Economics Bulletin

Volume 32, Issue 2

Collusion in Software Markets

Francisco Martínez-sánchez
University of Murcia

Abstract

In this paper we analyze firms' ability to tacitly collude on prices in software markets. We show that network externality hinders collusion. We also show that firms collude if they value future profits sufficiently.

I acknowledge the financial support from the Spanish MICINN under Project ECO2010-19830. I would like to thank Derek Laing (Associate Editor) for their clear, precise and useful comments and suggestions.Any remaing errors are, of course, mine alone.
Citation: Francisco Martínez-sánchez, (2012) "Collusion in Software Markets", *Economics Bulletin*, Vol. 32 No. 2 pp. 1345-1352.
Contact: Francisco Martínez-sánchez - fms@um.es.
Submitted: September 21, 2011. **Published:** May 07, 2012.

1. Introduction

The software industry is characterized by the existence of network externalities,[1] which are generated by the exchanging files of the same (original or pirated) software among consumers (Brynjolfsson and Kemerer (1996), Gandal (1994) and Gayer and Shy (2003a). It has been shown that the software developers can benefit from network externality since the software becomes more valuable to consumers as more consumers use the software (Gayer and Shy (2003a, 2003b)). However, network externalities can affect the firm's ability to tacitly collude. Despite the benefits of the positive externality just noted, network externalities also can have a deleterious effect on firms by hindering their ability to tacitly collude. This paper, offers a theoretical treatment of this trade-off.

We know that firms in markets for piratable goods can collude on prices through sharing the cost of digital rights management systems (DRM) to prevent the copying of their goods (Park and Scotchmer (2006)) or when they value future profits sufficiently (Martínez-Sánchez (2011)).[2]

In this paper we investigate firms' ability to tacitly collude on prices in markets for software in an infinitely repeated duopoly game of horizontal product differentiation. To that end we use the model developed by Shy and Thisse (1999). They analyze the firms' software protection policy in a duopoly model of horizontal product differentiation with price competition, assuming that consumer utility depends on the number of consumers who use the same software. Shy and Thisse show that firms decide to not protect their software when network externality is strong.

The possibility that firms can collude in markets for horizontally differentiated products has been analyzed by Chang (1991). He develops a model à la Hotelling in which producing cost is assumed to be zero, assuming that firms play trigger strategies as in Friedman (1971). His principal finding is that firms find more difficult to collude the smaller is the degree of product differentiation. Moreover, Häckner (1996) has shown that Chang's results are robust to changes in the mechanism of punishment for deviating from collusion.

Given the importance of network externalities in software market we assume that firms do not protect their software. We show that the greater the importance of the network externality the lower the scope for collusion among firms. We also show that firms collude if and only if their discount factor is high enough.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 obtains the static equilibriums and Section 4 obtains and analyzes the equilibrium in the supergame that we consider. Section 5 concludes.

[1] See Shy (2011) for a survey of network economics.

[2] In markets for piratable goods, price strategies become very important for deterring consumer from copying and from buying pirated goods (Papadopoulos (2003), Papadopoulos (2004), Bae and Choi (2006), Martínez-Sánchez (2010) and López-Cuñat and Martínez-Sánchez (2011)).

2. The model

Following Shy and Thisse (1999) we consider an environment in which there are two firms that produce two horizontally differentiated types of software, denoted by A and B. Both types of software are located at the endpoints of the interval [0,1], respectively. Software can be copied without cost by consumers.[3] In order to avoid problem of existence of equilibrium we follow the slightly modified model develop by Peitz (2004), although Shy and Thisse's results continue to hold in this environment. More specifically, we consider that there are two types of consumers: high-value consumers who obtain a high utility from any software, especially originals, and low-value consumers who obtain a low utility from any software and are indifferent whether it is an original or a copy. High-value consumers are indexed by $x \in [0,1]$ and low-value consumers are indexed by $y \in [0,1]$, where x and y follow a uniform distribution and represent the ideal software of consumers.

We assume that files of different software are incompatible and consumers' utility increases with the number of consumers using the same software whether it is an original or a copy. Let n_i be the number of consumers who use an original or a pirated version of the software $i=A, B$. High-value consumers are assumed to buy one unit of a software and not pirate any software. Thus, the utility of high-value consumer x is:

$$U(x)=\begin{cases} k+\mu n_A - x - p_A & \text{if he buys software } A \\ k+\mu n_B-(1-x)-p_B & \text{if he buys software } B, \end{cases} \tag{1}$$

where k represents the utility obtained from consuming his ideal and original software, μ is the parameter measuring the importance of the network externality, x ($1-x$) represents the disutility from not consuming his ideal software if he buys software A (B) and p_i is the price of the software $i=A, B$. On the other hand, low-value consumers are assumed to pirate at most one unit of the software or not to use any software. These consumers do not obtain extra utility from consuming his ideal software and from consuming an original software. Thus, the utility of low-value consumer y is:

$$U(y)=\begin{cases} \mu n_A - y & \text{if he pirates software } A \\ \mu n_B-(1-y) & \text{if he pirates software } B \\ 0 & \text{if he does not use software,} \end{cases} \tag{2}$$

where y ($1-y$) represents the disutility from not consuming his ideal software if he pirates software A (B). Let $\hat{y}_i$ be the low-value consumer who is indifferent between pirating software $i=A, B$ and not using any software. From (2), $\hat{y}_A=\mu n_A$ and $\hat{y}_B=1-\mu n_B$. Let $\hat{x}$ be the high-value consumer who is indifferent between buying software A and buying software B. From (1), $\hat{x}=(1+\mu(n_A-n_B)+p_B-p_A)/2$. Thus, the demands faced by firms are:

$$D_A(p_A,p_B)=\hat{x} \text{ and } D_B(p_A,p_B)=1-\hat{x}. \tag{3}$$

We assume that the cost incurred by firms in developing each software is a sunk cost and that production is costless. Thus, the firms' profits are:

[3] See Peitz and Waelbroeck (2006) for a survey of piracy in which copies are made exclusively by end consumers, and Belleflamme and Peitz (2010) for a survey of the recent theoretical literature on digital piracy.

$$\pi_A(p_A, p_B) = p_A \hat{x} \text{ and } \pi_B(p_A, p_B) = p_B(1-\hat{x}). \tag{4}$$

In order to guarantee that firms earn positive profits we assume that the network externality is bounded, $\mu \in (0,1/2)$. As in Shy and Thisse (1999) we also assume that $k > 3/2$, which means that high-value consumers always find it optimal to use a software.

Following Friedman (1971), we consider an infinitely repeated game in which firms play trigger strategies. In particular, firms start by charging collusive prices and continue charging these prices if neither firm has deviated in a previous stage. However, if either firm deviates in a stage, then both firms revert to the Nash equilibrium in the following stages. We assume perfect monitoring, so if a firm has deviated it is immediately detected but the punishment is implemented in the following stage.

We seek to find the subgame perfect equilibrium (SPE) of the infinitely repeated game. Thus, collusion on prices is an SPE of the game if and only if the present value of collusion profits exceeds the deviation profit plus the present value of the punishment profits of each firm, i.e. if and only if

$$\sum_{t=0}^{\infty} \delta^t \pi_i^C \geq \pi_i^D + \sum_{t=1}^{\infty} \delta^t \pi_i^N \ \forall i = A, B, \tag{5}$$

where δ represents the discount factor and π_i^C, π_i^D and π_i^N are the one period collusion, deviation and Nash profits of firm $i=A,B$, respectively. In order to make the paper more readable we eliminate subscript i on prices and profits.

In the next section, we look for the one period Nash equilibrium in duopoly and multiproduct monopoly and the firms' optimal deviation strategies from the collusion agreement.

3. Static Equilibrium

We now look for the punishment profits which are the Nash profits corresponding to the duopoly equilibrium. Shy and Thisse show that, in duopoly, there exists a symmetric equilibrium in which both firms price p^N and obtain the profit π^N, where

$$p^N = \frac{1-2\mu}{1-\mu} \text{ and } \pi^N = \frac{1-2\mu}{2(1-\mu)}. \tag{6}$$

When firms collude on prices, they behave as a multiproduct monopoly. Given that firms, A and B, are symmetrical and are located at the endpoints of the interval [0,1], they maximize profits by raising prices until the high-value consumer with preferences x=1/2 is indifferent between buying and not buying, so they price $p^C = k + \mu n_i^C - 1/2$. Notice that setting a lower price would not increase demand and setting a higher price would make some consumers decide not to buy. The number of consumers that use each software is

$$n_A = \hat{x} + \hat{y}_A; n_B = 1 - \hat{x} + 1 - \hat{y}_B.$$

From Lemma 2 in Shy and Thisse (1999) we show that the market for low-value consumers is partially covered, so that $\hat{y}_A = \mu n_A$ and $\hat{y}_B = 1 - \mu n_B$. Thus, we obtain the following proposition.

Proposition 1 *When both firms collude on prices, the price that they set and his profit are:*

$$p^C = k - \frac{1-2\mu}{2(1-\mu)} \text{ and } \pi^C = \frac{p^C}{2} = \frac{k}{2} - \frac{1-2\mu}{4(1-\mu)}. \tag{7}$$

Proof: see Appendix.

Given that $\mu \in (0,1/2)$ and $k > 3/2$, we find that $p^C > p^N$, which is opposing to the result obtained by Belleflamme and Picard (2007). This is because they assume that copying technology by consumers exhibits increasing returns to scale, which implies goods become complementary.

A firm deviates from collusion agreement if it is profitable. In this case, he can set a lower price and captures a fraction of the market if rival's price is low or captures the whole market if rival's price is high. If a firm decides to capture the whole market, he sets a price that makes the consumer that most dislikes its software indifferent between both software.[4] Therefore, the optimal deviation price is given by

$$p^D(p) = \begin{cases} \frac{p}{2} + \frac{1-2\mu}{2(1-\mu)} & \text{if } p \le \frac{3(1-2\mu)}{1-\mu} \\ p - \frac{1-2\mu}{1-\mu} & \text{if } p > \frac{3(1-2\mu)}{1-\mu}. \end{cases} \tag{8}$$

Given that $p^C = k - (1-2\mu)/2(1-\mu)$, the optimal deviation price and profit are

$$p^D = \begin{cases} \frac{k}{2} + \frac{1-2\mu}{4(1-\mu)} & \text{if } k \le \frac{7(1-2\mu)}{2(1-\mu)} \\ k - \frac{3(1-2\mu)}{2(1-\mu)} & \text{if } k > \frac{7(1-2\mu)}{2(1-\mu)}, \end{cases} \tag{9}$$

$$\pi^D = \begin{cases} \left(\frac{k}{2} + \frac{1-2\mu}{4(1-\mu)}\right)\left(\frac{1}{8} + \frac{k(1-\mu)}{4(1-2\mu)}\right) & \text{if } k \le \frac{7(1-2\mu)}{2(1-\mu)} \\ k - \frac{3(1-2\mu)}{2(1-\mu)} & \text{if } k > \frac{7(1-2\mu)}{2(1-\mu)}. \end{cases} \tag{10}$$

Notice that the cheating firm captures the whole market if k is high enough; otherwise he captures a fraction of the market.

4. Analysis

As we can see in Proposition 2 the cheating firm decides to deviate if and only if their discount factor is low enough.

Proposition 2 *Collusion is sustainable as an SPE if and only if*

$$\delta \ge \underline{\delta} = \frac{\pi^D - \pi^C}{\pi^D - \pi^N} = \begin{cases} \frac{4(1-\mu)^2 k^2 - 12(1-\mu)(1-2\mu)k + 9(1-2\mu)^2}{4(1-\mu)^2 k^2 + 4(1-\mu)(1-2\mu)k - 15(1-2\mu)^2} & \text{if } k \le \frac{7(1-2\mu)}{2(1-\mu)} \\ \frac{2(1-\mu)k - 5(1-2\mu)}{4[(1-\mu)k - 2(1-2\mu)]} & \text{if } k > \frac{7(1-2\mu)}{2(1-\mu)}, \end{cases} \tag{11}$$

where $\underline{\delta}$ represents the lowest discount factor that is needed to sustain collusion between firms.[5]

From Proposition 3 we obtain that a higher network externality hinders collusion

[4]We have that $\hat{x} = 1$, $n_A = 1/(1-\mu)$, $n_B = 0$ and $\hat{y}_A = \mu/(1-\mu) < 1$ (since $\mu < 1/2$) if firm A captures the whole market, but $\hat{x} = 0$, $n_A = 0$, $n_B = 1/(1-\mu)$ and $\hat{y}_B = (1-2\mu)/(1-\mu) > 0$ (since $\mu < 1/2$) if firm B captures the whole market. Thus, the market for low-value consumers is partially covered under deviation.

[5]This condition is obtained from inequality (5).

because it has a larger impact on deviation profit. In particular, an increase in the importance of the network externality implies a higher deviation profit because the deviation price increases and the cheating firm gets a higher fraction of the market or even the whole market.

Proposition 3 *The lowest discount factor that is needed to sustain collusion is increasing on μ.*

$$\frac{\partial \underline{\delta}}{\partial \mu} = \begin{cases} \frac{16k}{(5+2k-2\mu(5+k))^2} > 0 & \text{if } k \leq \frac{7(1-2\mu)}{2(1-\mu)} \\ \frac{k}{4(4\mu+k(1-\mu)-2)^2} > 0 & \text{if } k > \frac{7(1-2\mu)}{2(1-\mu)}. \end{cases}$$

We obtain that the lowest discount factor that is needed to sustain collusion positively depends on k in the limit case in which $\mu = 0$ for a positive value of k. However, in the limit case in which $\mu = 1/2$, it is independent of k since $\lim_{\mu \to 1/2} \underline{\delta} = 1/2$. Thus, it is possible that both firms collude even if the network externality becomes very large.

5. Conclusions

In this paper we analyze firms' ability to collude in markets for software and the consequences of network externality on that ability. The framework of analysis used is an infinitely repeated duopoly game of horizontal product differentiation with price competition.

According to our model firms tacitly collude if and only if they value future profits sufficiently, and a higher importance of the network externality hinders collusion. These results and those obtained in Martínez-Sánchez (2011) suggest that authorities should pay special attention to the evolution of markets for information goods to prevent tacit collusion between firms.

Appendix

Proof of Proposition 1 We make the conjecture that the market for high-value consumers is fully covered, so that firms set the price of each software in such a way that the consumer who is indifferent between buying software A and buying software B ($\hat{x}$), does not obtain utility if he buys any software. Thus, $p_A = k + \mu n_A - \hat{x}$ and $p_B = k + \mu n_B - (1 - \hat{x})$. Given that $n_A = \hat{x} + \hat{y}_A$, $n_B = 1 - \hat{x} + 1 - \hat{y}_B$, $\hat{y}_A = \mu n_A$ and $\hat{y}_B = 1 - \mu n_B$, we find that:

$$n_A = \frac{\hat{x}}{1-\mu}; \quad n_B = \frac{1-\hat{x}}{1-\mu}; \quad p_A = k - \frac{(1-2\mu)\hat{x}}{1-\mu}; \quad p_B = k - \frac{(1-2\mu)(1-\hat{x})}{1-\mu}.$$

The joint profit of the firms and the first order condition are:

$$\max_{\{\hat{x}\}} \pi(\hat{x}) = p_A\hat{x} + p_B(1-\hat{x}) = \left(k - \frac{(1-2\mu)\hat{x}}{1-\mu}\right)\hat{x} + \left(k - \frac{(1-2\mu)(1-\hat{x})}{1-\mu}\right)(1-\hat{x})$$

$$\frac{\partial \pi(\hat{x})}{\partial \hat{x}} = \frac{2(1-2\mu)(1-2\hat{x})}{1-\mu} = 0 \tag{12}$$

From the first order condition (12), we find that $\hat{x}^* = 1/2$ maximizes the joint profit. Thus, the software prices are:

$$p^* = p_A^* = p_B^* = k - \frac{1-2\mu}{2(1-\mu)}.$$

We will now show that our conjecture of the market for high-value consumers being fully covered was correct. If the prices are higher than p^*, then the market would be partially covered because those high-value consumers located around the center of interval [0,1] do not buy any software. In this case, we have that $n_A = \hat{x}_A + \hat{y}_A$ and $n_B = 1 - \hat{x}_B + 1 - \hat{y}_B$. Given that $\hat{y}_A = \mu n_A$ and $\hat{y}_B = 1 - \mu n_B$, the number of consumers that use software *A* and *B* are:

$$n_A = \frac{\hat{x}_A}{1-\mu} \text{ and } n_B = \frac{1-\hat{x}_B}{1-\mu}. \quad (13)$$

Notice that the firm *i=A, B* sets the price in such a way that the consumer who is indifferent between buying software *i=A, B* and not buying any software ($\hat{x}_i, i = A, B$) does not obtain utility if he buys the software. So that we have:

$$k + \mu n_A - \hat{x}_A - p_A = 0 \text{ and } k + \mu n_B - (1-\hat{x}_B) - p_B = 0. \quad (14)$$

From (13) and (14), we find that the number of buyers of each software is:

$$\hat{x}_A = \tfrac{1-\mu}{1-2\mu}(k-p_A); \quad 1-\hat{x}_B = \tfrac{1-\mu}{1-2\mu}(k-p_B).$$

When the market for high-value consumers is partially covered, the joint profit function and the first order conditions are:

$$\max_{\{p_A,p_B\}} \pi(p_A,p_B) = p_A\hat{x}_A + p_B(1-\hat{x}_B) = [p_A(k-p_A) + p_B(k-p_B)]\frac{1-\mu}{1-2\mu}$$

$$\frac{\partial\pi(p_A,p_B)}{\partial p_i} = (k-2p_i)\frac{1-\mu}{1-2\mu} \; i = A,B.$$

Given that we assume that *k > 3/2*, we obtain that:

$$\frac{\partial\pi(p_A^*,p_B^*)}{\partial p_i} = \left(\frac{1-2\mu}{1-\mu} - k\right)\frac{1-\mu}{1-2\mu} < 0 \; i = A,B.$$

Therefore, firms have no incentive to raise the prices above p^*, and the market for high-value consumers is fully covered. Given that $\hat{x}^* = 1/2$, we have that $\pi^*=p^*/2$.■

References

Bae, S.-H. and J. P. Choi (2006) “A Model of Piracy” *Information Economics and Policy* **18**, 303-320.

Belleflamme, P. and M. Peitz (2010) “Digital Piracy: Theory” CESifo Working Paper Series 3222, CESifo Group Munich.

Belleflamme, P. and P.M. Picard (2007) "Piracy and Competition" *Journal of Economic and Management Strategic* **16**, 351-383.

Brynjolfsson, E. and C. Kemerer (1996) "Network Externalities in the Microcomputer Software: An Econometric Analysis of the Spreadsheet Market" *Management Science* **32**, 255-280.

Chang, M-H. (1991) "The Effect of Product Differentiation on Collusive Pricing" *International Journal of Industrial Organization* **9**, 453-469.

Friedman, J. W. (1971) "A Non-cooperative Equilibrium for Supergames" *Review of Economic Studies* **38**, 1-12.

Gandal, N. (1994) "Hedonic Price Indexes for Spreadsheets and an Empirical Test of the Network Externalities Hypothesis" *RAND Journal of Economics* **25**, 160-170.

Gayer, A. and O. Shy (2003a) "Internet and Peer-to-Peer Distributions in Markets for Digital products" *Economics Letters* **81**, 197-203.

Gayer, A. and O. Shy (2003b) "Copyright Protection and Hardware Taxation" *Information Economics and Policy* **15**, 467-483.

Häckner, J. (1996) "Optimal Symmetric Punishments in a Bertrand Differentiated Products Duopoly" *International Journal of Industrial Organization* **14**, 611-630.

López-Cuñat, J. M. and F. Martínez-Sánchez (2011) "Anti-piracy policy and quality differential in markets for information goods" IVIE WP-AD 2011-02.

Martínez-Sánchez, F. (2010) "Avoiding Commercial Piracy" *Information Economics and Policy* **22**, 398-408.

Martínez-Sánchez, F. (2011) "Collusion, Competition and Piracy" *Applied Economics Letters* **18**, 1043-1047.

Papadopoulos, T. (2003) "Determinants of International Sound Recording Piracy" *Economics Bulletin* **10**, 1-9.

Papadopoulos, T. (2004) "Pricing and Pirate Product Market Formation" *Journal of Product and Brand Management* **13**, 56-63.

Park, Y. and S. Scotchmer (2006) "Digital Rights Management and the Pricing of Digital Products" *mimeo*.

Peitz, M. (2004) "A Strategic Approach to Software Protection: Comment" *Journal of Economic and Management Strategic* **13**, 371-374.

Peitz, M. and P. Waelbroeck (2006) "Piracy of Digital Products: A Critical Review of the Theoretical Literature" *Information Economics and Policy* **18**, 449-476.

Shy, O. (2011) "A Short Survey of Network Economics" *Review of Industrial Organization* **38**, 119-149.

Shy, O. and J.-F. Thisse (1999) "A Strategic Approach to Software Protection" *Journal of Economic and Management Strategic* **8**, 163-190.