A NOTE ON THE NETWORK EFFECT

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ABSTRACT

This note studies the effect of network externalities on firms in Cournot equilibrium. The existence of network externalities, in which individual consumer demand depends on total market demand, results in increased output. In addition, the existence of network externalities enables firms to sustain a higher level of fixed costs. Alternatively, for a given level of fixed costs the existence of network externalities results in the market being able to support a greater number of firms.

INTRODUCTION

The network effect occurs when the quantity demanded by a consumer at a given price is influenced by the market demand for the product[1]. Examples of the network effect are numerous. A teen-ager's demand for a CD produced by a rock group is affected by the fact that the group is popular and has a high market demand. A consumer's demand for tickets to a football game is enhanced if the game is expected to be well attended. A customer's demand for dining at a particular restaurant is a function of the number of patrons that dine at the restaurant. A person is more likely to purchase a particular video game if he or she feels that his or her friends will purchase that game, and so forth.

The network effect has received some attention in the literature. Leibenstein [6] introduced the seminal demand formulation of the network effect. Becker [1] developed a model of the network effect and discussed its implications for the slope of the demand curve. A formal oligopoly model including the network effect has been developed by Katz and Shapiro [4], while Liebowitz and Margolis [7]contains an extensive discussion of different types of network externalities. The effect of network externalities on planned product obsolescence has been studied by Choi [3]. The impact of network externalities on product quality has been examined by Bental and Spiegel [2]. Lee and McKenzie [5] argue that interrelated demand between customers can lead to less aggressive price competition between firms.

The purpose of the present note is to develop a formal model of the network effect on firm-level demand as it relates to equilibrium in less than perfectly competitive markets. Specifically, we develop an N-firm Cournot model that includes a network effect. This model leads to some conclusions concerning the network effect not previously mentioned. The model is used to examine the implications for the network effect on the interaction between fixed costs and the number of firms in equilibrium. This extends the work of Lee and McKenzie which is primarily concerned with impact of this effect on firm capacity in a monopoly setting.

A MODEL OF THE NETWORK EFFECT IN COURNOT EQUILIBRIUM

The central feature of the models we are studying is the interrelationship between market demand and individual demand. Becker's formulation of the network effect assumes that an individual's demand is a function of total market demand at a given price. The Lee and McKenzie formulation fixes quantity and assumes that the price a firm charges to a particular customer increases if the customer believes that higher prices attract more desirable clientele. Lee and McKenzie use the term "client effect" in referring to this phenomenon. Our formulation takes the former approach.

Assume a market with N firms producing a product that can be aggregated into a single market demand. Within this market, each firm has a demand for its product with its own price coefficients. For simplicity we assume demand is linear. We also assume that there is a network effect affecting firm level demand.

Under these assumptions demand for the ith firm's output is

$$q_i = \alpha_i - \beta_i P + \gamma_i \sum_{j=1}^{N} q_j, \quad \alpha_i, \beta_i > 0, \gamma_i \geq 0, \quad (1)$$

i = 1, 2,…., N, where q_i is the output of firm i and P is market price. According to (1) the quantity demanded of the ith firm's output decreases with market price and increases with total market demand[2]. This formulation in which demand for the ith firm's output depends on market price is consistent with our use of a Cournot model, for which firms are assumed to be price takers.

The network effect enters firm level demand via the coefficient γ_i, which increases firm demand as the sum of output of the firms in the market increases. Note that for any firm for which there is no network effect, $\gamma_i = 0$. For sake of simplicity, to rule out the possibility of an upward-sloping market demand curve after firm level demand is aggregated, we assume that the sum of the network effects across all firms adds up to less than 1. Formally, $\Sigma\gamma_i < 1$.

Firms are assumed to have identical linear costs curves. Both the assumption of linearity and the assumption of identical cost curves have been made to simplify the analysis. Therefore, for i = 1, 2, ... N,

$$TC_i = FC + MCq_i, \quad (2)$$

where FC is the fixed cost of the ith firm and MC is the per unit marginal cost. Also note that by this specification firm costs are not subject to network externalities. The analysis can easily be extended to allow for this possibility.

Solution of the model first requires aggregating across firms to obtain total market demand

$$Q = q_1 + q_2 + ... + q_N = \alpha_1 + \alpha_2 + ... + \alpha_N - (\beta_1 + \beta_2 + ... + \beta_N)P + (\gamma_1 + \gamma_2 + ... + \gamma_N)\sum_{j=1}^{N} q_j$$

$$= \alpha - \beta P + \gamma Q. \quad (3)$$

Solving (3) for price results in

$$P = \frac{\alpha}{\beta} - \frac{(1-\gamma)}{\beta} Q = A - BQ. \quad (4)$$

Using (2) and (4) obtains the total profit for the ith firm

$$Profits_i = Pq_i - TC_i = (A - B(q_1 + q_2 + ... + q_N))q_i - FC - MCq_i. \qquad (5)$$

Differentiating (5) obtains the first-order conditions

$$\frac{\partial Profits_i}{\partial q_i} = A - MC - 2Bq_i - B\sum_{j \neq i} q_j = 0, \qquad (6)$$

for i = 1, 2,…, N. Observe that in the above system of equations, each firm's response depends identically on the sum of the individual firm demand parameters as captured in the coefficient B. This system of equations can be solved for the q_i by noting that due to this symmetry of firm response, in equilibrium $q_i = q^*$ for all i[3]. Substituting into (6) results in

$$A - MC - 2Bq^* - B(N-1)q^* = A - MC - B(N+1)q^* = 0. \qquad (7)$$

Solving (7) for equilibrium output obtains

$$q_1 = q_2 = ... = q_N = \frac{1}{N+1}\left[\frac{A - MC}{B}\right] > 0. \qquad (8)$$

THE EFFECT OF THE NETWORK EFFECT

The effect of the network effect can be seen by solving (8) in terms of α, β, and γ

$$q_1 = q_2 = ... = q_N = \frac{1}{N+1}\left[\frac{\alpha - \beta * MC}{1-\gamma}\right] > 0. \qquad (9)$$

Since $0 < \gamma < 1$, equation (9) shows that the effect of the network effect is to increase the output of the firms in Cournot equilibrium. To draw an analogy to macroeconomic theory, the form of equation (9) suggests that the network effect works like a Keynesian consumption multiplier. Demand for output produced by any firm makes consumption in the market in which the firm operates seem attractive to consumers in general. This feedback increases demand for the firm's output, and so forth. The overall effect is an increase in demand for each of the firm's output. This can also be seen by differentiating (9) with respect to γ to obtain

$$\frac{\partial q_i}{\partial \gamma} = \frac{\alpha - \beta * MC}{(N+1)(1-\gamma)^2}, \qquad (10)$$

which is strictly positive as long as firm output defined in (8) and (9) is positive.

Market output is N^*q_i. Substituting market output into (4) obtains the equilibrium market price

$$P = \frac{\alpha + N * \beta * MC}{\beta(N+1)}. \qquad (11)$$

Note that the price in equation (11) does not depend on the parameter γ. This means that although firm and market output is increased by the network effect, equilibrium market price is not. This is a natural consequence of our use of a Cournot model, in which firms act as price takers.

Differentiating (11) with respect to N results in

$$\frac{\partial P}{\partial N} = \frac{\beta(\beta MC - \alpha)}{\beta^2 (N+1)^2}. \qquad (12)$$

Since each firm is assumed in equilibrium to make a non-negative profit, MC < α/β. The partial derivative in (12) is therefore positive. In other words, the equilibrium market price decreases with the number of firms, which is consistent with Cournot models in which there is no network effect.

The profit of the ith firm is

$$\mathrm{Pr}\,ofit_i = TR_i - TC_i = Pq_i - MCq_i - FC, \qquad (13)$$

where P is defined in (11) and q_i is defined in (9). In a monopolistically competitive industry, firms will enter the industry if profits are positive or exit the industry if profits are negative. This process will drive total profits to zero. There are two ways to view the impact the network effect will have on this process.

The first is to fix the total number of firms, assuming a monopolistically competitive equilibrium, and solve for the maximum amount of fixed cost per firm that the industry can support in equilibrium. Setting profits in (13) equal to zero and solving for fixed costs using (9) and (11) results in

$$FC = \frac{1}{\beta(1-\gamma)} \left[\frac{\alpha - \beta * MC}{N+1} \right]^2. \qquad (14)$$

Differentiating (14) with respect to γ results in

$$\frac{\partial FC}{\partial \gamma} = \frac{1}{\beta(1-\gamma)^2} \left[\frac{\alpha - \beta * MC}{N+1} \right]^2 > 0. \qquad (15)$$

Equation (15) shows that the fixed costs per firm that can be sustained in Cournot equilibrium increases with γ over the interval 0 < γ < 1. This result is in the spirit of

Lee and McKenzie (1998), who argue that the network effect results in firms with excess capacity being less willing to bid down prices than otherwise.

An alternative way of looking at this process is to hold the fixed cost per firm constant, and solve for the number of firms the industry can support given the assumed level of fixed costs. Solving equation (14) for N obtains

$$N = (\alpha - \beta * MC)\sqrt{\frac{1}{(1-\gamma) * \beta * FC}} - 1. \qquad (16)$$

Differentiating (16) with respect to γ obtains

$$\frac{\partial N}{\partial \gamma} = \frac{(\alpha - \beta * MC)}{2\sqrt{\beta * FC}(1-\gamma)^{3/2}}. \qquad (17)$$

As (17) shows, N increases as γ increases. In equilibrium, as the network effect becomes larger so does the number of firms.

Two possible examples of this result come to mind. First is the proliferation of multi-plex movie theaters built in upscale suburban areas over the past few years. Our model predicts that a possible factor reinforcing this growth is that clients of these theaters prefer to frequent theaters with similar clients[4]. A second example is the airline industry. In the 1970s, before deregulation, airlines relied more heavily on non-price competition than during the post-regulatory period. It is plausible that in this setting the network effect was an important factor influencing airline demand, since it allowed airlines to price considerably above marginal cost. Our model suggests that if the network effect has diminished in importance since deregulation, we would expect a smaller number of airlines and a smaller price cost margin than otherwise[5].

CONCLUSION

Although numerous aspects of the network effect have been studied, the relationship between the network effect fixed investment and the equilibrium number of firms has not been addressed. The present note builds a Cournot model to address this issue.

The primary conclusions were threefold. First, we found that the network effect resulted in larger firm output than otherwise. Second, because of the network effect firms were able to support a higher level of fixed costs in Cournot equilibrium. Finally, for a given level of fixed costs per firm, the network effect resulted in more firms entering the market.

ENDNOTES

1. An alternative name for this phenomenon is the bandwagon effect.

2. A referee has pointed out that there is the possibility of a negative bandwagon effect in which consumer demand increases because of continued scarcity for a product. For example, until recently, Harley Davidson motorcycles in some markets were not available without a wait of many months and possibly years. This had the effect of creating a certain appeal based on the difficulty of obtaining a particular model.

3. See Samuelson and Marks [8], pages 400 and 401.

4. Another possible reason for the growth of multiplex theaters is economies of scale.

5. This conclusion is contingent on holding price constant.

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