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Dynamic game analysis in multiple marginalization problems

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ABSTRACT
In an industry, there are often upstream enterprises and downstream enterprises, if they choose to cooperate in production, then different degrees of double marginalization is inevitable. In the process of this dynamic game, different enterprises need to decide whether to participate in cooperative production or how to share to maximize benefits according to different situations. If the loss caused by double marginalization is too high, the company can choose to complete the industrial chain alone without cooperation. Similarly, different sharing decisions can be used in cooperation to mitigate the loss of double marginalization.

KEYWORDS
Double marginalization; Linear pricing; Fix percentage

1 Introduction

Double marginalization occurs especially between monopoly companies in two consecutive production stages. Enterprises located in the upstream of the industry will carry out a marginalization calculation in order to maximize their benefits, and enterprises located in the downstream of the industry also need to carry out a marginalization calculation again with the upstream price as the cost to maximize their benefits. Thus, two marginalization calculations are made from product manufacturing to consumer purchase. This leads to an increase in the total cost of production, an increase in the price of the final product, and a decrease in the demand for it by consumers. This reduces production, profits, and consumer surplus.(Spengler, 1950; Tirole, 1998) In other words, if the manufacturer and the distributor are both monopolies, each adds a monopoly markup, so consumers face two markups instead of one.

2 Literature review

The double marginalization effect was first observed by Curnot (1927). Previous literature research mainly focuses on two parts. The first is the explanation of the problem of double marginalization. Takanori and Ebina(2014)analyzed the cost transfer problem from upstream to downstream enterprises. It shows that the marginal cost of the upstream manufacturer is converted into the wholesale price of the downstream retailer, and the retailer will again translate this cost into the retail price.

The second key research part is how to eliminate the production problems caused by this double marginalization. Vertical mergers of enterprises is a conclusion recognized by most literatures. Vertical mergers can generate efficiencies, including through elimination of double marginalization (EDM) as in the familiar successive monopoly scenario (Spengler, 1950). In other words, reducing two marginalization calculations to one is the most direct method of elimination. However, vertical

integration also has negative social benefits. When firms use different Cobb-Douglas technologies, the welfare effects can be non-monotonic (Moresi, 2021).A common view in antitrust analysis is that mergers of complements can have raising rivals ' costs and elimination of double marginalization effects, with the net effect on consumer welfare thus unclear (Akgün,2020).There are other ways to eliminate the mark-ups caused by double marginalization. Durham (2000) shows that if at least one of the two markets is not monopolistic but perfectly competitive in the sense that it sells at marginal cost, double marginalization can be eliminated.

However, in terms of different enterprises in different positions in the industrial chain, they have their own different ways to avoid the low returns brought by double price increases. For manufacturers upstream of the industry chain, they are producers of goods, and cooperating with retailers can gain a larger consumer market. But they can also sell directly to consumers. For retailers downstream of the industry chain, they can choose the way to share the revenue from sales cooperation with manufacturers to make up for their profits due to the impact of double price increases.

3 Model-setting

The first is the basic market setting, the upstream manufacturers and downstream retailers of the industrial chain have their own inherent consumer groups and markets. The price of product follows: $P = a - bQ$. Manufactures and retailers have their own markets demand a_1 and a_2. If the two sides cooperate, their markets will merge to A. If the manufacturer chooses to produce it separately and sell it directly to consumers, then it only enjoys its own market.

The second is the role of the manufacturer, which will purchase raw materials at a certain cost c for production. Manufacturers can decide whether to cooperate with retailers to sell. If they decide to sell directly, they can avoid the dilemma of double markup, and if they sell to retailers for repackaging, they can get a bigger market.

The third is the setting of the retailer, which will buy the product from the manufacturer and sell it to the consumer. Retailers can decide how transactions are split: First, the retailer can choose linear pricing. The retailer will purchase the product at the wholesale price Pw set by the manufacturer and receive all final sales

proceeds. Second, retailers can choose to take a fixed percentage. Both parties will negotiate to get a fixed share ratio r and share the final sales proceeds according to this ratio.

4 Research methods

4.1 No cooperation

In cases where the manufacturer does not choose to cooperate. The manufacturer will produce and sell directly to the consumer, and will enjoy all the benefits, minus the purchase cost of the raw materials. Therefore, manufacture ' s problem is:

Maximum $(a_1 - bq_0 - c)q_0$

At this point, the manufacturer's decision is to choose the best output to maximize their profits :

$d\Pi_0/dq_0 = d(a_1 - bq_0 - c)q_0/dq_0$

$q_0 = (a_1 - c)/2b$

Bringing the yield at maximum benefit back into the revenue equation will give us the highest return if the manufacturer does not cooperate to produce alone:

$\Pi_0 = (a_1 - c)^2/4b$

At the same time, the consumer surplus is also available:

Table 1 Parameter definition

Parameter	Description
a_i,i=1,2	Demand in market i
A	Total demand of the whole market
b	Price sensitive parameter of demand
c	The marginal cost of M
Mi,i=1,2	R's decision of Method i
P_w	Wholesale price of Method 1
q_{Ri},i=1,2	R's optimal quantity under Method i
q_{Mi},i=1,2	M's optimal quantity under Method i
π_{Ri},i=1,2	R's maximum revenue under Method i
π_{Mi},i=1,2	M's maximum revenue under Method i
r	The fixed proportion of Method 2
q0	M's optimal quantity under no cooperation
π_i,i=0,1,2	Total revenue in market
CS_i,i=0,1,2	Consumer surplus

$CS_0 = (a_1 - c)^2/8b$

4.2 The first method(Method 1)

When the manufacturer chooses to cooperate and the retailer chooses the first sharing scheme, the following will happen: First, the manufacturer proposes the wholesale price of the product Pw. As a result of the partnership, the two companies can enjoy both their own and each other's consumer markets. The total market demand will become the sum of the respective market demand of both parties. Retailers will then use this wholesale price to calculate their own optimal output and maximum profit through marginalization:

$Maximum(A - bq_{R1})q_{R1} - P_w q_{R1}$

Retailers will choose their own optimal output based on the wholesale price:

$q_{R1} = (A - P_w)/2b$

From this we know that retailers' earnings will be closely related to wholesale prices. Manufacturers also know that retailers will make such decisions, so they will decide in advance to choose the wholesale price that will maximize their profits:

$Maximum(P_w - c)q_{R1}$

$P_w = (A + c)/2$

By bringing the retailer's optimal output and the manufacturer's wholesale price that maximizes profit back into the revenue function, the final profit of the two companies can be obtained in the optimal case:

$\Pi_{R1} = (A - c)^2/16b$

$\Pi_{M1} = (A - c)^2/8b$

Add the profits of the two companies to get the total profit in the market and calculate the consumer surplus:

$\Pi_1 = 3(A - c)^2/16b$

$CS_1 = (A - c)^2/32b$

4.3 The second method (Method 2)

Now the retailer will choose the second method of sharing, and the two parties will work out a fixed percentage to share the sales proceeds. Unlike Method 1, the manufacturer is not required to

propose a wholesale price, but it is passed directly to the retailer to sell to the consumer. The retailer can be considered to have no production costs, but only receive a portion of the proceeds from the sale of the final product rather than all of it.The retailer's profit equation can be written as follows:

The retailer's decision is still to optimize production to ensure maximum profit:

$q_{R2} = A/2b$

When the retailer determines the optimal output, the manufacturer's revenue is also determined with the retailer's revenue:

$\Pi_{M2} = (A^2r - 2Ac)/4b$

At the same time, the retailer's profits can be obtained:

$\Pi_{R2} = (1 - r)A^2/4b$

Using the same method as above, we can calculate the total market profit of the two companies and the consumer surplus at this time:

$\Pi_2 = (A^2 - 2Ac)/4b$

$CS_2 = A^2/8b$

5 Findings from different models

In this dynamic game, the manufacturer is the first to move. The manufacturer will decide whether to cooperate with the retailer first. If it does not cooperate, it is produced by the manufacturer alone and sold directly to consumers. If a partnership is chosen, it is up to the retailer to choose how the profits are shared. The retailer can choose to buy the product at the cost of the wholesale price proposed by the manufacturer and sell it, ultimately receiving all the proceeds from the sale. The retailer may also choose to share the final sales profit with the manufacturer on a fixed percentage basis.

The subgame perfect Nash equilibrium of this dynamic game can be obtained by backward induction. At this point, consider the retailer's decision first, if the manufacturer chooses to cooperate in production, then the retailer's decision will be what? Comparing the Π_{R1} and the Π_{R2}, the retailer's decision will be to choose the larger of the two. When $1 - r > (A - c)^2/4A^2$: R will choose Method2. At this point, consider the decision of the manufacturer, who understands that if co-production is chosen, the retailer will choose the second sharing method. Therefore, the manufacturer will compare the revenue when it does not cooperate Π_0 with the revenue when it is shared according to a fixed proportion Π_{M2}, and choose the one with high profit to make a decision. If $r > [(a1 - c)2 + 2Ac] / A^2$: M will choose cooperation. The resulting manufacturer and retailer decisions are the subgame refined Nash equilibrium of this dynamic game. In the previous case, the sub-game perfect Nash equilibrium is: the manufacturer chooses to cooperate in production, and the retailer chooses to take a fixed percentage.

Here's some additional analysis. When you look at the market from a holistic perspective, what is the overall profit picture? By comparing Π_0, Π_1, Π_2 with the size of CS_0, CS_1, CS_2 the whole can be effectively discussed. The unconditional size relation is that CS_2 must be greater than CS_1. And if A is greater than 3c, Π_2 will be higher than Π_1. This suggests that consumer surplus is higher, at least for consumers, when retailers opt for a fixed percentage. Consumers get the goods at a better price. The method of sharing a fixed percentage can be understood to some extent as the production and sale of a commodity is done by a "big" company. The division of sales between manufacturers and retailers is considered a division within the "big" company. This method of proportional sharing is actually combining two marginalised optimal calculations into one. In the previous article, we can directly compare the calculation of the decision under the two methods, and the manufacturer's maximum benefit in the second method is also indirectly determined by the retailer's decision.

Therefore, when using the method of fixed proportion sharing, consumers must benefit, and the income of the two enterprises will be determined by the cost of raw materials.

The analysis of the manufacturer focuses on the comparison of its own market demand and the total market demand after the cooperation. Manufacturers choose to cooperate in order to enjoy a larger consumer market. The influence of upstream enterprises on consumer demand and brand effect is not as good as that of downstream enterprises. Cooperation can obtain more consumer demand, and the higher the total demand, the more manufacturers will be inclined to cooperate. However, if the loss of dual marginalization pricing exceeds the gain from additional market demand, manufacturers may choose not to cooperate to avoid low-margin sales.

6 Extended discussion from real conditions

When manufacturers suffer from low margins due to double marginalization, they can also choose to partner with retailers while also entering the market to sell goods directly to consumers. To a certain extent, this will affect the profits of retailers, and they will also face competition with their own situation. Arya(2007) shows that when manufacturers sell products to both consumers and retailers, if manufacturers use linear pricing methods, they must reduce wholesale prices in order to avoid competing with themselves. This is good news for retailers.

In this case, if what the manufacturer is selling and what the retailer is reselling are homogeneous products, then the manufacturer must be the more advantageous party. If we assume that the manufacturer sells directly to the consumer a product of different quality (which may be inferior), then the final profit of the manufacturer is related to the price sensitivity coefficient of the output of the commodity.(Arya,2007)

The situation gets even more complicated when a retailer faces multiple manufacturers. At this time, retailers can use different sharing strategies to maximize their profits from different manufacturers. Saraswati (2014) made a survey that in the cooperation between airports and airlines, airports often adopt the method of fixed percentage sharing for dominant airlines and linear pricing for non-dominant airlines. In this example, the airport is the retailer and the airline is the manufacturer. Because the dominant manufacturers have high quality products and are more likely to attract consumers for higher profits, retailers will choose methods that reduce the loss of double marginalization. For companies that are not in a dominant position, linear pricing can ensure a stable profit.

7 Conclusion

The problem of double marginalization or double price increase between two monopolies in an industrial chain will bring great losses to both enterprises and consumers. High retail prices, small sales are not willing to appear in the market. In this paper, a dynamic game model is established to provide manufacturers and retailers with some solutions to mitigate the losses caused by the double marginalization problem. The model provides manufacturers with options for making decisions about whether to partner with retailers, as well as giving retailers the option of linear pricing and a pro rata cut. As a result, the retailer's use of a fixed percentage is more beneficial to the overall market and consumers. The decision of the manufacturer depends more on the additional market demand brought about by the cooperation. This article also mentions three extension discussions, manufacturers can cooperate while also directly selling the same or different quality of goods. When retailers face multiple consumers, they can choose the corresponding sharing strategy according to the manufacturer's product quality and manufacturing level.

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