V.I. Soloviev, Ph.D.
State University of Management, Moscow, Russia

CURRENT STATE OF WINDOWS/LINUX COMPETITION IN THE EAST-ASIAN SERVER OPERATING SYSTEMS MARKET

The paper is motivated by Microsoft Windows and Linux competition at the server operating systems market. Microsoft/Linux mixed duopoly dynamics is analyzed using optimal control mathematical model where Microsoft is considered as a profit-maximizing competitor while Linux as an open source software project is assumed non-for-profit.

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 attention in the model presented is given to a piracy of Windows and strategic contribution to Linux issues which for the first time were discussed also by Cassadeus-Masanell and Ghemawat (2006).

Introduction. At the moment all the software users are choosing between the three options:

- to buy licenses and use the commercial software (e. g. Microsoft Windows as an operating system, Microsoft Office as an office suite, Microsoft SQL Server as a database server, Microsoft Internet Information Server as a web server, etc.);
- to use free or open source software (e. g. Linux as an operating system, OpenOffice as an office suite, MySQL as a database server, Apache as a web server, etc.);
- to pirate (i. e. to use the commercial software without buying licenses.

These options correspond to three types of software market players:

- profit-maximizers (for example, Microsoft);
- non-for-profit players (for example, Linux team);
- pirates.

In this paper we do not differentiate free and open source software, we refer to these two types of software as non-commercial software.

At the software market the product cost is the sum of fixed cost, vendor profit (margin), and maintenance cost. Fixed costs of commercial and non-commercial software tend to zero, 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 pirating at the software market is legally prohibited (this prohibition is hardly stimulated by for-profit players, especially by Microsoft). We discuss the software pirating in Soloviev (2008), here we concentrate mostly on the duopoly of commercial and non-commercial software.

It may appear that the buyer's choice is very simple: to use non-commercial software due to significantly lower cost of ownership (and some other advantages in case of open software where the user can directly affect the product quality). But the situation is much more complex because at the start point of competition between commercial and non-commercial software (in early 1990's) almost 100% of the market were occupied by for-profit players and it was very difficult for non-commercial players to distribute their products widely due to high authority of famous commercial products, and almost absolutely no awareness of free software reliability, security, etc. It is known that in 1994 Linux has 0% of server operating systems market, and now Linux has something about 40% of this market (and approximately the same share of market is occupied by Microsoft Windows).

The paper is motivated by Microsoft Windows and Linux competition at the server

operating systems market. Microsoft/Linux mixed duopoly dynamics is analyzed using optimal control mathematical model where Microsoft is considered as a profit-maximizing competitor while Linux as an open source software project is assumed non-for-profit.

The history of duopoly studies begins with the works of Cournot (1838), Stackelberg (1934), et al who have studied the symmetric duopolies, while the duopoly of commercial and non-commercial software is asymmetric. In addition, the solutions of Cournot, Stackelberg, Arrow, Nash, et al are static but the main interest at the moment is on the dynamics of software market competition.

The software market players compete in the presence of learning-by-doing (which means that the authority of non-commercial products is growing while the users are learning using these products). The learning-by-doing competition theory initiated by Spence (1981) is focused on the impact of cumulated output on cost reduce.

The prior research of commercial and non-commercial software competition was focused mainly on the customer choice as make-or-buy decision see, e.g., Kuan (2001). .

Lee and Mendelson (2008) assume that the software market consists of two customer segments with different preferences and is characterized by positive network effects. The commercial player makes product and pricing decisions to maximize its profit. The non-commercial player make product decisions to maximize the weighted sum of the segments' consumer surplus, in addition to their intrinsic motivation.

One of the recent steps in the duopoly theory was to combine the classic market duopoly theory with the demand-side learning and to extend this approach to a dynamic situation where the objectives of players are mixed rather than symmetric. This step was done by Cassadeus-Masanell and Ghemawat (2006) who have presented a dynamic mixed duopoly model and applied this model to Windows/Linux competition dynamics investigation.

This paper presents some extensions and modifications of Cassadeus-Masanell and Ghemawat's model. Cassadeus-Masanell and Ghemawat assumed that at the demand side of the model in each period of time a new cohort of potential users enters the market, and the size of this cohort does not depend on time. We here assume that the cohort size is increasing exponentially. It is important that the demand side is learning and it affects the cost side. Another addition to the Cassadeus-Masanell and Ghemawat's model is that the cost investments in learning are endogenous.

Using the optimal control theory we obtain 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 attention in the model presented is given to a piracy of Windows and strategic contribution to Linux issues which for the first time were discussed also by Cassadeus-Masanell and Ghemawat (2006).

We use some results obtained in our works Soloviev (2008a), Soloviev (2008b), Soloviev (2007a), Soloviev (2007b), Soloviev (2005), Soloviev (2004a), Soloviev (2004b) as well as some very recent and unpublished results.

The model. The model presented in this paper is modification of Cassadeus-Masanell and Ghemawat's model (2006).

We assume that the operating systems market grow at rate ν. Let $q(t)$ be the portion of new users entering the market at the moment t, who buy Windows, $\rho(t)$ — the portion of new users who pirate Windows, $\varepsilon(t)$ — the portion of new users who are strategically commited to Linux; each user can either buy Windows, or pirate Windows, or download Linux, $y_W(t)$ and $y_L(t)$ — the cumulative number of Windows and Linux users respectively, w. Then

$$\frac{dy_W(t)}{dt} = \nu q(t), \tag{1}$$

$$\frac{dy_L(t)}{dt} = \nu\big(1-q(t)\big). \tag{2}$$

Let the demand functions of Windows and Linux be linear:

$$p = \alpha_W\big(y_W(t) - sy_L(t)\big)\big(1-q(t)\big) \tag{3}$$

and

$$p = \alpha_L\big(y_W(t) - sy_L(t)\big)\big(1-q(t)\big), \tag{4}$$

here p is the OS's value to a user, $s > 0$ is the strength of Linux (which means that the increase of s corresponds to strengthening of Linux due to network externalities),

$$\alpha_W\big(y_W(t) - sy_L(t)\big) \quad \text{and} \quad \alpha_L\big(y_W(t) - sy_L(t)\big)$$

are S-shaped technological curves see Foster (1988). of Windows and Linux.

When Linux is free and Windows is available at the moment t at price

$$p(t) \geq 0, \tag{5}$$

the portion of customers, precisely indifferent between two operating systems, is given by the next formula:

$$\begin{aligned}&\alpha_W\big(y_W(t) - sy_L(t)\big)\big(1-q(t)-\rho(t)-\varepsilon(t)\big) - p(t) = \\ &= \alpha_L\big(y_W(t) - sy_L(t)\big)\big(1-q(t)-\rho(t)-\varepsilon(t)\big).\end{aligned} \tag{6}$$

Hence

$$\begin{aligned}&p(t) = \big(\alpha_W\big(y_W(t) - sy_L(t)\big) - \alpha_L\big(y_W(t) - sy_L(t)\big)\big)\times \\ &\times\big(1-q(t)-\rho(t)-\varepsilon(t)\big)\end{aligned} \tag{7}$$

At the initial moment (t = 0) we assume that

$$\alpha_W\big(y_W(0) - sy_L(0)\big) > \alpha_L\big(y_W(0) - sy_L(0)\big). \tag{8}$$

Microsoft is willing to maximize its integral discounted (at the rate) profit:

$$J\big(p(t)\big) = \int_0^{+\infty} \nu q(t) p(t) \mathrm{e}^{-\delta t}\, dt \to \max \tag{9}$$

subject to (1), (2), (5), (7), (8).

Results and discussion. Now, China is beginning to look at open source software as a way out of the intellectual property quagmire that doesn't involve paying high costs. Linux is a keystone in this strategy.

There are many driving forces behind Linux adoption by various individuals and organizations, including security and stability, innovation and flexibility, empowerment of the skilled programmer and cost savings in development and deployment.

The most popular Linux distributions, for example, in China are Red Flag, TurboLinux, Sunwah and Ubuntu.

Not far ago the state-owned Industrial and Commercial Bank of China (ICBC) decided to roll out Linux in all of its 20,000 retail branches. The news was trumpeted by Turbo Linux, the Tokyo-based vendor that won the contract. ICBC has 100 million customer accounts, and 8 million corporate accounts. It is the largest bank in China, and will buy an unrestricted

user license and integrate Linux throughout its entire banking operations network over the next three years. It's the largest Linux deployment to date in the Chinese financial industry.

The bank will use Linux as the basis for its web server and a new terminal platform, and TurboLinux will provide three years of upgrade availability, virus protection, and maintenance service support. TurboLinux said that ICBC was looking to business with a company that was involved in systems research, development, and service, has a proven track record, meets deadlines, and can offer long-range and immediate technical support. And that's just the beginning, said Tony Le, deputy general manager for TurboLinux China. He promised more customer announcements in the Chinese government and financial sectors in the next few months.

Linux has, by the way, a significant market share not only in the server operating systems market, but also in desktop OS market. For example, as of 2006, Red Flag Linux had more than 80% market share for Linux desktops in China (at province and city governments even 95%). In September 2006, Dell and HP announced to sell Red Flag Linux Desktop 5.0 in China pre-installed on desktop computers and notebooks.

So the Linux market share is expected to grow rapidly not only in the server operating systems market but in the desktop operating systems market too.

The main result of the paper is formulated as follows: piracy does not help Microsoft to maximize its profit, but helps Microsoft to keep the market share in the East Asia, and the strategic commitments to Linux lead to the opposite changes in Windows/Linux competition.

References

1. Cassadeus-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.

2. Cournot, A.A. Recherches sur les Principes Mathématiques de la Théorie des Richesses. Paris: Hachette, 1838.

3. Foster, R. Innovation: The Attacker’s Advantage. New York: Summit Books, 1986.

4. Kuan, J.W. “Open Source Software as Consumer Integration Into Production” (January 2001), Available at SSRN: http://ssrn.com/abstract=259648.

5. Lee, D and H. Mendelson. “Divide and Conquer: Competing with Free Technology Under Network Effects”, Production and Operations Management, Vol. 17, No. 1 (January-February 2008): 12-28.

6. 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, 2008: 1041-1044.

7. Soloviev, V. I. “Game Theory Model of the Conflict in the Market of Licenced and Pirate Software**”,** Mathematical Methods in Technnology MMTT-21, 2008 (8): 108-109 (in Russian).

8. Soloviev, V. I. “Real Options As a Tool for Innovative Projects Evvectiveness Evaluation”, State University of Management Bulletin (Vestnik Universiteta), 2007 (19): 320—329 (in Russian).

9. Soloviev, V. I. “Optimal Control of Innovations Diffusion”, Mathematical Modelling of Social and Economical Dynamics MMSED—2007: 246—248 (in Russian).

10. Soloviev, V. I. “Pontryagin’s Maximum Principle for the Distributed Systems Optimal Control Problems with Partial Differential Equations of Movement”, State University of Management Bulletin (Vestnik Universiteta), 2005 (10): 71—80 (in Russian).
11. Soloviev, V. I. “Optimal control of distributed systems and its applications in economics”, Mathematical Modelling of Social and Economical Dynamics MMSED—2004: 343—346 (in Russian).
12. Soloviev, V. I. “The Generalized Maximum Principle as a Necessary Condition of Optimum in the Distributed Optimal Control Problem with Partial Differential Equations of Movement”, Surveys in Applied and Industrial Mathematics (Obozrenie prikladnoi i promyshlennoi matematiki), 2004 (11): 120—122 (in Russian).
13. Spence, A.M. “The Learning Curve and Competition”, The Bell Journal of Economics, Vol. 12, No. 1 (Spring 1981): 49-70.
14. von Stackelberg, H. Marktform und Gleichgewicht. Vienna: Springer, 1934.