

In Search of Predatory Pricing Strategy in the Network Industry : A Multiple Period Experiment

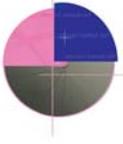
Yingyot Chiaravutthi*

ABSTRACT

This paper reports data from an experiment confirming the existence of predatory pricing in the presence of network externalities when the technology of competing firms are identical. An experiment was conducted based on a seven-period and one-market design. Subjects were recruited and assigned a role as seller before they were paired together randomly and played the game for two rounds. Sellers were classified into superior and inferior sellers where sellers' superiority came from buyers' willingness to pay. Buyers were simulated and had different, pre-programmed preferences over the goods offered by two sellers. In each period, subjects had to make an entry decision and a price decision in a posted offer market institution. The sub-game perfect Nash equilibrium is for superior seller to engage in predatory pricing and for inferior seller not to enter the market. The observations strongly support the presence of predatory pricing. Additionally, the predatory pricing strategy was quite effective in driving rivals out. Unexpectedly, predation was evidently pursued by both superior and inferior sellers, and inferior sellers also had a chance to dominate the market. It can be concluded that predatory pricing strategy exists in the market that exhibits network externalities, and this strategy is quite powerful in eliminating competitors.

Keywords : Predatory pricing Network externalities Entry deterrence Firm strategy

*Business Administration Division Mahidol University International College



การทดลองแบบหลายช่วงเวลาเพื่อค้นหากลยุทธ์ การตั้งราคาแบบปรักษ์ ในตลาดที่ลูกค้ามีความสัมพันธ์แบบเครือข่าย

ยิ่งยศ เจียรวุทธิ*

บทคัดย่อ

ผลจากการทดลองยืนยันว่ากลยุทธ์การตั้งราคาแบบปรักษ์สามารถเกิดขึ้นได้กรณีที่ผู้ขายแข่งขันกันเพื่อเพิ่มจำนวนฐานลูกค้าในตลาดที่ลูกค้ามีความสัมพันธ์แบบเครือข่าย การทดลองมีสมมติฐานเพื่อพิสูจน์ว่าผู้ขายจงใจตั้งราคาเพื่อกำจัดคู่แข่งให้ออกจากตลาดหรือไม่ นักศึกษาที่ร่วมการทดลองได้รับบทบาทเป็นผู้ขายที่มีวัตถุประสงค์คือการสร้างกำไรสูงสุด ผู้ขายสองรายที่ถูกจับคู่กันมีความแตกต่างกัน โดยผู้ขายรายหนึ่งมีสินค้าที่ผู้ซื้อต้องการมากกว่าผู้ขายอีกรายหนึ่ง รอบของการทดลองประกอบด้วย เจ็ดช่วงเวลา การตัดสินใจของลูกค้าในแต่ละช่วงเวลาเป็นไปตามโปรแกรมที่ถูกออกแบบไว้ให้เครือข่ายของลูกค้าในอดีต ส่งผลทางตรงต่อความเต็มใจในการซื้อสินค้าในอนาคต คุณลักษณะของเกมคือการที่ผู้ขายที่เหนือกว่าเป็นผู้ตั้งราคาแบบปรักษ์ในขณะที่ผู้ขายที่ด้อยกว่าไม่เข้าร่วมแข่งขันในตลาดดังกล่าว ผลการทดลองพบหลักฐานการตั้งราคาแบบปรักษ์จำนวนมาก นอกจากนี้ การตั้งราคาแบบปรักษ์ประสบความสำเร็จในการกำจัดคู่แข่งออกจากตลาด อย่างไรก็ตามในบางกรณีผู้ขายที่ด้อยกว่า อาจสามารถครอบครองตลาดได้หากการตั้งราคาแบบปรักษ์ของตนประสบความสำเร็จในการกำจัดคู่แข่งที่เหนือกว่า ผลการทดลองสรุปได้ว่า ตลาดที่ลูกค้ามีความสัมพันธ์แบบเครือข่ายกระตุ้นให้ผู้ขายตั้งราคาแบบปรักษ์ และกลยุทธ์นี้มีประสิทธิภาพในการกำจัดคู่แข่งออกจากตลาด

คำสำคัญ : การตั้งราคาแบบปรักษ์ ความสัมพันธ์แบบเครือข่าย การกีดกันการเข้าร่วมตลาด
กลยุทธ์ของผู้ขาย

* มหาวิทยาลัยมหิดล วิทยาลัยนานาชาติ นครปฐม

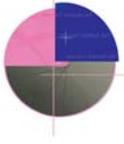
Introduction

Predatory pricing is a firm's strategy of cutting price and sacrificing profits in the short run in order to eliminate competitors or deter potential entrants, and gain monopoly profits in the long run. For the legal purpose, Areeda and Turner proposes a simple measurement of predation which is pricing less than short-run marginal cost, or average variable cost when data on marginal cost is unavailable (1). Nevertheless, some economists reject the existence of predation on the rationality that predatory pricing would have to be followed by a period of setting high prices for the purpose of recoupment, and the recoupment period would encourage entry again.

While some economists contend that predatory pricing is a myth, others argue the opposite. The reason lies partly on the inaccessibility of the field data. Because the field data are hard to find, experiments are an attractive alternative. Isaac and Smith is the first study to search for predatory pricing in the laboratory (2). In their duopoly setting, a large firm (seller A) has an advantage in terms of an initial cash endowment and lower marginal cost over the smaller firm (seller B). In each period, each seller selects a price and a maximum supplied quantity corresponding to the price. Both sellers A and B make their decisions without any

information regarding each other's cost structures. On the demand side, buyers are computer simulated. Isaac and Smith define predatory pricing as the fulfillment of 1) $P_A(Q_A) < MC_A(Q_A)$ and $P_A < \min AC_B(Q_B)$ where P_i , Q_i , AC_i , and MC_i are firm i's price, quantity supplied, average cost, and marginal cost, respectively, 2) quantities offered by A may not leave any excess demand for B to satisfy at a higher price, and 3) B exits and does not enter even when A subsequently raises its price. Predatory pricing according to this definition was not observed in Isaac and Smith's experiment. Specifically, they found "zero" evidence in all of their experiments, even after including a sunk entry cost, complete information about competitors' costs, and additional predatory incentives.

Harrison reclassifies the definitions of predatory pricing, and introduced a multi-market design (3). He defines four types of predatory pricing. Harrison separated type I predatory pricing into "strong" and "weak" depending on the quantity offers by seller A. Isaac and Smith's definition of predatory pricing corresponds to strong type I predatory pricing while seller A's weak type I predatory pricing leaves a residual demand to be satisfied by seller B. Harrison's type II predatory pricing allows seller A to price below the predatory price range without any quantity constraint.



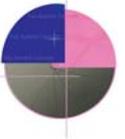
The non-negative profit constraint is applied to strong type I, weak type I, and type II predatory pricing. Type III predatory pricing occurs when seller A sets its price and quantity in such a way as to result in a net loss for that period. Type IV predatory pricing focuses on when seller B sets its price below the minimum average cost of seller A.

The design of the experiment was adjusted to incorporate a multi-market nature which serves as an alternative revenue option or “escape opportunity” for seller B. There were five markets with identical but independent demand curves. The roles of sellers A and B were assigned to four and seven subjects, respectively. At the beginning of each period, both sellers A and B were required to make decisions regarding which one of the five markets they wanted to enter, and simultaneously offer a price and quantity in that market. Each seller A was implicitly assigned to one of the five markets. After all decisions were made in each period, prices along with subjects’ identification numbers were publicly written on the blackboard for reputations to develop. From 132 observations (11 subjects in 12 periods), only 9, 3, 1, and 2 pricing decisions consistent with type I, type II, type III, and type IV predatory pricing cases were observed, respectively

Harrison’s five-market setup was replicated in Goeree and Gomez’s first series

of experiments (4). In the first series, the authors found only 3 decisions (out of 144 pricing decisions) which were in the range of Harrison’s type II predatory pricing. In their second series of experiments, they modified Harrison’s setup in three important aspects. First, sellers B announced their entry decisions and these decisions were made public before all sellers A and B selected prices and quantities in order to reflect the common market fact that a pricing decision can be changed quicker than entry decisions. The second aspect involved a simplified three-step demand schedule. There were only three markets with one seller A in each of markets I and II, and four sellers B who could enter any of the three markets. Third, seller A had complete information about seller B’s cost structure, but not the other way around. Predatory pricing existed in this series of experiments. The three-market design and three-step demand was also replicated and explained in Capra et al., with the focus on adapting this experiment for the purpose of teaching classroom students (5). Also see Jung et al. for a more sophisticated rational theory of predation by allowing “reputation” to occur in their sequential-game design (6).

Based on literature review above, predatory pricing may not commonly be observed both in the real world and even in the laboratory. Nevertheless, the predatory



pricing strategy could be more credible under certain circumstances. For example, in dynamic industries with network externalities, it has been thought by economists that predation was theoretically possible. The topic of network externalities has been studied for almost two decades, but has received more attention recently because many “high tech” products seem to exhibit some kinds of network externalities. A product creates direct network externalities when the utility that an agent derives from consuming the product increases with the number of other agents consuming the same product.

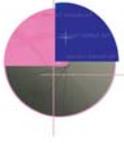
Katz and Shapiro and Farrell and Saloner analyze pricing strategies employed by firms for the purpose of expanding network size (7,8). Katz and Shapiro discuss consumers’ adoption decisions of a new technology when facing firms’ pricing strategies in a two-period model. Farrell and Saloner mention the possibility of predatory pricing by an incumbent as a means to deter entry in the presence of network externalities. The model assumes that potential users arrive over time. They show that the incumbent can induce new users to stay with its technology by reducing the price and incurring a short-run loss. When the rival is kept out of the market, the incumbent monopolist can raise its price without inducing reentry because it has a substantial advantage of installed base.

Since previous experiments did not consider the presence of network externalities in their designs, the hypothesis of this experiment is to answer whether predatory pricing emerges in the presence of network externalities when firms are identical in terms of technology and cost structure but goods are differentiated and incompatible.

Materials and Method

There is a single market which lasts for seven periods. Two sellers, A and B have the same cost structure but sell differentiated goods. The cost of producing each unit is Baht 10.00 for both sellers and for all periods, and both sellers have complete and symmetric information about each other’s marginal cost. There is no production constraint for both sellers, so they always meet demand. In the first period, both sellers have to make a pricing decision which is governed by a posted-offer institution. At the beginning of the second period and all subsequent periods up to the seventh period, both have to decide whether they want to enter that period. The entry decision is made public before they are asked to post prices. However, if they decide to enter, they must pay a fee of Baht 50.00. There is no entry fee in the first period, so it can be considered sunk.

Computer simulated buyers have different preferences over the goods offered



by the two sellers. There are 5 buyers in each period, and each buyer values seller A's and B's products as shown in the second row of Table 1. It is assumed that buyers in the first period have no information regarding which technology will dominate in the future, and which technology will be chosen by future-period buyers. Buyers make purchase decisions by comparing the surplus they would get from buying either of the two goods. The surplus is calculated as the difference between the buyer's willingness to pay and the price posted for the good. If the surplus from purchasing either product is equal, the buyer's decision will be randomly determined.

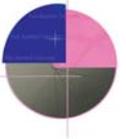
There are seven generations of new buyers who make independent decisions: one generation for each period. The products offered by the same seller across different periods are compatible with each other, while the products offered by different sellers are not compatible with each other. As a result, if a seller can sell more units than another seller, additional buyers' valuations of the product with more units sold will be higher due to the benefits from product compatibility but the buyer valuations of the other good are unaffected. This is network externalities which states that buyers' willingness to pay increases with the number of buyers purchasing the same product or compatible products (9). The utility function is the one where each consumer

i's willingness to pay, p_i consists of two components:

$$p_i = a_i + b_i N^e, \quad b_i > 0 \quad [1]$$

Consumers' tastes and preferences are not homogeneous so a_i can generally be different among consumers. N^e is the expected number of consumers who use a particular good or compatible goods. The utility increases with the number of consumers, capturing the network externalities. Generally, for theoretical purposes it can be assumed that all consumers have the same valuation of network benefits, so $b_i = b$ for all i . The actual size of the network, N , is usually measured by the number of compatible units sold.

In this experiment, sellers are classified into superior seller (seller A) and inferior seller (seller B). Sellers' superiority is derived from buyers' valuations of seller A's product more than seller B's. Specifically, a_i for seller A is higher than that of seller B in equation [1]. Network externalities are built up starting in the second period based on the sales in the earlier period(s). Specifically, WTP of each buyer increases by Baht 5.00 for each unit sold in the past by a given seller. For example, if seller A sells 2 units in the first period, WTP for its product in the second period increases by $2 * \text{Baht } 5.00 = \text{Baht } 10.00$ for each buyer. Period two WTP becomes Baht 60.00, 50.00, 40.00, 30.00, and 20.00 for buyer 1, 2, 3, 4,



and 5, respectively. Examples are provided in the third and fourth row of Table 1.

For the purpose of this experiment, predatory pricing is classified into either a “strong” or “weak” form as follows:

1. Strong predatory pricing is defined as either seller A or B pricing below marginal (and average) cost (Baht 10.00).
2. Weak predatory pricing is defined as seller A or B setting its price between Baht 10.00 and Baht 19.99. This price range guarantees a loss to the seller after considering the entry fee of Baht 50.00. As a result, this definition is applied only from the second to the seventh period since neither seller has to pay a first-period entry fee.

Since the goal of adopting a predatory pricing strategy is to eliminate competitors, “successful predation” is defined as when a seller pricing in the range of strong or weak predatory pricing, and a competing seller does not enter in the subsequent period.

The proposed equilibrium for this game is for seller A to engage in predatory pricing during the first 3 periods and price high during the last 4 periods, and for seller B not to engage in predatory pricing. If a seller cannot sell any unit during the first 3 periods, the seller should not enter the fourth and subsequent periods since earnings from the last 4 periods are insufficient to cover the loss in the earlier periods.

Payoffs to both sellers are different, depending on their strategies. When both seller A and B engage in predatory pricing, seller A's payoff is Baht 2,324.85 while seller B's payoff is Baht -100.00. In this case, seller A sets its price at Baht 9.99, 34.99, and 59.99 in period 1, 2, and 3, respectively in order to ensure that seller B cannot sell any unit in those periods. If seller A engage in predatory pricing but seller B does not, seller A's payoff is Baht 2,324.85 while seller B's payoff is Baht 0. If seller A does not engage in predatory pricing but seller B does, seller A's payoff is Baht 0 while seller B's payoff is Baht 1,975.00. When both do not engage in predatory pricing, seller A's payoff is Baht 356.25 while seller B's payoff is Baht 181.25. As a result, predation is a weakly dominant strategy for seller A which guarantees an income of Baht 2,324.85. Then it is better for seller B not to enter the market (payoff of Baht 0) than enter (payoff of Baht - 100.00).

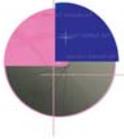
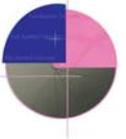


Table 1 Examples of Buyers' Willingness to Pay with Different Cumulative Units Sold

If the cumulative units sold by seller A or seller B is	Then		
		WTP for A	WTP for B
0	Buyer 1	50	40
	Buyer 2	40	30
	Buyer 3	30	20
	Buyer 4	20	10
	Buyer 5	10	0
1		WTP for A	WTP for B
	Buyer 1	55	45
	Buyer 2	45	35
	Buyer 3	35	25
	Buyer 4	25	15
	Buyer 5	15	5
If A has sold 2 units while B has sold 4 units		WTP for A	WTP for B
	Buyer 1	60	60
	Buyer 2	50	50
	Buyer 3	40	40
	Buyer 4	30	30
	Buyer 5	20	20

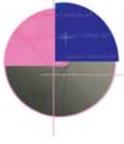
Note: Subjects are presented with the current WTP for both products. For example, if seller A has sold 2 units and seller B has sold 4 units cumulatively in period 1 and 2, both seller A and B will be presented with the information similar to the last row of Table 1 (not the whole table) in period 3



The experiment was conducted manually at Mahidol University International College in Thailand. Subjects made their decisions in private cubicles before the data was entered into a computer program that allocated demand in the market to sellers in the usual ways. Fifteen subjects were recruited from Business Administration and Social Sciences Divisions and participated in the training session. The training experiment consisted of four rounds. In each round, subjects played a monopoly game with network externalities. They were seller A during the first two training rounds, and seller B during the last two training rounds. There were seven periods in each of the four training rounds. Each received the show-up fee of Baht 100.00. Two days later, ten of them were invited back to the actual session which lasted for approximately 2 hours. Since each actual round consisted of seven periods, only two rounds were played without having to rush any subject. Subjects 1 through 5 were assigned the role of seller A in round 1, and were seller B in round 2, while subjects 6 through 10 faced the opposite role. Subjects were paired randomly and re-matched between each actual round to avoid repeated game effects. Subjects were not paid for all rounds, but a few rounds were randomly picked by a lottery and paid for.

Results

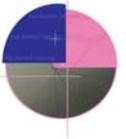
Table 2 summarizes basic results from the experiment. Considering period 1 of both rounds, there exists 14 evidences of strong predatory pricing, out of 20 total pricing decisions. Another 6 decisions are at the boundary of predation which is pricing at Baht 10.00. Additionally, out of 14 predatory pricing decisions, 9 sellers set his/her price at Baht 0 which resulted in a loss of Baht 50.00 in the first period. No seller was planning to make a profit in this period: they either incurred a loss or accepted a break-even. In period 2, I found 13 evidences of predation where 7 could be classified as strong predatory pricing and 6 as weak predatory pricing. There were also 5 sellers who priced at Baht 0 and lost Baht 100.00 in this second period. In period 3, there were 3 more evidences of strong predatory pricing decisions.

**Table 2** Pricing decisions in round 1 and pricing decisions in round 2**Pricing Decisions in Round 1 (in Baht)**

Seller	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
A	10.00	35.00	60.00	85.00	110.00	134.00	160.00
B	10.00	20.00	xxxx	xxxx	xxxx	xxxx	xxxx
A	10.00	9.50*	20	xxxx	xxxx	xxxx	xxxx
B	0.00*	14.99**	39.99	75	89.99	125.00	150.00
A	10.00	9.98*	24.98	58.99	55.00	46.99	xxxx
B	0.00*	24.99	24	23.98	39.98	49.5	48.97
A	0.00*	0.00*	59.99	84.99	110	135.00	160
B	0.00*	0.00*	xxxx	xxxx	xxxx	xxxx	xxxx
A	10.00	10.00**	xxxx	10.00**	30.00	10.00**	10.00**
B	0.00*	10.00**	50	20	90.00	110.00	135.00

Pricing Decisions in Round 2 (in Baht)

Seller	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
A	8.88*	34.99	59.99	84.99	109.99	135.00	160.00
B	0.00*	0.00*	0.00*	0.00*	xxxx	xxxx	xxxx
A	9.99*	34.99	60.00	85.00	110.00	135.00	160.00
B	4.88*	10.00*	xxxx	xxxx	xxxx	xxxx	xxxx
A	5.00*	30.00	55.00	85.00	110.00	135.00	160.00
B	0.00*	0.00*	0.00*	xxxx	xxxx	xxxx	xxxx
A	10.00	10.00**	xxxx	xxxx	xxxx	xxxx	xxxx
B	0.00*	14.99**	50.00	75.00	100.00	124.99	89.99



Discussion

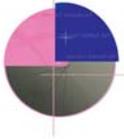
Predation was observed most of the time in this experiment. The average price set by seller A in the first period is Baht 8.39 while the average price by seller B of only Baht 1.49, which is clearly below the strong predatory price of Baht 10.00. From the sign test of the first period's prices of both rounds, I can reject the hypothesis that prices are above strong predatory price range of Baht 10.00 ($\alpha = 0.10$). But for the second and third period, the sign tests fail to reject the null hypothesis that prices are above weak predatory price range of Baht 20.00 ($\alpha = 0.10$).

The predatory pricing strategy was quite successful in eliminating another rival in the market. There were 6 instances of successful predation where either seller A or seller B decided not to participate in a particular period after facing predatory pricing by another seller in the previous period. Additionally, after a seller gets rid of another one, the winning seller resorts to the profit-maximizing price as predicted by the equilibrium in most cases. Note that if seller A prices at Baht 9.99, 34.99, and 59.99 in period 1, 2, and 3, respectively, and seller B does not enter the market in period 4 to 7, seller A's predicted pricing decisions would be Baht 85.00, 110.00, 135.00, and 160.00 in period 4, 5, 6, and 7, respectively.

The experiment also provides two unexpected findings. First, the game was not always played as predicted by the equilibrium. Seller B which was inferior also engaged in predation during the first period. There were 9 instances of seller B's predation: 8 instances of pricing at Baht 0 and 1 instance of pricing at Baht 4.88. Additionally, seller B's predatory intent was more obvious than seller A's. For period 1, the sign tests cannot reject the hypothesis that seller A's prices above strong predatory price range, but can reject the hypothesis about seller B's prices ($\alpha = 0.05$).

Second, inferior sellers could eventually win the market if they set their prices "wisely" during the first few periods. Out of the 6 instances of successful predation, seller A which was superior seller were driven out of the market two times. In the network industry where seller are differentiated, both superior and inferior sellers compete intensely for the market share, and anyone could win the market. Seller B has an incentive to steal the market in the first few periods which may eventually mean winning the whole game.

The results from the experiment confirm the possibility of employing the predatory pricing strategy in the network industry. Especially when sellers are not identical, this strategy could be effective in getting rid of competitors.



For future research, the design can be extended to incorporate the invention of a superior technology by a seller during the middle of the multi-period game, and observe whether the new technology can replace the existing one. Additionally, this paper does not discuss the welfare effect of the predation, or whether inferior seller's dominance results in a loss to the society. It would be beneficial to focus the experiment on the demand side. Subjects may assume the role of buyers who have to make a choice between two technologies. Simulated sellers can be programmed to employ certain pricing strategies, and observe whether and how an inferior technology becomes dominant in the long run, and how that affects the social welfare.

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References

1. Areeda, P. E. and Turner, D. F. : Predatory pricing and related practices under section 2 of the Sherman Act. *Harvard Law Review* 88:697-733, 1975.
2. Isaac, M. R., and Smith, V. L. : In search of predatory pricing. *JPE.* 93: 320-345, 1985.
3. Harrison, G. W. : Predatory pricing in a multiple market experiment: a note. *JEBO.* 9: 405-417, 1988.
4. Goeree, J. K., and Gomez, R. : Predatory pricing in the laboratory. draft, University of Virginia, 1998.
5. Capra, M. C., Goeree, J. K., Gomez, R. and Holt, C. A. : Predation, asymmetric information, and strategic behavior in the classroom: an experimental approach to The teaching of industrial organization. *IJIO.* 18:205-225, 2000.
6. Jung, Y. J., Kagel, J. H. and Levin, D. : On the existence of predatory pricing: an experimental study of reputation and entry deterrence in the chain-store game. *RJE.* 25:72-93, 1994.
7. Katz, M. L. and Shapiro, C. : Technology adoption in the presence of network externalities. *JPE.* 94:822-841, 1986.
8. Farrell, J., and Saloner, G. : Installed base and compatibility: innovation, product preannouncements, and predation. *AER.* 76:940-955, 1986.
9. Katz, M. L. and Shapiro, C. : Network externalities, competition, and compatibility. *AER.* 75:424-440, 1985.