.G., Zhang J., Du J.G., 2010, Evolutionary Game Analysis on Reverse Auction, Chinese Journal of Management Science, Beijing, China, 18, 171-178.

Zhou Z., Wang S.N., Wang Y.X., 2016, Study on Financing Strategy of Small and Medium-Sized Chemical Enterprises, Chemical Engineering Design Communications, Changsha, China, 12, 139-440, DOI: 10.3969/j.issn.1003-6490.2016.12.122