STANDARDS COMPETITION AND COOPERATION AT THE COMPUTER HARDWARE AND SOFTWARE MARKET

Vladimir I. Soloviev
State University of Management, Moscow, Russia

ABSTRACT

The paper is motivated by competition and cooperation of hardware (Intel, AMD), operating systems (Microsoft Windows and Linux), and software applications (Microsoft Office and OpenOffice).

The objective of the paper is to show the conflicts in pricing and the frequency of new releases which is contrary to the general view of well aligned incentives of complementary network products.

The research of competing complementary products have started with the classic work of Cournot published in 1838. The usual modern approach in such studies is to consider network effects in complements competition as one-sided.

This paper presents some extensions and modifications of the dynamic model of Windows/Intel competition presented by Cassadesus-Masanell and Yoffie in 2007 who have introduced the two-sided network effects approach into research of competing complements. In this model the two-stage game is analyzed when at the first stage the competitors invest into R&D, and at the second stage they set prices. Cassadeus-Masanell and Ghemawat assumed that in each period of time a new "cohort" of potential users enters the market. We here measure the market size not in "cohorts" but in "users" assuming that the market is growing and in each period of time the fixed number of potential users enters the market.

Another extension to Cassadesus-Masanell and Ghemawat's model brings into consideration competitive interactions between Microsoft Windows and Linux, Intel and AMD, Microsoft Office and OpenOffice.

The mechanism of the conflict is investigated when Intel sets prices too high and supports Linux team, the major competitor of Microsoft, while Microsoft releases new versions too late and backs AMD, Intel's main competitor.

The investigation of hardware and software opposition provided in this paper is important for revealing the nature and mechanisms of competition at the knowledge markets. The model could be used as an instrument for decision-making at the IT market and as a basis for future research.

The assumption of linear market growth and particular attention given simultaneously to a conflicts between hardware and software manufacturers, competing software vendors, and competing hardware manufacturers form the basis of the model's originality.

INTRODUCTION

The paper is motivated by competition and cooperation of hardware (*Intel*, *AMD*), operating systems (*Microsoft Windows* and *Linux*), and software applications (*Microsoft Office* and *OpenOffice*).

The product at the personal workstations market is a combination of hardware and preinstalled operating system. At the modern PC workstations hardware market there is a duopoly of two manufacturers: *Intel* and *AMD*, and at the operating systems market there is a duopoly of commercial (proprietary) operating system *Microsoft Windows* and open source (free) OS *Linux*.

The software product cost is the sum of fixed cost, vendor profit (margin), variable cost and maintenance cost. Fixed costs of commercial and non-commercial software are quite small, variable costs of commercial and non-commercial software tend to zero (it costs almost nothing to write a CD or to put a release to Internet), maintenance costs of these two types of software are approximately equal, and the profit of commercial software vendor is positive while one of non-for-profit player is equal to zero. Non-for-profit players indeed earn their money but (opposed to profit-makers) not on sales but on maintenance.

The hardware product cost is also the sum of fixed cost, vendor profit, and maintenance cost, where fixed cost is relatively large, variable cost tend to zero (to produce a chip one should build a plant which is very expensive like several $M and then variable cost of one chip is less than $1), hardware maintenance cost is approximately equal to software maintenance cost, and the profit of hardware vendor is positive.

The objective of the paper is to show the conflicts in pricing and the frequency of new releases which is contrary to the general view of well aligned incentives of complementary network products.

The research of competing complementary products have started with the classic work of Cournot published in 1838.

There are several publications on network effects investigation in the IT economics [Brandenburger and Nalebuff (1996), Chen, Nalebuff and Nalebuff (2006), Choi and Stefanadis (2001), Dockner, Jorgensen, Van Long and Sorger (2000), Economides (1996), Farrell and Katz (2000), Katz and Shapiro (1985), McAfee, McMillan and Whinston (1989), Varian, Farrell and Shapiro (2004), Yu (1998)]. The usual modern approach in such studies is to consider network effects in complements competition as one-sided.

Some special attention to free software economics was put by Bitzer and Srhroder (2006), and the problem of Intel, Microsoft and Cisco leadership was diskussed by Gawer and Cusumano (2002).

The dynamic mixed duopoly of *Linux* and *Windows* was investigated by Casadesus-Masanell and Ghemawat (2006) and by Soloviev (2008a, 2008b). They combined the classic market duopoly theory with the demand-side learning and extended this approach to a dynamic situation where the objectives of players are mixed rather than symmetric.

Using the optimal control theory Casadesus-Masanell and Ghemawat (2006), and (with some extensions) Soloviev (2008a, 2008b) have obtained the conditions when *Linux* and *Windows* coexist at the market and when *Linux* is pushed out by *Windows* and vice versa are obtained and discussed. The special focus in these models was given to a piracy of *Windows* and strategic contribution to *Linux* issues.

This paper presents some extensions and modifications of the dynamic model of *Windows*/*Intel* competition presented by Cassadesus-Masanell and Yoffie in 2007 who have introduced the two-sided network effects approach into research of competing complements. In this model the two-stage game is analyzed when at the first stage the competitors invest into R&D, and at the second stage they set prices.

Cassadeus-Masanell and Ghemawat assumed that in each period of time a new "cohort" of potential users enters the market. We here measure the market size not in "cohorts" but in "users" assuming that the market is growing and in each period of time the fixed number of potential users enters the market.

Another extension to Cassadesus-Masanell and Ghemawat's model brings into consideration competitive interactions between *Windows* and *Linux*, *Intel* and *AMD*, *Microsoft Office* and *OpenOffice*.

The mechanism of the conflict is investigated when *Intel* sets prices too high and supports *Linux* team, the major competitor of *Microsoft*, while *Microsoft* releases new versions too late and backs *AMD*, *Intel*'s main competitor.

MODEL

We assume that *Intel* (denoted by *I* bottom index in all the formulae) is a monopolist at the workstation hardware market, and there are two competing products at the operating systems market: *Microsoft Windows* (denoted by *M*) which is commercial (proprietary), and *Linux* (denoted by *L*) which is free. Hardware and operating system are strictly complementary products which means that the bundle "hardware + operating system" is valuable for the customer while neither a PC alone nor an OS alone have any value for the user. It is reasonable because every computer is selling with preinstalled operating system, and the competition between Windows and Linux grows because for example at cheap notebooks segment the price of *Windows* makes more than 10% of the price of the combined product while *Linux* is free.

The buyers at the market value *Intel* more than *AMD* and they value *Windows* more than *Linux*, that's why *Intel* and *Microsoft* are not pushed out from the market but dominate there. *AMD* is cheaper than Intel, and *Linux* is free while the price of Windows license is positive that's why *AMD* and *Linux* co-exist at the market with *Intel* and *Microsoft*.

Let us denote $q_{\max}$ the size of the computer workstations market, C_I the maximal price of a PC with *Linux* C_{I+M} the maximal price of *Intel*-based PC with *Windows* (it is assumed that users value PC with *Windows* more than PC with *Linux*), and use the linear demand functions

$$q_{I+M}(c) = q_{\max}\left(1-\frac{c}{C_{I+M}}\right), \tag{1}$$

and for *Intel*-based PC with *Microsoft Windows*

$$q_{I+L}(c) = q_{\max}\left(1-\frac{c}{C_I}\right) \tag{2}$$

for the PC with *Linux*.

Then if *Intel* sets the price for a PC at c_I, and *Microsoft* sets the price for *Windows* at c_M the demand for PCs with *Windows* will be

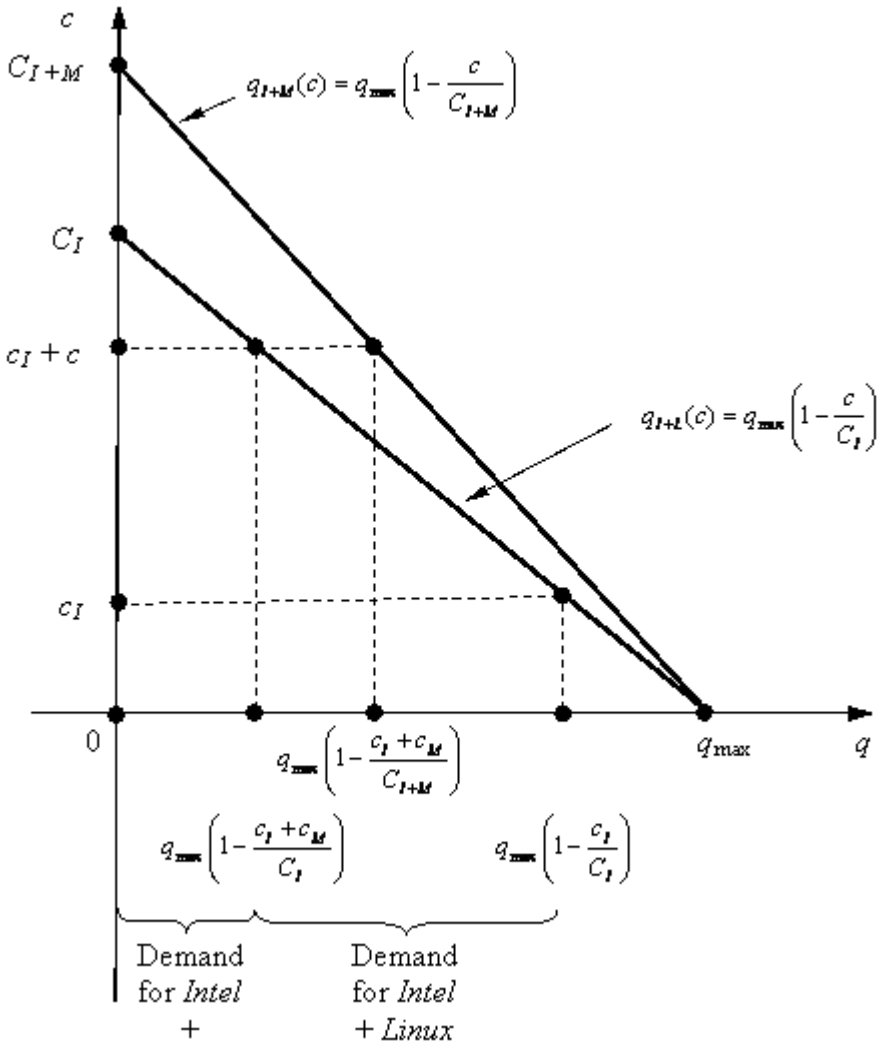
$$q_M = q_{\max}\left(1-\frac{c_I+c_M}{C_I}\right), \tag{3}$$

and the demand for PCs with *Linux* will be

$$q_L = q_{\max}\left(1-\frac{c_I}{C_I}\right) - q_{\max}\left(1-\frac{c_I+c_M}{C_I}\right) = q_{\max}\frac{c_M}{C_I}. \tag{4}$$

It means that a user will buy a PC with *Windows* if and only if he or she value this product more than its price (see Fig. 1).

Figure 1. Demand functions



The overall demand for *Intel* is

$$q_I = q_{\max}\left(1-\frac{c_I+c_M}{C_I}\right)+q_{\max}\frac{c_M}{C_I} = q_{\max}\left(1-\frac{c_I}{C_I}\right). \quad (5)$$

It is important that the demand on *Linux*-based PCs depends only on *Windows* price but not on the PC price, and overall demand for *Intel* depends only on *Intel* hardware price but not on the PC price, while the demand on *Windows*-based PCs depends on *Windows* price and on the hardware price!

If f_I and v_I are fixed and variable costs for *Intel*-based PC, and f_M and v_M are fixed and variable costs for *Microsoft Windows*, then we can state the problem of *Intel*:

$$\pi_I = q_I\left(c_I - v_I\right) - f_I = q_{\max}\left(1-\frac{c_I}{C_I}\right)\left(c_I - v_I\right) - f_I \to \max, \quad (6)$$

and the problem of *Microsoft*:

(7) $$\pi_M = q_M\left(c_M - v_M\right) - f_M = q_{\max}\left(1 - \frac{c_I + c_M}{C_I}\right)\left(c_M - v_M\right) - f_M \to \max .$$

Here π_I and π_M are the profits of *Intel* and *Microsoft*.

INVESTIGATION

The first-order conditions for *Intel* problem gives us its solution:

(8) $$\frac{d\pi_I}{dc_I} = 0 \Leftrightarrow q_{\max}\frac{C_I - 2c_I + v_I}{C_I} = 0 \Leftrightarrow c_I^* = \frac{C_I + v_I}{2},$$

and the maximal profit of *Intel* is

(9) $$\pi_I^* = q_{\max}\frac{\left(C_I - v_I\right)^2}{4C_I^2} - f_I .$$

Then *Microsoft*'s best response function could be found from the following conditions:

(10) $$\left.\frac{\partial\pi_M}{\partial c_M}\right|_{c_I = c_I^* = \text{const}} = 0 \Leftrightarrow q_{\max}\left(\frac{C_I + v_M - c_I^* - 2c_M}{C_I}\right) = 0 \Leftrightarrow c_M^* = \frac{C_I + v_M - c_I^*}{2} \Leftrightarrow c_M^* = \frac{C_I + 2v_M - v_I}{4},$$

and the maximal profit of *Microsoft* is

(11) $$\pi_M^* = q_{\max}\frac{\left(C_I - 2v_M - v_I\right)^2}{16C_I} - f_M .$$

RESULTS

We can see that

(12) $$\frac{\partial c_M^*}{\partial c_I^*} = -\frac{1}{2}$$

which means that if *Intel* raise the price by $1 then *Microsoft* should cut the price by 50 cents.

Let us find the conditions when *Intel*'s profit is greatest than *Microsoft*'s:

(13)

$$\pi_I^* > \pi_M^* \Leftrightarrow q_{\max}\frac{\left(C_I - v_I\right)^2}{4C_I^2} - f_I > q_{\max}\frac{\left(C_I - 2v_M - v_I\right)^2}{16C_I} - f_M \Leftrightarrow q_{\max}\frac{4\left(C_I - v_I\right)^2 - \left(C_I - 2v_M - v_I\right)^2}{16C_I\left(f_I - f_M\right)} > 0 \Leftrightarrow$$

$$\Leftrightarrow q_{\max}\frac{\left(3C_I - 3v_I - 2v_M\right)\left(C_I + 2v_M - v_I\right)}{16C_I\left(f_I - f_M\right)} > 0.$$

We can assume that $f_I > f_M$, $C_I + 2v_M > v_I$, therefore *Microsoft*'s profit is greater than *Intel*'s if and only if

$$v_M < \frac{3(C_I - v_I)}{2}, \quad (14)$$

and this condition is executed in practice.

The competitive interactions between *Windows* and *Linux*, *Intel* and *AMD*, *Microsoft Office* and *OpenOffice* will be discussed, and the mechanism of the conflict when *Intel* sets prices too high and supports *Linux* team, the major competitor of *Microsoft*, while *Microsoft* releases new versions too late and backs *AMD*, *Intel*'s main competitor.

The differences between this model and a model when there are just two vendors of complementary products (*Intel* and *Microsoft*) are discussed as well.

REFERENCES

Bitzer, J. and P.J.H. Srhroder (Eds.). *The Economics of Open Source Software Development*. Amsterdam: Elsevier, 2006.

Brandenburger, A. and B. Nalebuff. *Co-Opetition*. New York: Doubleday, 1996.

Casadesus-Masanell, R. and P. Ghemawat. "Dynamic Mixed Duopoly: A Model Motivated by Linux vs. Windows," *Management Science*, Vol. 52, No. 7 (July 2006): 1072-1084.

Casadesus-Masanell, R. and D.B. Yoffie. "Wintel: Cooperation and Conflict," *Management Science*, Vol. 53, No. 4 (April 2006): 584-598.

Chen, M., K. Nalebuff and B. Nalebuff. "One-Way Essential Complements," *Cowles Foundation Discussion Paper*, No. 1588 (2006).

Choi, J. and C. Stefanadis. "Tying, Investment, and the Dynamic Leverage Theory," *RAND Journal of Economics*, Vol. 32, No. 1 (2001): 52-71.

Cournot, A.-A. *Recherches sur les principes mathematic de la theorie des richesses*. Paris: Calmann Levy, 1838.

Dockner, E., S. Jorgensen, N. Van Long and G. Sorger. *Differential Games in Economics and Management Science*. Cambridge: Cambridge University Press, 2000.

Economides, N. "The Economics of Networks," *International Journal of Industrial Organization*, Vol. 14, No. 2 (1996): 675-699.

Farrell, J. and M.L. Katz. "Innovation, Rent Extraction, and Integration in Systems Markets," *Journal of Industrial Economics*, Vol. 48, No. 4 (2000): 413-432.

Gawer, A. and M. Cusumano. *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*. Boston: Harvard Business School Press, 2002.

Katz M.L. and C. Shapiro. "Network Externalities, Competition, and Compatibility," *The American Economic Review*, Vol. 75, No. 3. (June 1985): 424-440.

McAfee, P., J. McMillan and M. Whinston. "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values," *Quarterly Journal of Economics*, Vol. 104, No. 2 (1989): 371-383.

Soloviev, V.I. "Duopoly of Linux and Microsoft as competing server operating systems," *Evolution and Revolution in the Global Knowledge Economy: Enhancing Innovation and Competitiveness Worldwide: Global Business and Technology Association Tenth International Conference: Readings Book*. New York: GBATA, 2008: 1041-1044.

Soloviev, V.I. "Mathematical modelling of strategic commitments and piracy in Windows / Linux competition," *2008 International Conference on Management Science and Engineering: 15th Annual Conference Proceedings*. Piscataway: IEEE, 2008: 10-12.

Varian H.R., J. Farrell and C. Shapiro. *The Economics of Information Technology: An Introduction*. Cambridge: Cambridge University Press, 2004.

Yu, A. *Creating the Digital Future*. New York: Free Press, 1998.

