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Does Standardization Really Increase Production?

Katz and Shapiro's result revisited

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ABSTRACT. – In market structures with network externalities, it is often asserted that there is a natural tendency toward standardization. In this paper it is argued that incompatible products may survive in static models. Like KATZ and SHAPIRO [1985], I develop a simple multi-product oligopoly in which the demand for one of these commodities increases with the number of agents consuming this good. Instead I introduce a variety of cost functions and discuss the limitations of their results of Katz and Shapiro and exhibit an example that reverses their conclusions.

La standardisation accroît-elle le niveau de production ? Le résultat de Katz et Shapiro revu

RÉSUMÉ. – Dans des structures de marché caractérisées par des externalités de réseau, on montre généralement qu'il y a une tendance naturelle vers la standardisation. Dans cet article, on se propose de montrer que des standards incompatibles peuvent subsister et cela même dans des modèles statiques. Comme Katz et Shapiro, je considère un oligopole multi-produit où la demande pour chaque bien est croissante avec le nombre de consommateurs de ce bien. En introduisant des fonctions de coût, il sera possible de discuter de limite de leurs analyses. On veillera en particulier à exhiber un exemple inversant l'essentiel de leurs résultats.

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1 Introduction

For many products, the utility that a consumer derives from consumption is affected by the number of the other consumers buying the same commodity. These markets are said to exhibit "*network externalities*" [1]. These externalities are generated through a direct or an indirect effect of the number of consumers on the quality of the product or of products which complement this one [2]. The behavior and the performance of the network good markets are therefore profoundly affected by the presence of these adoption effects. If several network incidently complete, the standardization problem becomes an interesting issue. If one restricts oneself to static models in which the demand for a network good is a function of both its price and the expected size of the network, it is often asserted that there is a natural tendency toward de facto standardization. Multiple incompatible products only last if there exists a trade off between profits today and losses in the future related for instance to a reduction of variety or to an increase in the degree of competition.

In this note, I want to point out that there is no natural tendency toward standardization. As KATZ and SHAPIRO [1985], I develop a multi-product Cournot model in which the utility that an agent derives from consumption increases with the number of consumers. In this framework, these two authors show that the level of total output is greater under industrywide compatibility than in any equilibrium with less than complete compatibility. Moreover they also prove that if two groups of firms make their products mutually compatible then (a) the average output of the firms in the merging coalition will rise (b) the output of any firm not in the merging coalition will fall and (c) industry output will rise. Combined with a surplus analysis, these facts engender a natural tendency toward standardization. But, to obtain these results, they assume that the firms do not supports production costs. The purpose of this note is to show that their results break down if cost functions are introduced.

In order to verify this statement, this paper will be organized as follows. In section 2, I briefly introduce a model which is very closed to the one used by these authors. In section 3, I present the limits of their argument if cost function are introduced. Section 4 is devoted to a counter-example. Section 4 concludes this note.

1. For an overview of this litterature see BESSEN-FARREL [1994], KATZ-SHAPIRO [1994] or PERROT [1993].

2. To illustrate direct effects, the reader is referred to ROHLFS [1974] or KATZ-SHAPIRO [1985]. Examples of indirect effects can be based on the "*Hardware/Software*" paradigm (see CHOU-SHY [1990] or CHURCH-GANDAL [1991]) or on lock-in effects (see FARREL-SHAPIRO [1989]).

2 The Model

In order to make their point, Katz and Shapiro develop a partial equilibrium oligopoly model in which each commodity delivered to the market is characterized by one of the m available standards or brands (indexed by i). These goods are produced by n firms (indexed by j). Producer j). Product j only delivers one brand in quantity q_j. Let me denote by N_i the set of firms selling goods of standard i.

With regards to the demand side, each consumer purchases one unit of this good and his willingness to pay for one commodity of standard i is given by $r + v_i$. These agents are heterogeneous in r but homogeneous in their valuations of the anticipated network externality v_i. In order to handle with externalities, I also assume that v_i is related to the anticipated market size y_i^e of brand i by a function $v\left(y_i^e\right)$ satisfying $v\left(0\right) = 0$, $v'\left(x\right) > 0$, $v''\left(x\right) < 0$ and $\lim\limits_{x \to +\infty} v'\left(x\right) = 0$. As Katz and Shapiro, I do not explicitly model the process through which consumer's expectations are formed. I however require that these expectations are fulfilled at equilibrium. Finally, if r which varies across consumers is assumed to be uniformly distributed between $-\infty$ and $A > 0$, the inverse demand for each brand i is given by $P_i\left(\sum_{j=1}^n q_j,\, v_i\right) = \max\left\{A + v_i - \sum_{j=1}^n q_j,\, 0\right\}$.

Concerning the supply side, each producer chooses his production level q_j by taking for given (a) the expectations about the sizes of the networks (or equivalently the $(v_i)_{i=1}^m$), and (b) the output level of the other firms. In order to produce q_j, he however supports a production cost. This one is assumed to be the same across firms and is given by a function $c\left(q\right)$ which satisfies $c'\left(q\right) > 0$, $c''\left(q\right) \geq 0$.

At equilibrium, no firm has an incentive to change his production level and the expectation are fulfilled. Hence

DEFINITION: A rational expectation Cournot equilibrium is a vector $(\hat{q}_j)_{j=1}^n \in \mathbb{R}_+^n$ which satisfies:
(i) $\forall\, i = 1, ..., m,\ \forall\, j \in N_i\ \hat{q}_j \in \arg\max\limits_{q_j \in \mathbb{R}_+} P_i\left(\sum_{j=1}^n q_j,\, v_i\right) \cdot q_j - c\left(q_j\right)$
(ii) $\forall\, i = 1, ..., m,\ \ v_i = v\left(\sum_{j \in N_i} \hat{q}_j\right)$

Having in mind this definition, one immediately notices that some firms may not produce at equilibrium because their inverse demand function which is defined by max $\left\{A + v_i - \sum_{j=1}^n q_j,\, 0\right\}$ can be zero. To simplify the presentation, let me only concentrate, as Katz and Shapiro, on equilibria in which all firms are active [3]. In this case, the behavior of each producer can be summarized by the first order condition of this maximization

3. Because the cost functions are the same across firms, if one firm is inactive, the same must be true for all the other firms producing the same standard. The inactivity simply induces a reduction of the number of available standards.

program [4]. If one also takes into account that the expectations are fulfilled, an equilibrium simply satisfies:

$$(1)\quad \forall i=1,...,m,\ \forall j\in N_i,\quad q_j+c'(q_j)=A+v\left(\sum_{j\in N_i} q_j\right)-\sum_{j=1}^{n} q_j$$

Moreover, because prices $p_i = A+v\,(\sum_{j\in N_i} q_j)-\sum_{j=1}^{n} q_j$ are unique for one standard and because $q_j+c'(q_j)$ is increasing, every firm belonging to N_i produces in equilibrium the same amount of output. If one denotes by Q_i the total production of goods of standard i, an equilibrium reduces to this new set of equations;

$$(2)\qquad \forall i=1,...,m,\ \frac{Q_i}{n_i}+c'\left(\frac{Q_i}{n_i}\right)=A+v\,(Q_i)-\sum_{i=1}^{m} Q_i$$

3 The Limits of Katz and Shapiro's Argument

In order to make their point, Katz and Shapiro sum up the preceding set of equation. Doing the same and rearranging the terms, one obtains:

$$(3)\qquad \sum_{j=1}^{m} Q_i=\frac{n}{n+1}\left(A+\sum_{i=1}^{m}\frac{n_i}{n}\cdot\left(v\,(Q_i)-c'\left(\frac{Q_i}{n_i}\right)\right)\right)$$

if m standards coexist and

$$(4)\qquad Q=\frac{n}{n+1}\left(A+v\,(Q)-c'\left(\frac{Q}{n}\right)\right)$$

under industrywide compatibility. Without cost functions, their argument is immediate. Because v is concave and increasing, one can state that:

$$(5)\qquad \frac{n}{n+1}\left(A+\sum_{i=1}^{m}\frac{n_i}{n}\cdot v\,(Q_i)\right)\le\frac{n}{n+1}\left(A+v\left(\sum_{i=1}^{m} Q\right)\right)$$

The curve $\frac{n}{n+1}\,(A+v\,(Q))$ therefore lies above $\frac{n}{n+1}\,(A+\sum_{i=1}^{m}\frac{n_i}{n}\cdot v\,(Q_i))$ where $Q=\sum_{i=1}^{m} Q_i$. As long as $\frac{n}{n+1}\,(A+v\,(0))=\frac{n}{n+1}\cdot A>0$. The

4. Because each producer takes as given the expected size of his network, the second order condition $\frac{d\pi}{dq_j}=-2-c''(q_j)<0$ is always satisfied.

total production equilibrium level which corresponds to the intersection of these curves with the 45 degree line must be greater under industry-wide compatibility than under incomplete compatibility.

Now if one tries to extend Katz and Shapiro's proof to situations in which cost functions matter, one has to verify that (i) $v(Q) - c'\left(\frac{Q}{n}\right)$ is concave and (ii) $A > c'(0)$. But neither of these two requirements are convincing. Concerning point (i), one immediately notices that $v(Q) - c'\left(\frac{Q}{n}\right)$ is concave if one assumes that the marginal cost function is not too concave. But this condition induces a non standard restriction on the cost function (*i.e.* on its third derivative). Let me now turn to restriction (ii). In network economies, the size of each network crucially affects each consumer's willingness to pay. It seems therefore difficult to exclude situations in which markets for network goods are not viable (*i.e.* $A + v(0) \leq c'(0)$) for small production levels. For many network goods, the highest reservation price which do not make into account the externalities if often close to zero [5]. It is for instance not very interesting to be the only one to have a phone.

4 A Simple Counter-Example

Let me consider a market structure composed by three firms characterized by the following cost function $c(q) = 1/2 \cdot a \cdot q^2 + b \cdot q$. The network externality are described by $v(x) = c \cdot x - d \cdot x^2$ for $x \leq \frac{c}{2d}$ and $v(x) = \frac{c^2}{4d}$ for $x \geq \frac{c}{2d}$. In this simple example, three levels of standardization are available. The products of these firms are neither compatible, partially compatible or totally incompatible. As long as $q_i \in [0, \frac{c}{2d}]$, one easily verifies, by computation, that an equilibrium in each of these three situations is respectively given by:

- $(q_1, q_2, q_3) = (q/3, q/3, q/3)$ and q satisfies

(6) $$d \cdot q^2 + \left(\frac{4+a}{3} - c\right) \cdot q + b - A = 0$$

- $(q_1, q_2, q_3) = (q_C/2, q_C/2, q_I)$ and (q_C, q_I) satisfies

(7) $$\begin{cases} d \cdot q_C^2 + \left(\frac{3+a}{2} - c\right) \cdot q_C + q_I + b - A = 0 \\ d \cdot q_I^2 + (2 + a - c) \cdot q_I + q_C + b - A = 0 \end{cases}$$

5. It is even possible to assume that A is negative if one wants to capture the idea that a network good is only viable if a minimal number of people are interested.

• $(q_1, q_2, q_3) = (q, q, q)$ and q satisfies

$$d \cdot q^2 + (4 + a - c) \cdot q + b - A = 0 \tag{8}$$

If one chooses [6] $a = 1$, $b = 13$, $c = 8$, $d = .05$, $A = 10$, the equilibrium production levels [7] are, in these three cases, respectively given by (.158, .158, .158), (.313, .313, .730), (1.017, 1.017, 1.017) and the profits are respectively (.036, .036, .036), (.149, .149, .797), (1.551, 1.551, 1.551). This simple example induces the following remarks:

• The aggregated production level is smaller under industrywide compatibility then in an equilibrium with less than complete compatibility. This total production level is even increasing with the number of incompatible standards.

• Let me now suppose that two firms decide to make their products mutually compatible (i.e. compare cases (ii) and (iii)). In the postmerger equilibrium, (a) the average output of the firms in the merging coalition will fall from 1.017 to .313, (b) the market size of the firm not in the merging coalition will rise from 33% to 54% and of course (c) the total output will fall.

• If one takes the sum of the producers' and consumers' surplus as a social welfare measure, one obtains in this three cases .220, 2.014, 9.307. This quantity increases with the number of incompatible standards. There is therefore a strong social incentive for network incompatibility.

• Keeping in mind that the compatibility or incompatibility of the products is the result of explicit decisions by the firms, one also notices that the equilibrium profits are increasing for each firm with the number of incompatible standards. If the switching costs are not too high, there are also private incentives for network incompatibility.

One can also notices that if one chooses $a = 0$, $b = 13$, $c = 8$, $d = .05$, $A = 10$, the model produces the following equilibrium values. With full compatibility the production levels are (.151, .151, .151), the profits are given by (.024, .024, .024) and the total surplus is 0.175. With partial compatibility one respectively observes (.278, .278, .595), (.078, .078, .352),

6. By computation one can also verify that these results are robust. They remain true for instance by choosing $a \in [0, 3]$, $b \in [11, 15]$ and $c \in [6, 10]$.

7. The reader surely notices that their is another root to these equations which lead to higher production levels. This multiplicity is not really surprising if one keeps in mind that the equilibrium production plan must be consistent with the expectations. Moreover because the objective of this note is to build a counter-example, one can of course select the bad-behaved equilibria.

and 1.172. Finally with incompatibility one obtains (.757, .757, .757), (.573, .573, .573), and 4.298. The reader immediately notices that the preceding remarks remain true and that the cost function reduces, in this example, to a function characterized by a constant marginal cost equal to 13. Katz and Shapiro's result can therefore not even be extended to the class of constant marginal cost functions [8].

5 Conclusion

In market structures in which network externalities occur, it is often asserted that there is a natural tendency toward de facto standardization. Consequently, several incompatible systems only survive, if the decision of producing these goods is a part of a more complex intertemporal strategy. In this paper it was argued that incompatible products may survive in static models.

To illustrate this case I have developed a simple multi-product Cournot model with network externalities. The model presented in this paper was very close to the one introduced by KATZ and SHAPIRO [1985]. The only difference consists in the addition of cost functions. In this setting, I have exhibited an example which invalidate their conclusions.

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8. To be more precise, these two authors introduced a linear cost function $c(q) = a + c \cdot q$. They assumed that the fixed cost can be set to zero as long as this one is smaller than the firm's equilibrium revenues minus variable costs. But they also claim that the variable costs can be set to zero without loss of generality. In fact, they argued that it is equivalent to rescale r the willingness to pay. But in this case one also needs to redefine its upper bound and this one can become negative.

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