DISCUSSION PAPER SERIES

Discussion paper No. 220

On excess capacity in a monopoly market with network externalities

Tsuyoshi TOSHIMITSU
(School of Economics, Kwansei Gakuin University)

October 2020

MASTERY FOR SERVICE

SCHOOL OF ECONOMICS

KWANSEI GAKUIN UNIVERSITY

1-155 Uegahara Ichiban-cho
Nishinomiya 662-8501, Japan

On excess capacity in a monopoly market with network externalities

Tsuyoshi TOSHIMITSU☆

School of Economics, Kwansei Gakuin University

Abstract

Using a capacity-then-production choice model, we consider whether excess capacity results hold in a monopoly market with network externalities. We demonstrate that if consumers form expectations of network sizes after (before) the capacity-scale decision, the capacity scale is larger than (equal to) the production quantity. Furthermore, we examine the first-best and second-best policies and find that excess capacity results hold (do not hold) in the second-best (first-best) policy, irrespective of the timing of consumer expectations.

Keywords: consumer expectation; capacity-then-production choice; network externality; monopoly

JEL Classification: D42, L12, L15

☆ School of Economics, Kwansei Gakuin University, 1-155, Nishinomiya, 662-8501, Japan
Tel: +81 798 54 6440, Fax: +81 798 51 0944, E-mail: ttsutomu@kwansei.ac.jp

1. Introduction

Theoretical and empirical studies of the relationship between market structure and excess capacity are important in the fields of industrial organization and industry policy. It is well-known that maintaining excess capacity plays an essential role as a strategic device in an oligopoly market. In particular, it has been found that firms maintain excess capacity to make their rivals reduce output levels or to deter market entry. Thus, *excess capacity exists in a pure oligopoly market where profit-maximizing firms compete with each other* (emphasis added).[1] If so, can excess capacity arise in a pure monopoly market where there are no competing firms and no entries? The answer is that it cannot.

The purpose of this paper is to examine whether or not excess capacity results hold in a monopoly market with network effects, which implies consumption externalities (hereafter, network externalities). Using a capacity-then-production choice model, we consider how network externalities and the timing of consumer expectations affect the capacity-scale decision by a monopoly. In the presence of network externalities, we focus on the following points: players in the games are both owners of the monopoly and consumers, and thus, the timing of consumer expectations of network sizes plays an essential role.[2] In particular, in a capacity-then-production choice model, forming expectations either before or after the capacity-scale decision affects the behavior of the monopoly.

[1] There are many studies of excess capacity in various contexts, e.g., a mixed oligopoly market where private and public firms compete (Nishimori and Ogawa, 2004; Ogawa, 2006), a labor-managed industry (Haruna, 1996; Zhang, 1993), and others.

[2] With respect to the timing of consumer expectations, we use the definition of Hurkens and López (2014), i.e., passive and responsive expectations. Following this definition, Toshimitsu (2017) considered how the type of consumer expectations affects profit and consumer surplus in a monopoly model.

The following papers consider the relationship between the timing of consumer expectations and firms' investment decisions. Boivin and Vencatachellum (2002) examined how network externalities affect cost-reducing R&D investments in a homogeneous duopoly. It is assumed in the model that consumers form their expectations before the R&D investments. Naskar and Pal (2020) considered process (cost-reducing) R&D investments in horizontally differentiated Cournot and Bertrand duopoly and compared the Cournot and Bertrand equilibria. In their model, they assume that consumers form the expectations after the R&D investments. In our model, where a monopoly provides a network product, we consider two cases of consumer expectations and compare the results of both cases. We demonstrate that whether excess capacity arises in a monopoly market depends on the timing of consumer expectations. However, the excess capacity in the monopoly market is socially insufficient. Furthermore, we examine the first-best and second-best policies and that show excess capacity arises (does not arise) under the second-best (first-best) policy, irrespective of the timing of consumer expectations.

2. The Model

2.1 Setup: Monopoly in a capacity-then-production choice model with network externality

Using the utility function included with network externalities presented by Hoernig (2012), we assume the following utility function of a representative consumer:

$$U = q_0 + Aq - \frac{1}{2}q^2 + n\left(yq - \frac{1}{2}y^2 \right), \tag{1}$$

which is subject to the budget constraint, i.e., $I = pq + q_0$, $p_0 = 1$. A is the intrinsic market size,

q is the production quantity of a monopoly, q_0 is the quantity of a numeral product, $n \in [0,1)$ is the parameter expressing network externalities, and y is the expected network size. Based on equation (1), we obtain the following inverse demand function:

$$p = p(q, y; n) = A - q + ny. \tag{2}$$

Following Vives (1986), Horiba and Tsutsui (2000), and Nishimori and Ogawa (2004), we assume that the monopoly has the following U-shaped cost function:

$$C(q, x) = \frac{c}{2}(x - q)^2, \quad c > 0, \tag{3}$$

where x is the capacity scale. Given equations (2) and (3), the profit function of the monopoly becomes

$$\Pi(q, x) = p(q, y; n)q - C(q, x) = (A - q + ny)q - \frac{c}{2}(x - q)^2. \tag{4}$$

As mentioned above, we consider games in which players are both owners of the monopoly and consumers. There are two different game structures depending on the timing of consumer expectations.[3] In particular, the first case is as follows: at the 1st stage, the monopoly decides the capacity scale; at the 2nd stage, consumers form expectations of network sizes; and finally, at the 3rd stage, the monopoly decides the production quantity. The second case is as follows: at the 1st stage, consumers form expectations of network sizes; at the 2nd stage, the monopoly decides the capacity scale; and finally, at the 3rd stage, the monopoly decides the production quantity. We derive a subgame perfect Nash equilibrium in each of the two games by backward induction. Hereafter, the first (second) case is referred to as *ex post* (*ante*) expectations.

[3] In the Appendix, we examine the case of responsive expectations where consumers believe the announced production quantity of the monopoly (i.e., active beliefs). In this case, the monopoly can commit to the production quantity before consumers form expectations of network size.

2.2 The case of *ex post* expectations

In this case, consumers form expectations of network sizes after the capacity scale and before the production quantity decisions of the monopoly. In the final stage, given the capacity scale and the expected network sizes, i.e., x and y, the monopoly decides the production quantity to maximize the profit. The first-order condition (FOC) is given by:

$$\frac{\partial \Pi(q,x)}{\partial q} = p - q + c(x-q) = A - 2q + ny + c(x-q) = 0.$$

Thus, we have

$$q = q(x,y;n) = \frac{A+cx+ny}{2+c}. \tag{5}$$

Under fulfilled expectations, i.e., $y = q$, equation (5) is rewritten as:

$$q = q(x;n) = \frac{A+cx}{2+c-n}, \tag{6}$$

where $\frac{\partial q}{\partial x} = \frac{c}{2+c-n} > 0.$ Given the FOC, because it holds that $p = q - c(x-q)$, the profit function, i.e., equation (4), can be rewritten as:

$$\Pi(q(x;n),x) = q(x;n)^2 - \frac{c}{2}\left(x^2 - q(x;n)^2\right) = \left(1+\frac{c}{2}\right)q(x;n)^2 - \frac{c}{2}x^2.$$

The FOC of profit maximization with respect to capacity scale is given by:

$$\frac{\partial \Pi(q(x;n),x)}{\partial x} = 2\left(1+\frac{c}{2}\right)q(x;n)\frac{\partial q}{\partial x} - cx = \frac{c(2+c)}{2+c-n}q(x;n) - cx = 0.$$

Thus, we obtain the following capacity scale in the subgame perfect Nash equilibrium:

$$x^* = \frac{(2+c)A}{2(2+c)(1-n)+n^2}. \tag{7}$$

Using equations (6) and (7), we derive the following production quantity:

$$q^* = \frac{A + cx^*}{2 + c - n} = \frac{(2 + c - n)A}{2(2 + c)(1 - n) + n^2}. \tag{8}$$

In view of equations (7) and (8), it holds that $x^* > q^*$. Thus, the excess capacity arises. However, without network externalities, i.e., $n = 0$, the capacity scale is equal to the production quantity, i.e., $q^* = x^* = \frac{A}{2}$.

2.3 The case of *ex ante* expectations

In this case, consumers form expectations of network sizes before the capacity scale and production quantity decisions are made by the monopoly. Given the capacity scale and the expected network sizes, i.e., x and y, the monopoly decides the production quantity to maximize its profit. Thus, by a similar process to that in the case of *ex post* expectations, we have equation (5) where $\frac{\partial q}{\partial x} = \frac{c}{2 + c} > 0$. The effect of an increase in the capacity scale does not depend on network externalities. The profit function is rewritten as:

$$\Pi\left(q(x, y; n), x\right) = q\left(x, y; n\right)^2 - \frac{c}{2}\left(x^2 - q(x, y; n)^2\right) = \left(1 + \frac{c}{2}\right)q(x, y; n)^2 - \frac{c}{2}x^2.$$

Given the expected network size, the FOC is given by:

$$\frac{\partial \Pi\left(q(x, y; n), x\right)}{\partial x} = 2\left(1 + \frac{c}{2}\right)q(x, y; n)\frac{\partial q}{\partial x} - cx = c\left\{q(x, y; n) - x\right\} = 0. \tag{9}$$

Under fulfilled expectations, i.e., $y = q$, using equations (5) and (9), we obtain the following outcomes in the subgame perfect Nash equilibrium:

$$q^{**} = x^{**} = \frac{A}{2 - n}. \tag{10}$$

Equation (10) implies that the capacity scale is equal to the production quantity. This result differs from that in the case of *ex post* expectations. Furthermore, without network externalities, the equilibrium outcomes are identical to those in the case of *ex post* expectations.

Therefore, when consumers form the expectations of network sizes before the capacity decision, excess capacity does not arise in the monopoly market, irrespective of the presence of network externalities.

We can interpret this game as follows. The equilibrium in this game is the same as that in the game where, given the expected network sizes, the monopoly decides both capacity scale and production quantity, simultaneously. That is, we derive the same outcomes as in equation (10) by solving three equations: $\frac{\partial \Pi(q,x,y)}{\partial q} = A - 2q + ny + c(x-q) = 0$, $\frac{\partial \Pi(q,x,y)}{\partial x} = -c(x-q) \leq 0$, and $y = q$.

We summarize the results from Sections 2.2 and 2.3 as follows:

Result 1. In a monopoly market with network externalities, if consumers form the expectations of network sizes after (before) the capacity-scale decision, the capacity scale is larger than (equal to) the production quantity.

In particular, excess capacity arises in the case of *ex post* consumer expectations. That is, an increase in the expected network size shifts up the inverse demand function (see equation (2)). Under fulfilled expectations, the expected network size is equal to the realized production quantity, so that an increase in the capacity scale increases the production quantity (see equation (6)). Accordingly, the monopoly has an incentive to expand the capacity scale over the production quantity to increase the profit, even if the adjustment cost increases. On the contrary, in the case of *ex ante* expectations, as mentioned above, the monopoly must decide both the capacity scale and production quantity, given the expected network sizes. That is, because the capacity scale does not affect the demand, the monopoly makes the decision that the capacity scale is equal to the production quantity to reduce the adjustment costs as much as possible.

2.4 Comparison: Which timing of consumer expectations is rational?

In view of equations (7), (8), and (10), the following inequalities hold.

$$x^* > q^* > q^{**} = x^{**}. \tag{11}$$

Equation (11) shows that the production quantity in the case of *ex post* expectations is larger than that in the case of *ex ante* expectations. This implies that the timing of expectations affects consumer surplus. In particular, using equations (1) and (2), consumer surplus is given by $CS = \frac{1-n}{2} q^2$. Thus, based on equation (11), it holds that $CS^* > CS^{**}$. This result implies that the case of *ex ante* expectations is not rational for consumers. Accordingly, the monopoly does not believe the consumer expectations. In other words, the monopoly expects that even if consumers *ex ate* form expectations of network sizes before the capacity-scale decision, they would revise their expectations after the capacity decision.

Furthermore, the profits in the two cases are given by: $\Pi^* = \left(1 + \frac{c}{2}\right)\left(q^*\right)^2 - \frac{c}{2}\left(x^*\right)^2$ and $\Pi^{**} = \left(q^{**}\right)^2$. Using equations (7), (8), and (10), it holds that $\Pi^* > \Pi^{**}$. The profit of the monopoly in the case of *ex post* expectations is larger than that in the case of *ex ante* expectations. Therefore, the case of *ex post* expectations is preferable for not only consumers but also the monopoly.

We summarize the above discussion as follows:

Result 2. The commitment to ex ante expectations by consumers is not credible.

Result 2 implies that the game in the case of *ex ante* expectations is not rational for both players, i.e., consumers and the monopoly.

3. Optimal policies and social welfare

3.1 First-best policy

Using equations (1) and (4), the purpose of a government is to maximize social welfare, which is given by:

$$\begin{aligned} W(q,x,y,n) &= U(q,y;n) - pq + \Pi(q,x,y;n) \\ &= Aq - \frac{1}{2}q^2 + n\left(yq - \frac{1}{2}y^2\right) - \frac{c}{2}(x-q)^2. \end{aligned} \tag{12}$$

3.1.1 The case of *ex post* expectations

Given the capacity scale and expected network sizes, i.e., x and y, the government decides the production quantity to maximize social welfare. Based on equation (12), the FOC is given by:

$$\frac{\partial W(q,x,y;n)}{\partial q} = A - q + ny + c(x-q) = 0.$$

Under fulfilled expectations, i.e., $y = q$, we obtain the following: $q = q(x;n) = \frac{A+cx}{1+c-n}$, where $\frac{\partial q}{\partial x} = \frac{c}{1+c-n} > 0.$ Thus, the social welfare function, i.e., equation (12), is rewritten as:

$$W\left(q(x;n),x;n\right)=Aq-\frac{1}{2}(1-n)q^2-\frac{c}{2}\left(x-q\right)^2.$$

Using the above equation, the FOC of maximization of social welfare with respect to the capacity scale is given by:

$$\begin{aligned}&\frac{\partial W\left(q(x;n),x;n\right)}{\partial x}=\frac{c}{1+c-n}\left\{A-(1-n)q-(1-n)\left(x-q\right)\right\}\\&=\frac{c}{1+c-n}\left\{A-(1-n)x\right\}.\end{aligned}\tag{13}$$

Thus, we obtain the following capacity scale in the subgame perfect Nash equilibrium:

$$x^{F*}=\frac{A}{1-n}.\tag{14}$$

Furthermore, we derive the following production quantity:

$$q^{F*}=\frac{A+cx^{F*}}{1+c-n}=\frac{A}{1-n}.\tag{15}$$

In view of equations (14) and (15), excess capacity does not arise, i.e., $x^{F*}=q^{F*}$.

3.1.2 The case of *ex ante* expectations

In this case, as mentioned in Section 2.3, the game of the sequential decisions of production quantity and then capacity scale is identical to that of the simultaneous decisions of them, given the expected network sizes. In particular, in view of equation (12), we derive the following FOCs:

$$\frac{\partial W\left(q,x;y,n\right)}{\partial q}=A-q+ny+c\left(x-q\right)=0 \text{ and } \frac{\partial W\left(q,x;y,n\right)}{\partial x}=-c\left(x-q\right)\leq 0.\tag{16}$$

Using equation (16), and, under fulfilled expectations, i.e., $y=q$, we obtain the following equilibrium outcomes:

$$q^{F**}=x^{F**}=\frac{A}{1-n}.\tag{17}$$

In view of equations (14), (15), and (17), we obtain the following result:

Result 3. In the case of the first-best policy, the capacity scale is equal to the production quantity, irrespective of the timing of expectations.

In view of equations (10) and (17), when consumers can commit to the expectations of network sizes before the capacity decision, the capacity scale is equal to the production quantity, regardless of whether a provider is a private profit maximizer or a social welfare maximizer. This is because the provider knows that consumers form expectations of network size equal to the actual production quantity, whenever the expectations are rational. As a result, the provider decides the capacity scale, which is equal to the production quantity, to reduce adjustment cost losses.

3.1.3 Comparison: Monopoly vs. first-best policy

Based on the results derived in the previous sections, we easily show the following relationships:

$$x^{F*} > x^{*} \quad \text{and} \quad q^{F*} > q^{*}, \tag{18}$$

$$x^{F**} > x^{**} \quad \text{and} \quad q^{F**} > q^{**}. \tag{19}$$

Thus, we obtain the following:

Result 4. Compared with the first-best policy, both capacity scale and production quantity in the monopoly market are socially insufficient, irrespective of the timing of expectations and even without network externalities.

3.2 Second-best policy: Capacity-scale control and excess capacity

In this case, the government can control the capacity scale, and then, the monopoly decides the production quantity, given the controlled capacity scale.

3.2.1 The case of *ex post* expectations

In view of Section 2.2, at the final stage of the production quantity decision, under fulfilled expectations, equation (6) holds, i.e., $q = q(x;n) = \dfrac{A+cx}{2+c-n}$. The social welfare function is rewritten as:

$$W\left(q(x;n),x;n\right) = Aq - \frac{1}{2}(1-n)q^2 - \frac{c}{2}\left(x-q\right)^2.$$

Using the above equation, the FOC of maximization of social welfare with respect to the capacity scale is given by:

$$\begin{aligned}&\frac{\partial W\left(q(x;n),x;n\right)}{\partial x} = \frac{c}{2+c-n}\left\{A-(1-n)q-(2-n)\left(x-q\right)\right\}\\ &= \frac{c}{2+c-n}\left\{A-(2-n)x+q\right\} = 0.\end{aligned} \tag{20}$$

Thus, we obtain the following outcomes in the subgame perfect Nash equilibrium:

$$x^{S*} = \frac{(3+c-n)A}{(4+c)(1-n)+n^2}, \tag{21}$$

$$q^{S*} = \frac{A+cx^{S*}}{2+c-n} = \frac{(2+c-n)A}{(4+c)(1-n)+n^2}. \tag{22}$$

In view of equations (21) and (22), it holds that $x^{S*} > q^{S*}$. Thus, excess capacity arises. Furthermore, even without network externalities, i.e., $n = 0$, excess capacity also arises.

3.2.2 The case of *ex ante* expectations

In view of Section 2.3, equation (5) holds, given the expected network size, i.e., $q = q(x,y;n) = \dfrac{A+cx+ny}{2+c}$. Thus, the social welfare function is expressed as:

$$W\left(q(x,y;n),x,y;n\right)=Aq-\frac{1}{2}q^2+n\left(yq-\frac{1}{2}y^2\right)-\frac{c}{2}\left(x-q\right)^2.$$

The FOC of maximization of social welfare with respect to the capacity scale, given the expected network size, is as follows:

$$\frac{\partial W\left(q(x,y;n),x;y,n\right)}{\partial x}=\frac{c}{2+c}\left\{A-q+ny-2\left(x-q\right)\right\}=0. \tag{23}$$

Under fulfilled expectations, i.e., $y=q$, we derive the following outcomes in the subgame perfect Nash equilibrium:

$$x^{S**}=\frac{(3+c)A}{4+c-n(2+c)}, \tag{24}$$

$$q^{S**}=\frac{A+cx^{S**}}{2+c-n}=\frac{(2+c)A}{4+c-n(2+c)}. \tag{25}$$

In view of equations (24) and (25), it holds that $x^{S**}>q^{S**}$. Thus, excess capacity arises. Furthermore, without network externalities, i.e., $n=0$, excess capacity also arises.

Result 5. In the case of the second-best policy, excess capacity arises, irrespective of the timing of expectations and even without network externalities.

In view of equations (21) and (24), and equations (22) and (25), we derive the following inequalities:

$$x^{S*}>x^{S**} \text{ and } q^{S*}>q^{S**}. \tag{26}$$

In the case of the first-best policy, the capacity scale and production quantity are the same, irrespective of the timing of expectations. However, in the case of the second-best policy, the capacity scale and production quantity in the case of *ex post* expectations are larger than those in the case of *ex ante* expectations. The reason is the same as that in the case of a monopoly market (see equation (11)).

3.2.3 Comparison: Monopoly vs. second-best policy

Based on the results derived in the previous sections, we easily present the following relationships:

$$x^{S*} > x^{*} \ \text{ and } \ q^{S*} > q^{*}, \tag{27}$$

$$x^{S**} > x^{**} \ \text{ and } \ q^{S**} > q^{**}. \tag{28}$$

Thus, we obtain the following:

Result 6. Compared with the second-best policy, both capacity scale and production quantity in the monopoly market are socially insufficient, irrespective of the timing of expectations and even without network externalities.

4. Conclusion

We have demonstrated that excess capacity arises in a monopoly market with network externalities when consumers form expectations of network sizes after the capacity-scale decision and before the production quantity decision. Otherwise, excess capacity never arises when consumers form expectations of network sizes before the capacity-scale decision. Furthermore, excess capacity arises in the second-best policy whereas it never arises in the first-best policy.

Even in a monopoly market where there are no strategic effects on competing firms and no threats of entry, the excess capacity results hold if consumers form expectations of network sizes after the capacity-scale decision. However, the capacity scale is not socially insufficient. Thus, for example, a government should subsidize the monopoly to increase the capacity scale in a network industry. The industrial policy issues remain for future research.

Appendix. Responsive expectations case

The case of responsive expectations implies that consumers have active beliefs around network sizes. In particular, consumers believe the announced level of production quantity and, thus, the monopoly can commit to the actual production quantity. The structure of the game is as follows: at the 1st stage, the monopoly decides the capacity scale; at the 2nd stage, the monopoly decides the production quantity; and finally, at the 3rd stage, consumers form expectations of network size, which is equal to the announced production quantity. By backward induction, we derive a subgame perfect Nash equilibrium in this game. As mentioned in Section 2.3, the equilibrium outcomes are the same as those in the game where the monopoly simultaneously decides both production quantity and capacity scale.

Equation (2) in the case of responsive expectations is revised as:

$$p = A - (1-n)q. \tag{A.1}$$

The profit function is expressed as:

$$\Pi(q,x) = p(q,q)q - C(q,x) = \{A - (1-n)q\}q - \frac{c}{2}(x-q)^2. \tag{A.2}$$

Based on equation (A.2), the FOCs of profit maximization with respect to the production quantity and capacity scale are given by:

$$\frac{\partial \Pi(q,x)}{\partial q} = p - (1-n)q + c(x-q) = A - 2(1-n)q + c(x-q) = 0, \tag{A.3}$$

$$\frac{\partial \Pi(q,x)}{\partial x} = -c(x-q) \le 0. \tag{A.4}$$

Thus, we obtain the following:

$$q^{***} = x^{***} = \frac{A}{2(1-n)}. \tag{A.5}$$

In view of (A.5), the capacity scale is equal to the production quantity in the case of responsive expectations. This result is the same as that in the case of *ex ante* expectations.

Furthermore, using the results in the text, we have the following results:

$$x^{***} > x^{*} > x^{**} \quad \text{and} \quad q^{***} > q^{*} > q^{**}. \tag{A.6}$$

Given equation (A.6), the following results hold:

$$CS^{***} > CS^{*} > CS^{**} \quad \text{and} \quad \Pi^{***} > \Pi^{*} > \Pi^{**}. \tag{A.7}$$

References

Haruna S. (1996). A note on holding excess capacity to deter entry in a labor-managed industry. *Canadian Journal of Economics*, Vol. 29, pp. 493−499.

Hoernig, S. (2012). Strategic delegation under price competition and network effects. *Economics Letters*, Vol. 117 (2), pp. 487–489.

Horiba Y. & Tsutsui, S. (2000). International duopoly, tariff policies and the case of free trade. *Japanese Economic Review*, Vol. 51, pp. 207−220.

Hurkens, S. & López, A. L. (2014). Mobile termination, network externalities and consumer expectations. *Economic Journal*, Vol. 124, pp. 1005−1039.

Nishimori, A., & Ogawa, H. (2004). Do firms always choose excess capacity?. *Economics Bulletin*, Vol. 12, pp. 1−7.

Toshimitsu, T. (2017). On consumer expectations in a network goods market: The monopoly case. *Economics Bulletin*, Vol. 37 (1), pp. 488−493.

Vives, X. (1986). Commitment, flexibility, and market outcomes. *International Journal of Industrial Organization*, Vol. 4, pp. 217−229.

Zhang, J. (1993). Holding excess capacity to deter entry in a labor-managed industry. *Canadian Journal of Economics*, Vol. 26, pp. 222−234.