RISK ASSESSMENT OF PRODUCTION CAPACITY INVESTMENT IN GROWING COMPONENT MARKET

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Abstract
Supply and demand increase rapidly in a Hi-Tech component market which is in its growing stage, due to the demand increase of finished products with components performance improvement. Intense price competition among the component manufacturers occurs due to less difference in component performance within same generation. In this type of market, large errors often occur between the predicted market price and the actual price, as a result, high amount capacity investment is very susceptible to price prediction errors. If a mistake is made in the decision-making of capacity investment, the component manufacturer may face huge loss. In the worst case, the component manufacturer may have to make the decision on whether to withdraw from the market. In the past, Japanese component manufacturers led the world with low-margin high-turnover strategy in such uncertain market with their high technological innovation in production. But in recent years, they have lost in the price competition with Korea and Taiwan companies. The reason is thought to be the change of market environment, such as the market expansion with globalization. In this study, we will focus on the decision-making of capacity investment. Characteristics of manufacturers are defined as the different estimation of the demand sensitivity with price decrease and experience curve of investment amount which are the required information for decision-making. In this study, after the modeling of decision-making of capacity investment, the deficit risk of production capacity investment with different characteristics of manufacturers is to be evaluated. To avoid the deficit risk, how to correct the estimation of the information of the demand sensitivity with price decrease and experience curve of investment amount while doing the decision-making of capacity investment under a growing market is shown in the result.

Keywords:
Component market, capacity investment, price uncertainty, risk assessment.

1 INTRODUCTION
In fast growing component markets, supply and demand increase rapidly. Increase in demand of existing products and new product markets formation are considered as the reasons for demand increase of components. Especially, in a high-tech component market, such as liquid crystal panel market and solar battery market, demand grows at a high rate due to frequent improvement of component performance. On the contrary, intense competition occurs among component manufacturers. In order to acquire more market share to become a market leader in the future, component manufacturers should focus not only the frequent performance improvement, but also positive decision on production capacity investment. As a result, total supply also grows quickly.

![Figure 1. Transaction amount of liquid crystal panel market.](image1)

![Figure 2. Price and production cost of liquid crystal panel.](image2)

In such markets, supply-demand balance is collapsed easily due to intense price competition between component manufacturers. Therefore, a large error between the predicted transaction price and the actual price often happens. With this problem, production capacity investment is always accompanied by high risk. Especially in high-tech component business, it is very susceptible to the price prediction error, because the component manufacturer is necessary to make his decision on huge production investment based on long-term forecasting.

In manufacturing industry including the liquid crystal panel business in the past, Japanese manufacturers such as Sharp and Sony, had driven the market as the top of the world. With their high technological innovation power, they can benefit from the economies of scale, meaning that they
can produce components at a lower production cost than their competitors. Due to globalization during recent years, price competition has been intensified because of the sharp increase in supply and demand of the market. The difference of technological innovative power between Japanese manufacturers and overseas manufacturers is also getting smaller and smaller. As a result, a huge deficits occurred. It is very difficult for the Japanese manufacturers to get survived in such markets anymore. In this study, we focus on the decision-making of production capacity investment in a fast growing market. We use risk assessment to reveal how the decision making of capacity investment is affected by market environment conditions such as purchasing behavior of product manufacturers and supply behavior of component manufacturers. The result of this study can be used to support decision makers while they are making their decisions on production capacity investment.

2 PRODUCTION CAPACITY INVESTMENT IN GROWING MARKET

In this section, characteristics of a fast growing market and the production capacity investment under uncertainty are to be discussed.

2.1 Market environment

Market environment can be roughly divided into two viewpoints which are supply and demand.

Firstly, let’s talk about the market environment on the demand side. As a whole, the demand of high-tech components is increasing sharply due to the increase in demand of multiple finished products. High-tech components discussed in this research, just like the liquid crystal panel, new models of components are being developed one after another by production technological innovation. There are many finished products that require this kind of component. With performance improvement of the component, new products were also developed and new product markets were formed. So, not only increase in demand of the existing product market, but also the demand of new product markets formation are the reasons of increase in demand of components. Moreover, in the growing high-tech component market in this research, the component performance is improved with the passage of time, but there is no significant difference in performance among all the manufacturers. As a result, purchasing price is the only factor to be considered while the purchasing side determining the purchasing amount of the components. We use price elasticity in economics to express the purchasing behavior, because the component demand is uniquely determined by price in such market.

Secondly, let’s talk about the market environment on the supply side. As demand increasing rapidly, aggressive production capacity investment and frequent new entries are found in such market with high intense competition. The competition is not a performance competition, but a price competition. The component manufacturers raise their demand in the market by lowering price to expand their market share. The degree of price decline is determined by the behavior of the component manufacturer. It is very difficult to predict the behavior, in most cases, the predicted price and the actual price are greatly different. The difference is considered as the price uncertainty in this study. The technological innovation power of the component manufacturer can be considered as an important factor to do price prediction. Technological innovation power in this study is considered as the investment amount for unit production capacity. For an example, in liquid crystal panel industry, the investment amount is decided by the equipment price. It is also related to the size of the glass substrate. The relation between the investment amount per glass substrate area and the operating time of the liquid crystal production line is summarized in figure 3. From figure 3, we can find that the investment amount per glass substrate area has decreased to about 1/10 in only 11 years. Kameyama factory of Sharp once got a big success with higher technological innovation power than other competitors even with an intense price decline. Several years later, Sharp fell into management difficulties with over investment problem in Sakai factory. From figure 3, we can find the investment amount per glass substrate area in Sakai factory far deviated from the Nakata’s rule.

![Figure 3. Changes in investment amount (Sharp).](image)

With sufficient technical innovation power, production capacity investment was once successful, but the limit of technological innovation power is coming. With a high technical innovation power, component manufacturers make decision making on capacity investment positively. As a result, production capacity increases rapidly and market price decreases sharply.

2.2 Production capacity investment

In this study, capacity investment for the next generation components is to be focused on. We also consider the investment as a one-time investment, not the step-by-step investment. For high-tech components, such as liquid crystal panels, it is necessary to get production capacity for each generation. The span until next-generation components comes out is very short, just about 2 to 3 years. The collection period of investment is set as 3 years with referring the case of liquid crystal panel. In the 3 years, the component manufacturer will not take actions such as further expansion or equipment sale. When calculation the profitability of investment, forecast data such as market scale and market price is to be handled as a yearly basis. As shown in figure 4 , period $T_1$~$T_3$ is the production period in this study.

![Figure 4. Capacity investment period.](image)

Researches on decision making under uncertainty as a real option approach have been extensively studied. Also, their necessity is fully stated. There are two kinds of previous researches on decision-making on production capacity investment under uncertainty which are the researches targeting perfectly competitive markets and the
researches targeting imperfect competition markets. Hartman (1972) and Arnd (2001) discussed investment under an assumed situation which is a perfect competitive market and symmetrical adjustment cost. As the profit function of a manufacturer is convexity, more profit can be achieved by increasing uncertainty. It is indicated that uncertainty can make the manufacturers more positive do investment. On the contrary, Suzuki (2001) and Hatada (2005) discussed investment under an assumed the situation which is an imperfect competition market. With profit maximization objective function, manufacturers make their decision more negative on investment under income uncertainty and cost uncertainty.

Many researches talk about enterprise decision-making set corporate objective as profit maximization while designing the decision-making model. Guiltinan (1996) doubted this premise, he showed the importance of market share in making decision-making in his study. Armstrong (1994) emphasized on the importance on relative relations while determining the price of products, it is necessary to consider not the absolute amounts of profits, but how profits exceeding the competitors. From these previous studies, although profits are regarded as an important factor in decision-making, the market share acquisition is also an important factor. Especially, Japanese manufacturers got a strong tendency to acquire market share rather than achieving profits. Because they succeeded in their large-scale management in the past.

All of the previous researches on uncertainty and capital investment evaluated capacity investment based on profit maximization. As far as studied, there are no researches on decision-making with market share considered. There are also less researches discussed on risk evaluation on capacity investment with considering of market environment changing to analyze the failure factors of Japanese manufacturers.

3 COMPONENT MARKET MODEL

In this section, characteristics of supply and demand will be discussed to express the movement of market price and demand volume in a fast growing market.

3.1 Market movement

The high-tech components are supplied to multiple finished product markets. Product market scale expansion makes the component market grows rapidly. The component market is on its early growth stage, so it will continue to grow more and more in the near future. In the component market, price competition is occurred by several component manufacturers. Transaction volume of components increases in a short-term due to price competition.

Actually, only the information of market price and transaction volume can be achieved. To express the mechanism for market price and transaction volume in the market, concept of demand curve and supply curve in economics is to be used. Demand curve and supply curve are used to show changes in market with price competition.

Demand curve and the supply curve are set as $D_c$ and $S_c$. From figure 5, intersection of $D_c$ and $S_c$ moves from A to B due to the change (+ $\Delta s$) in supply curve could be found. Manufacturers in the market reduce the price to get more demand. With doing this, they also can reduce their excess production capacity. The more frequent and larger price competition occurs, the more market scale will grow. The market price will decline rapidly at the same time. As shown in figure 5, with such price competition, potential demand increase (+ $\Delta d$) is expected. So, as shown in figure 6, the intersection of $D_c$ and $S_c$ moves from B to C.

![Figure 5. Price competition.](image)

With potential demand increasing, trading price and transaction volume increase at the same time. Market value is increased, potential supply such as new entries into the market and production capacity investment is expected to increase (+ $\Delta s$). Figure 7 shows the increase in potential supply.

![Figure 6. Potential demand increase.](image)

The market is moving repeatedly according to the cycle which is shown from figure 5 to figure 7. After one cycle, market scale will expand with total amount of $\Delta p_1$, $\Delta q_2$ and $\Delta p_2$. The market price will decline with total amount of $\Delta p_1$, $\Delta q_2$ and $\Delta p_2$.

3.2 Price uncertainty

Only component price decline is taking into consideration in this study, since intense price competition always occurs in such market. Price uncertainty in this study is defined as the difference between the estimated price and the actual market price. It indicates that the actual transaction price may become higher or lower than the estimated price which is used for decision-making of production capacity.
investment. A binomial model of financial engineering is used to express the price uncertainty. The market price is assumed that it will fall by \( p_{t+1} \) after one year. At this time, the difference between actual price and estimated price is considered as an increase / decrease width of \( \pm \Delta \delta \) in an infinitely short period \( \Delta t \). It is assumed that the price increase or decrease occurs with almost the same probability. If a sufficient period of time passed, the probability distribution of the price decline can be approximated to a normal distribution. Price uncertainty is defined as the following formation. The period from \( T_k \) to \( T_{k+1} \) is one year.

\[
Pr(P) = \frac{1}{\sqrt{2\pi\sigma}} \exp \left( -\frac{(P - kP_0)^2}{2k\sigma^2} \right)
\]

When doing calculation of the price uncertainty, it would be calculated with a 95% confidence interval in this study.

4 DECISION-MAKING OF PRODUCTION CAPACITY INVESTMENT

4.1 Price elasticity of demand

With using the demand curve, the manufacturer makes his decision on the quantity and price of the components to supply in period \( T_k \). It is assumed that there is a forecast information of transaction volumes \( Q_{k-\text{aall}} \) and prices \( P_{k-\text{aall}} \) of the entire market in each period. At this time, when using the brand parameter \( \beta \) which shows the market share during period \( T_k \), the demand amount \( \beta Q_{k-\text{aall}} \) of this manufacturer can be calculated with the equilibrium price of the market. The higher value of brand parameter \( \beta \), share rate of the manufacturer in the component market is higher. The demand curve of the manufacturer can be obtained with equilibrium point \( (\beta Q_{k-\text{aall}}, P_{k-\text{aall}}) \) and the price elasticity of his demand. Price elasticity is a concept in economics often used when discussing price sensitivity. It is expressed as \( +\Delta Q / -\Delta P \). The following formula shows the demand curve.

\[
Q = \frac{\Delta Q}{\Delta P} \times P_{k-\text{aall}} + \left( \beta Q_{k-\text{aall}} - \frac{\Delta Q}{\Delta P} \times P_{k-\text{aall}} \right)
\]

In this study, price sensitivity shows the components purchasing behavior of product manufacturers. New product markets formation can be considered as a main reason for increasing in potential demand. More potential demand, the average purchasing behavior of all product manufacturers will become more positive. It is an important factor that the decision-maker should estimate based on the forecast information of \( Q_{k-\text{aall}} \) and \( P_{k-\text{aall}} \).

4.2 Investment amount function

The investment amount function shows the relation between production capacity and investment amount. As discussed before, with high technological innovation power, manufacturers can achieve remarkable effects in reducing the investment amount per production capacity. In other words, they can achieve more capacity with same investment amount. It is expressed as \( \Delta I / \Delta Ca \). The following formula shows the investment amount function.

\[
I(Ca) = \frac{\Delta I}{\Delta Ca} \times Ca + I_0
\]

\( I_0 \) is set as the minimum initial investment amount required for capacity investment. And \( Ca \) is the production capacity.

4.3 Decision-making model

Japanese manufacturers think that increase in sales leads to increase in profit directly, so they always place importance on sales achieving rather than profit achieving. As discussed in 2.2, they succeeded in their large-scale management in the past in such high-tech industry. Decision making of production capacity investment model based on maximizing sales is to be shown as the following 6 steps.

1. To estimate the average purchasing behavior \( \Delta\bar{P}/\Delta\bar{Q} \) of each period \( T_k \) on his own components with considering of the average purchasing behavior \( \Delta P/\Delta Q \) of the whole market.

2. To set the production capacity as the maximum demand volume of last period which can be calculated with the demand curve defined in 4.1. In this study, as shown in figure 4, the 3rd period is the last period.

3. To calculate the transaction volume and the transaction price with the largest sales in each period.

Figure 8 shows the decision on transaction volume and transaction price in period \( T_k \).

4. To calculate the expected total profit of the 3 periods with the investment plan. If it is not a deficit, the investment plan will be considered as a candidate plan.

5. To do the same calculation for each investment plan which is created with reducing capacity by a certain amount from the former investment plan until 0.

6. To choose the investment plan with the largest sales as his production capacity investment plan among all candidate investment plans.

The Object function and the restriction of decision-making are to be shown as below.

\[
\max \sum_{i=1}^{3} \max\left( P_i \times Q_i \right) \quad (4)
\]

s.t. \[ \sum_{i=1}^{3} \left[ (P_i - C_{V_i}(q) - C_{F_i}(Ca)) \times Q_i \right] > 0 \] (5)

\( P_k \) is the estimated price of period \( T_k \), \( Q_k \) is the estimated transaction volume of period \( T_k \), \( C_{V_i}(q) \) is the variable cost of period \( T_k \), \( C_{F_i}(Ca) \) is the fixed cost of period \( T_k \).

5 RISK ASSESSMENT

In this section, risk evaluation on the decided production capacity investment plan is to be discussed. Risk in this study is defined as the probability of loss due to price uncertainty which was discussed in 3.2. Figure 9 shows the concept of risk.
The risk is to be calculated with using the price uncertainty model. It can be expressed as the following formula.

\[
Risk = P \left( \sum_{i=1}^{n} \left( P_i - C_{V_i}(q) - C_{F_i}(Ca) \right) w \right) < 0
\]  

(6)

Just like the risk and return, probability of loss and the loss value are usually discussed at the same time. But in this study, whether the investment loss occurs or not is focused. So, only the probability of loss is to be considered in our data experiment.

6 DISCUSSION

High growth of market scale \( \Delta Q/\Delta T \) means that all manufacturers do investment positively, average production innovation power of all component manufacturers could be considered at a high value. On the other hand, sharp decline of market price \( \Delta P/\Delta T \) means that average purchasing behavior of all product manufacturers is negative, price elasticity could be considered at a low value.

As discussed before, the manufacturer make his decision on capacity investment with the information of estimated price elasticity \( \Delta P/\Delta Q \) and his production innovation power \( \Delta I/\Delta Ca \). In this study, existence / non-existence of investment plan and investment risk are to be analyzed with the following two viewpoints:

1. \( (\Delta I/\Delta Ca)/(\Delta Q/\Delta T) \): Production innovation power of the manufacturer against market scale growth.
2. \( (\Delta P/\Delta Q)/(\Delta P/\Delta T) \): Price elasticity of the manufacturer against price decline rate of the market.

6.1 Production innovation power on market growth rate

Figure 10 and figure 11 shows the existence / non-existence of investment plan and the result of risk assessment with production innovation power on market scale growth. Non-existence of investment plan means that there is no investment plan can satisfy the restriction under this environmental condition.

6.2 Price elasticity on price decline rate

As shown in figure 10, the capacity investment would be planned with a probability of 80% when the value of \( (\Delta I/\Delta Ca)/(\Delta Q/\Delta T) \) is less than 0.5. However, in the case of 1.6 or more, there would be no capacity investment plan with a probability of 80%. As shown in figure 11, probability of capacity investment risk occurring is 100% when the value of \( (\Delta I/\Delta Ca)/(\Delta Q/\Delta T) \) is more than 1.8. To the decision-makers, the lower the assumed production innovation power is estimated, capacity investment plan is less likely to be planned. Probability of investment risk is high if an investment plan was planned under such environmental condition.
As shown in figure 12, the capacity investment would be planned with a probability of 80% when the value of \(\frac{\Delta Q}{\Delta P} / (\Delta P/\Delta T)\) is more than 1.0. Investment plan would not be planned with a probability of 80% when the value of \(\frac{\Delta Q}{\Delta P} / (\Delta P/\Delta T)\) is less than 0.1. As shown in figure 13, probability of capacity investment risk occurring is more than 80% when the value of \(\frac{\Delta Q}{\Delta P} / (\Delta P/\Delta T)\) is less than 0.2. Probability of capacity investment risk occurring is less than 20% when the value of \(\frac{\Delta Q}{\Delta P} / (\Delta P/\Delta T)\) is more than 0.9. To the decision-makers, the lower the assumed price elasticity is estimated, investment plans with higher probability of investment risk is to be created.

7 Conclusions

After modeling the fast growing component market and decision-making of production capacity with considering of large-scale management, production capacity investment in a Hi-Tech component market was analyzed in this study. From the experiment results, not only market environmental condition such as increase in market scale and decline in market price, but also the estimation of components purchasing behavior and technological innovation power are heavily involved in success and failure of the production capacity investment.

In Hi-Tech manufacturing industry in the past, Japanese manufacturers got succeed in their market share expansion as well as profit achieving in these markets. But during recent years, it is difficult for almost of them to get survived in the same markets. As discussed before, globalization is a big reason for intense price competition. Price uncertainty is getting higher than before with intense price competition. Moreover, along with the progress of globalization, commoditization of components is also progressing fast. The difference of component performance between Japanese manufacturers and overseas manufacturers is getting smaller and smaller. So, component purchasing behavior of product manufacturers is changing from performance emphasis to price emphasis.

Under commoditization progressing fast, the difference of technological innovation power between Japanese manufacturers and overseas manufacturers is also getting smaller and smaller. During the decision-making of capacity investment, optimistic estimation of the component purchasing behavior and the technological innovation power with the past success experience can be considered as the main reason for failure during recent years.

To reduce the probability of deficit risk in such fast growing market is a big task for the Japanese manufacturers to deal with. Decision-makers of these manufacturers could use the results in this study to adjust their estimation results on components purchasing behavior of product manufacturers and their technological innovation power during the decision-making of capacity investment.

In this study, brand parameter \(\beta\) which shows the market share in each period \(T_n\) is assumed to be constant. But actually, in such fast growing market, the business scale of the manufacturer changes based on his brand loyalty. So, it is necessary to design a model to show the relation between brand parameter \(\beta\) for each period and the sales results of the previous period as one task of our future works. Furthermore, besides one-time investment which is discussed in this study, step by step investment is also planned to discuss in our future work.

8 References


