DIW Diskussionspapiere
Discussion Papers

Discussion Paper No. 231

Erosion of Monopoly Power due to the Emergence of Linux

by
Jürgen Bitzer

Berlin, November 2000

Deutsches Institut für Wirtschaftsforschung, Berlin
Königin-Luise-Str. 5, 14195 Berlin
Phone: +49-30-89789- 0
Fax: +49-30-89789- 200
Internet: http://www.diw.de
ISSN 1433-0210

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Jürgen Bitzer*

November 20, 2000

Abstract

The emergence and market success of Linux in recent years has been impressive. Contrary to common belief, commercial enterprises are active only in the provision of services (including distribution) related to Linux. The emergence of this service market has paved the way for Linux to become a low-cost product and a serious competitor in formerly monopolistic market segments. This paper demonstrates that there is no a priori reason why the incumbents should necessarily survive in these segments. Their exit would, in fact, lead to these segments' collapse. A simple model is used to show that the emerging price pressure on the former monopolists depends on the extent of the current heterogeneity between Linux and the operating systems of the incumbents and thus ultimately on customers' preferences. The absence of development costs for Linux distributors leads to cost advantages on the part of the entrants. This could lead the incumbents to stop development of their operating systems when the extent of product differentiation supported by the market no longer permits coverage of the their average costs. This in turn would result in the collapse of the respective market segments, as new entrants would offer only services related to Linux.

*German Institute for Economic Research (DIW). The author would like to thank Wolfram Schrettl for important contributions, Matthias Bahr for research assistance, Mechthild Schrooten for very helpful comments, SuSE GmbH, Nuremberg, for providing helpful information and Deborah Anne Bowen for proofreading the paper. The usual disclaimer applies.

1 Introduction

In these times of the anti-trust case against Microsoft and the high degree of software piracy, academic and public discussion often emphasizes the need for monopoly rents compensating research and development (R&D) expenditures as an incentive for progress in innovation. But this discussion often neglects the fact that in recent years, the highly innovative open-source operating system Linux has emerged in the shadow of Microsoft and the other huge commercial software producers, and is presently developing and spreading faster than any of its competitors. The hypothesis put forward in this paper is that the emergence of Linux is leading to the erosion of monopoly power in formerly non-contestable market segments.

The paper is structured in the following way. Section two describes the emergence and development of Linux in the last several years. In the third section, the participation of commercial enterprises in the recent development of Linux is examined more closely. In section four, the market structures existing before Linux's entry are described in brief. Section five introduces a Launhardt-Hotelling oligopoly model and with its help analyzes the current conditions on the formerly monopolistic markets. Section six discusses possible future developments of the operating system market segments. The last section concludes.

2 The short history of Linux

Linux[1] was an outsider among operating systems for quite some time. The open source operating system is being developed constantly by many programmers world-wide via the Internet and is also available via the Internet for free. After spending the last few years as a niche product intended for advanced users, Linux has established itself in the software market, particularly in the market for server operating systems. Linux[2] was born in August 1991 when Linus Benedict Torvalds[3], a then 21 year old student at the University of Helsinki in Finland, made his Linux kernel 0.01 available on the Internet. Torvalds started developing Linux with the aim of creating an operating system for his AT-386 PC; he was inspired by Mimix, a small Unix system developed by Andy S. Tanenbaum. From the beginning, Torvalds

[1]Linux is a registered trademark of Linus Torvalds (German trademark 2088936 and EU Registered Trademark 000851246, as well as in the USA).

[2]The term "Linux" refers only to the kernel, i.e. the basis of the operating system.

[3]Linus Torvalds official homepage can be found at [www.cs.helsinki.fi/u/torvalds/]. Further background information directly from Torvalds can be found in Torvalds (1999).

distributed his source code freely and therefore found an interested hacker community which supported the development of Linux. Whereas in 1991 the kernel was very limited in its use (e.g. no floppy driver available), in January 1992, version 0.12 was already a stable, smoothly functioning kernel to which important programming tools and utilities such as the GNU C-Compiler and the bash[4] had already been ported.[5] In March 1994, the first "official" version 1.0 of Linux was announced by Torvalds.[6] Due to the huge number of freely available utilities of the Free Software Foundation (FSF)[7], for which an operating system kernel did not exist, Linux was quickly equipped with the necessary tools. The current version of the kernel is 2.2.14, with the release of version 2.4 planned for the end of 2000.[8]The following table shows the rapid development of Linux in terms of estimated users and written lines of codes.

Table 1: Development of Linux 1991-2000

Year	**Version**	**Users**	**Lines of code**
1991	0.01	1	10,000
1992	0.96	1,000	40,000
1993	0.99	20,000	100,000
1994	1.0	100,000	170,000
1995	1.2	500,000	250,000
1996	2.0.xx	1,500,000	400,000
1997	2.0.2x	3,500,000	800,000
1998	2.0.3x	7,500,000	1,500,000
1999	2.2	12,000,000	2,300,000
2000	2.4	18,000,000	2,800,000

Source: McHugh (1998), information from SuSE, own enquiries.

The recent announcements of big IT companies such as IBM, SAP, Oracle, Siemens, etc. to offer professional support for Linux show that it has reached

[4]A command interpreter.

[5]Cf. Moody (1997).

[6]The history of Linux's development can be found at the following Internet sites: [www.linux.org] and [www.linuxinfo.de].

[7]The Internet web page for the Free Software Foundation can be found at [www.fsf.org]. The kernel of the FSF is called HURD.

[8]Cf. [www.linuxhq.de] , [www.kernel.org] and [www.kernelnotes.org]. Stable kernels receive even version numbers. Versions still in development, such as the current 2.3.99-pre3, are designated with odd numbers.

a level of quality at which it can be used in professional business applications. According to the International Data Corporation (IDC), Linux has conquered second place, behind Microsoft's Windows NT, in the market segment for server operating systems.[9]

Linux overtook Novell's Netware from 1998 to 1999, and in 1999 had a market share of 25%. This means that the number of Linux copies sold doubled within a year. However, the market study analyzed only the number of copies sold. The 1999 sales figures for Linux were given as 1.35 million copies. Windows NT saw sales of 2.1 million units, i.e. a 38% share in the market for server operating systems. However, such market studies into open source software, and in particular Linux, may be misleading because many Linux customers obtain their versions via the Internet for free, rather than via distributors. Furthermore, in contrast to commercial operating systems, one copy of Linux, which would count as a single unit statistically, can be installed legally on a number of computers for numerous users. Therefore, determining the actual usage and therefore market share based on sales figures appears to be misleading. However, given that sales of Linux units have grown almost four times, this alone is an impressive indicator of the rapid spread of the open-source operating system. Sales of Linux client operating systems, which are used by typical desktop and laptop computers, have also increased according to the IDC. With a market share of 4%, which equals around 3.9 million desktop installations, Linux is just behind MacOS with 5%. Microsoft still maintains its dominant position of around 90% market share with its Windows range of operating systems.

Table 2: Market share for server operating systems, units sold in %

Operating system	**1998**	**1999**
WindowsNT	38	38
Linux	16	25
Netware	23	19
Unix	19	15
Other	4	3

Source: International Data Corporation (URL: www.idc.com).

However, the financial dimension of system market shares should also be taken into account. Although Linux holds a strong second place behind Microsoft with 1.35 million units sold, the profits of the distributors

[9]Information on the Internet site of IDC, URL: [www.idc.com] date: 13th March 2000.

are, in comparison to other sellers, relatively low. While Microsoft earnings amounted to US$ 1.7 billion in 1999, Linux distributors in the same period recorded only US$32 million. The commercial Unix variants, in fourth place with respect to market share, earned 53% of the market value of US$ 5.7 billion. Commercial Unix computers are more likely to be found in expensive and complex installations, instead of the typical NT or Linux servers.

Various sources[10] indicate that there might be 10-12 million Linux users world-wide, with eight million machines running Linux. The increasing commitment in the commercial sphere suggests that these figures, which have been the result of Linux's self-assertion in the software market and of the support of developers, are now creating interest among companies, who for a long time regarded the terms 'open-source code' and 'free software' as suspect.

3 Business in connection with Linux

The successful non-commercial development of Linux and the fact that the GNU General Public License[11] (GNU GPL) guarantees free access to and use of Linux's source code and free distribution of Linux to anyone interested has created a need for new business models. Currently, roughly two different models can be identified. On the one hand, there are the enterprises which use Linux for product differentiation, and on the other, there are enterprises which offer services in connection with Linux. A market for the *product* Linux does not exist.

3.1 Diversification through Linux

The overwhelming majority of the recent announcements made by large IT-enterprises in connection with Linux were of plans to start supporting Linux. This basically means that they intend to expand their product range to include Linux. There are two different ways of doing so. Hardware producers use Linux for a diversification of their products. Thus, is it now possible to get a Netfinity server from IBM with the Linux operating system, which certainly leads to lower costs of the server. The same is true for the main competitors

[10] Cf. [www.linux.de]. How many users actually use the Linux programs available via the Internet and how many machines use Linux as their operating system is unknown because of the open-source character of the product. An attempt to determine the total number of machines and users world-wide can be found at [counter.li.org]. However, the figures are based on voluntary registration over the Internet.

[11] The exact wording of the GNU GPL can be found at [www.linux.de/linx/gnu.html] or the pages of the Free Software Foundation at [www.fsf.org/copyleft/gpl.html].

of IBM in the server market, such as Sun, Siemens, Dell, and so on. Linux has been introduced by the server producers even though it competes against their own developed proprietary operating systems. In the long term, this development could bring production of their own operating systems to a halt, which on the other hand would omit the immense development costs. The result of this growing support by hardware producers is that Linux is now already available for a large number of hardware platforms (see table 3).

Table 3: Linux supported hardware platforms

Manufacturer	**Processor**
Intel	i386, i486, Pentium series, Celeron, IA-64
AMD	K5, K6, Athlon
Cyrix	386, 486, 6x86
IDT	IDT C6
Sun	SPARC,UltraSPARC
Compaq	Alpha AXP
Macintosh	PowerPC
IBM	PowerPC, RS65 SMP III
MIPS Technologies	MIPS family
Motorola	PowerPC, Motorola 68000 (Atari ST, Amiga)
ARM	ARM Thumb family
Hitachi	SuperH
Hewlett Packard	PA-RISC

Source: Information on (URL: www.kernel.org).

In the case of supporting software enterprises, the situation is slightly different. Here it should be noted that Linux is supported by application software producers who extend their product range to the new open-source operating system. Furthermore, the transfer of a software program written for UNIX to Linux is much easier than one written for Windows. Thus, SAP announced at the CeBIT two years ago that it was going to begin offering its business software R/3 for Linux. Only one year later, the supply of products catering to the open-source operating system is mushrooming. For example, the data banks DB 2, Oracle8i and Informix, by IBM, Oracle and Informix respectively, are available, as well as Wordperfect 8, QuattroPro and CorelPresentations by Corel and StarOffice from Sun. Even Microsoft seems to be starting initial attempts to port its Office Suite to Linux.[12]

[12] Cf. Thurrott (2000).

But whereas the hardware producers have to invest in Linux to implement it on their hardware platforms, and the investments have to be shared with the whole Linux community, the support of application software producers only requires investments in their own proprietary software products. IBM has started an internal Linux initiative, which aims at supporting the development of Linux with 200 programmers, i.e. upgrading Linux to achieve compatibility with all IBM hardware platforms from laptops to supercomputers.[13]

3.2 Services: the core business with Linux

Given that Linux itself cannot generate revenues the way normal products do, enterprises have found profit opportunities in providing support services. The expansion of the market for services for Linux is pushed further by the increasing acceptance of Linux and its market diffusion. Very early on, a handful of small enterprises had recognized the opportunities of this service market segment and set up specialized enterprises which exclusively offer services for Linux. At present, the most important of these firms are: Red Hat (Durham, USA), SuSE (Nuremberg, Germany), Caldera (Orem, USA), Debian (Boston, USA) and Slackware (Concord, USA). The following consultants should also be mentioned: VA Linux Systems (Sunnyvale, USA), Linuxcare (San Francisco, USA) and TurboLinux (Brisbane, USA), ID-Pro (Bonn, Germany), Innominate (Bonn, Germany) and Linux Information Systems AG (Berlin, Munich, Germany).[14]

The services provided for Linux users comprise installation and configuration assistance along with the compilation and development of current open-source software and solutions for Linux, in addition to the delivery of commercial software products. Advice and support is also available, and can range from 24-hour hotlines to remote monitoring and training in Linux. Among these service activities, distribution - which includes installation and configuration activities - is still the largest part of the business.[15] A closer look at the GNU GPL, under which Linux was set up, makes it clear that the

[13] IBM took over a leading role in the support of Linux. This can be explained by IBM's very broad business range, which includes hardware, middleware and technical services. IBM expects to boost the sales of its classical products by making them compatible with Linux, thus offering entrance to other hardware platforms. Cf. website [www.ibm.com].

[14] At the end of 1999, over 1,200 Linux service providers in German-speaking countries were registered with the ISIS data bank, in comparison to just over 100 at the beginning of 1999. See [www.nomia.de/news/index.htm].

[15] SuSE made 70% of its revenues in 1999 with the sale of distributions. 10% of that came from programming and consulting services, 10% from the sale of complete solutions including hardware and software and 10% from miscellaneous activities.

distributors do not have any claims on Linux itself. Nevertheless it is seldom acknowledged that the distributors offer only a *service* and not a product. As a result of the GNU GPL, the distributors charge a fee for compiling a software selection, programming an open-source installation tool and offering an installation support hotline. However, these service providers are able to introduce Linux to professional customers because they offer professional support. In the model which will be introduced later, they are the new entrants to the operating system markets.

3.3 Competition in the market segment for Linux distributions

The business of Linux distributors consists of nothing more than compiling selected Linux components which enable the users to set up a Linux system on their computers. Today there are about 57 different English-language Linux distributions available.[16] Due to the "public good" character of Linux[17], investment by distributors in the further development of Linux is very limited. As the GNU GPL permits charging a fee for the physical act of duplicating the software, distributors use this opportunity to set up their business. As all these distributors offer the same basic product, and since entry barriers to this market - in terms of development costs - do not exist, the market structure comes close to perfect competition. Both because the duplication of Linux can be carried out by the users themselves and because the market is highly contestable, prices cannot stay far from the marginal costs of copying Linux.[18] With zero fixed costs, the cost function is simply $c \cdot x$, where x is the number of copies and c are the marginal costs, which equal the average costs (ac). The supply curve for Linux is therefore horizontal.

The demand curve has the usual downward-sloping form. q_L^m represents the maximum number of users if Linux were to be given away for free. The intersection of the demand and the supply curve determines the equilibrium price and quantity for commercially-provided Linux distributions. But note that the market does not provide the entire quantity of Linux. Additionally, in contrast to usual product markets, a provision of the good through self-production is possible and reasonable for a significant number of customers. Thus, with rising prices, some of the customers will produce Linux on their own ($q_L^{total} - q_L^{com}$).[19] The rest are no longer willing to buy or produce Linux and drop out of demand ($p_L^m - q_L^{total}$). Thus, the total provided quantity of

[16] Cf. [www.linux.org].

[17] The public good character of Linux will be discussed in another paper by the author.

[18] Cf. Hetze (1999).

[19] This is true if the prices charged by the distributors are above the prime production

Linux (q_L^{total}) exceeds the quantity traded on the commercial market (q_L^{com}). Figure 1 illustrates this graphically.

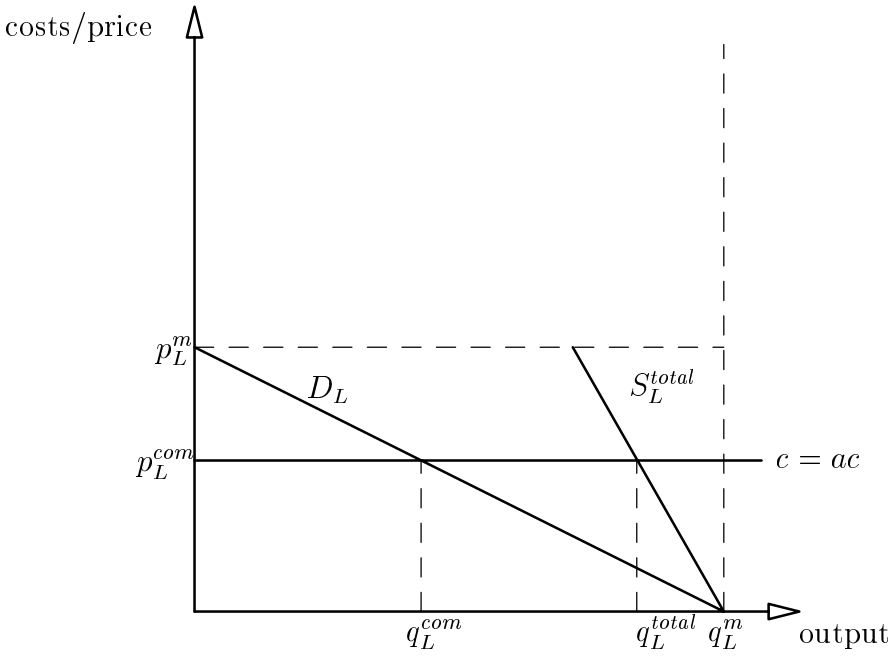

Figure 1: Demand and supply of Linux

4 Market structure before the entry of Linux

The *production* of software roughly consists of the *development* and the *duplication* of the software. The development of software is a labor-intensive business with low capital intensity. The immense development costs for the completion of software programs make the software business a fixed-cost business in which the variable costs are virtually zero.[20] The variable costs consist of the costs for the duplication of the software (e.g. pressing CDs, printing the manuals, packing the boxes, etc.) whereas the fixed costs are the development costs. The marginal costs can be assumed to be constant and the average costs - though decreasing - exceed the marginal costs permanently.

Therefore, the market segments for server operating systems have the form of a natural monopoly. Usually the enterprises can charge a monopoly price which includes per-unit-profits amounting to the difference between

costs for the customers. They can consist of download costs, costs for documentation, opportunity costs for a quick (automated) installation, installation support, the costs of borrowing the installation CDs from someone and so on.

[20] Cf. Blackburn/Scudder/van Wassenhove (1996), p. 1-2.

price and average costs per unit. Furthermore, entry barriers to the market exist in the form of cost and technology advantages. In particular, the high development costs hamper the entry of competitors into the market segments, i.e. already-established producers have, due to decreasing per-unit-costs, absolute cost advantages vis-à-vis new entrants. Furthermore, the development costs are sunk costs in the case of unsuccessful introductions to the market. The second important entry barrier consists in the technological advantages that established producers of operating software possess. These advantages result mainly from the close access to the proprietary computer technology for which the software is developed. Due to the fact that operating system software is hardware-oriented, i.e. precise knowledge of the hardware is required to develop faultless and powerful operating system software, hardware producers attain advantages through the development of such software.[21]

These theoretical reflections are confirmed by the market structures that were in place before the emergence of Linux. For every hardware platform (e.g. Intel, MIPS, Sparc), a single dominating enterprise used to provide the required operating system. In most segments, the hardware producer and the software developer were identical (e.g. IBM: RS, AIX; SUN: Sparc, Solaris). The only exception is the market segment for Intel-based computers, where, as is widely known, Microsoft has been developing the dominating operating system WindowsNT/2000. In recent years there have been some rare and unsuccessful attempts to enter one of these various market segments (e.g. OS/2 for Intel-based platforms and WindowsNT for DEC's Alpha processor platform). In particular, the cost advantages of the established operating system producers have led to the situation in which the markets for operating system software are non-contestable.

[21] Cf. Bitzer (1997a) for hardware network effects in the market segments for servers.

5 Changed markets through the emergence of Linux

As already stated, the production characteristics of complex operating system software imply a tendency towards the emergence of natural monopolies. With the emergence of the multi-platform operating system Linux, the situation changed fundamentally. Due to the no-cost development of Linux by voluntary programmers, the crucial entry barrier became ineffective. In all of the market segments mentioned, a second competitor - Linux distributors - emerged and the existing market structure changed from a natural monopoly to an oligopoly with a small number of competitors, strong entry barriers remaining for commercial software developers, and a large number of buyers.[22]

Within each market segment for operating systems, the former monopolist is now competing with the distributors and "self-producers" of Linux, and the latter two have significantly lower costs.[23] At the same time, the simple fact that Microsoft and the other operating system developers are still able to sell their products indicates that the goods offered are to some extent heterogeneous. Furthermore, due to the emergence of an additional competitor in the single market segments, prices play a more *active* role in competition. Whereas customers had to buy the AIX server operating system automatically when they chose IBM hardware, today they can choose between AIX and Linux. Prices become even more important as products become more homogenous.

Linux is most successful in market segments of other UNIXes. This can be explained by the relative homogeneity of the different UNIX variants and Linux. In market segments where the operating system is closely linked with a graphical user surface, such as Windows98/NT/2000 or MacOS, the success of Linux is much lower. Furthermore it can be observed that enterprises developing UNIX are increasingly active in providing Linux support, which seems logical in the light of the model to be discussed below. Ultimately this may result in the termination of the development of their own operating systems. The recent activities of IBM seem to point to this conclusion.

The current situation in the different market segments for server operating systems can be neatly analyzed in the framework of the oligopolis-

[22] Cf. market structure pattern of Stackelberg (1934).

[23] Self-producers do not appear explicitly as competitors on the market, but increasing prices of the commercial suppliers lead to an increasing number of self-producers and thus to shrinking markets. Collusion is therefore only possible in a limited range.

tic Launhardt-Hotelling competition model.[24] Within this model, the oligopolists offer heterogeneous products so that prices can differ to some extent without the lowest-price supplier taking the whole market. Nevertheless the products are substitutes for each other and therefore the sales volumes are not only functions of their own prices, but also of the prices of the competing goods. To apply the model to Linux and its competitors and to derive more concrete findings we restrict the analysis to a duopoly with competitor one being the former monopolist and competitor two being a representative Linux provider. The following demand functions are assumed:

$$y_1 = y_1(p_1, p_2) = \gamma_1 + \alpha_1 p_2 - \beta_1 p_1 \tag{1}$$
$$y_2 = y_2(p_1, p_2) = \gamma_2 + \alpha_2 p_1 - \beta_2 p_2 \tag{2}$$

Where y_1 represents demand for the product of the incumbent, y_2 the demand for the entrant (Linux); α_i, β_i are the marginal changes of demand with respect to prices p_1, p_2. It is assumed that $\alpha_i, \beta_i, \gamma_i > 0$. Demand for a product reacts positively to a price increase of the competitor's product and negatively to an increase in its own price. [25]Furthermore, $\beta_1 \neq \alpha_2$ and $\beta_2 \neq \alpha_1$ is due to the fact that y_1 and y_2 reproduce only the *commercial* demand. The self-production of Linux is not included. Therefore, the total market size ($y = y_1 + y_2$) can vary with price changes. It is assumed that each competitor is able to sell some of its products even if the competitor gives its product away for free: $y_i = \gamma_i - \beta_i p_i$ for some $p_i > 0$ and $p_j = 0$. The preferences of the customers include all characteristics of the product which influence the purchase decision, such as transaction costs (e.g. through network effects), ease of use/installation, quality, available programs for the operating system, and so on.

A supplier is able to attract the entire market only if the competitor sets its prohibitive price $\hat{p}$.

$$0 = \gamma_1 + \alpha_1 p_2 - \beta_1 \hat{p}_1 \Leftrightarrow \hat{p}_1 = \frac{\gamma_1}{\beta_1} + \frac{\alpha_1}{\beta_1} \cdot p_2 \tag{3}$$
$$0 = \gamma_2 + \alpha_2 p_1 - \beta_2 \hat{p}_2 \Leftrightarrow \hat{p}_2 = \frac{\gamma_2}{\beta_2} + \frac{\alpha_2}{\beta_2} \cdot p_1 \tag{4}$$

Note that the prohibitive price varies with the price of the competing product.

[24]Cf. Launhardt (1885), Hotelling (1929).

[25]It is assumed that the reaction on own price changes is stronger than on changes of the price of the competitor: $\beta_1 > \alpha_1$ and $\beta_2 > \alpha_2$.

Profits π_i of the duopolist differ in that the costs of the former monopolist include development costs as fixed costs C_1^F. Furthermore, we assume constant marginal costs c_i^v as an approximation for the software duplication process.[26] Thus,

$$\pi_1 = p_1 \cdot y_1(p_1, p_2) - C_1(y_1(p_1, p_2)) \tag{5}$$
$$\pi_2 = p_2 \cdot y_2(p_1, p_2) - C_2(y_1(p_1, p_2)) \tag{6}$$

with:

$$C_1 = C_1^F + c_1^v \cdot y_1(p_1, p_2)$$
$$C_2 = c_2^v \cdot y_2(p_1, p_2)$$

Inserting the corresponding cost and demand functions and taking the price of the competing product as given, each supplier maximizes profits by pricing its product such that:

$$\frac{\partial \pi_1}{\partial p_1} = \gamma_1 + \alpha_1 p_2 - 2\beta_1 p_1 + \beta_1 c_1^v = 0 \tag{7}$$
$$\frac{\partial \pi_2}{\partial p_2} = \gamma_2 + \alpha_2 p_1 - 2\beta_2 p_2 + \beta_2 c_2^v = 0 \tag{8}$$

This yields the reaction functions:

$$p_1 = \frac{\alpha_1}{2\beta_1} \cdot p_2 + \frac{\gamma_1}{2\beta_1} + \frac{1}{2} \cdot c_1^v \tag{9}$$
$$p_2 = \frac{\alpha_2}{2\beta_2} \cdot p_1 + \frac{\gamma_2}{2\beta_2} + \frac{1}{2} \cdot c_2^v \tag{10}$$

The price set by each duopolist depends on the price of the competitor, on the marginal costs, and in obvious ways on the various coefficients. The point of intersection of the two reaction functions represents the stable Nash Equilibrium.

[26] As already mentioned consists the software duplication process mainly of pressing CDs, printing manuals and packing the boxes. Cf. Houghton (1992) or Quintas (1994).

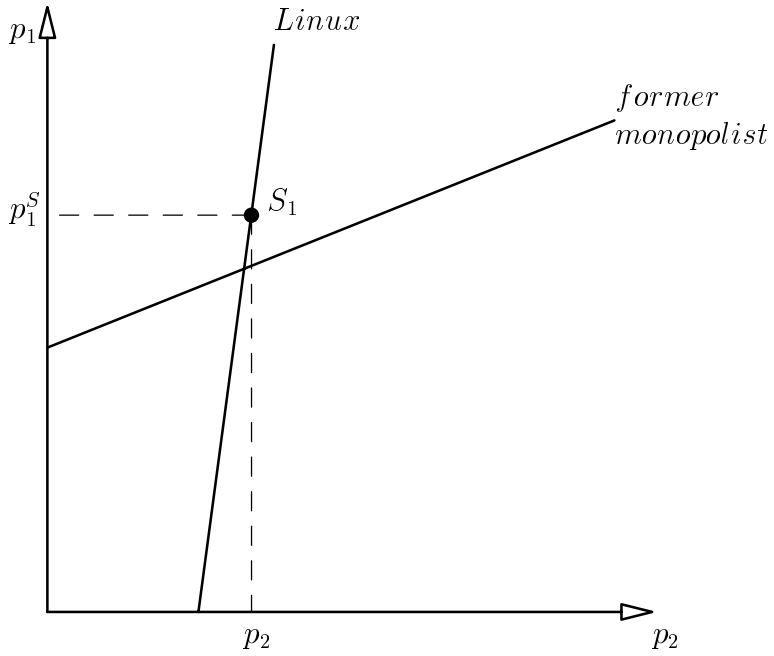

Figure 2: Reaction functions of former monopolist and Linux supplier

It may be more realistic to assume that the former monopolist, because of its experience in the market, is unilaterally able to take into account the reaction function of the Linux distributor, i. e. to act as Stackelberg leader. Considering the reaction function of the Linux distributor it maximizes its profits and sets its price to p_1^S. The Linux distributor takes this price as given and sets its price p_2 following its reaction function. The competition leads to three main outcomes: first, the equilibrium price p_1^S of the former monopolist is located on the reaction function of the Linux distributor (see figure 2 S_1) and is higher than in the Nash case.[27] Second, the price of the entrant is also higher than in the Nash case. Third, the profits of both competitors are higher in the Stackelberg case than in the Nash case.

However, in the long run, the price of the former monopolist has to cover the total average costs so that it does not make losses. But whether the former monopolist is able to get a price above the average costs depends on the preferences of the customers for its product, i.e. on the *extent* of the price differentiation permitted by them. It is by no means assured that the product heterogeneity and, as a result, price differentiation will be strong enough to allow the permanent survival of the former monopolist.[28]

Summing up the results of the formal analysis, it turns out that the price-setting and the profitability in the market segment depend on the preferences

[27] Cf. appendix for the formal derivation of that result.

[28] Cf. appendix for a illustration of this fact.

of the customers reflected by the parameters γ_i, α_i and β_i, and resulting from the heterogeneity of the products. Heterogeneity enables the former monopolists to stay in the market due to the possibility of charging higher prices for their products than for Linux. Thus, the survival of former monopolists depends on the maintenance of the product's heterogeneity. This, of course, is influenced by the technological development of the two competing products.

6 Expected strategies and future market developments

The previous conclusions provide the basis for a short, non-rigorous discussion at the level of plausibility of expected strategies of the market participants and the future development of the market segments. The available strategies for the incumbent depend strongly on the current extent of heterogeneity of its operating system to Linux and the importance of the operating system for its overall business. As the previous chapter has shown, the profitability of the incumbent's operating system depends on the heterogeneity of its product to Linux. This of course influences the investment decision on further development of its own product. Furthermore the decision about a continuation of its own proprietary operating system is influenced by how much the business contributes to the total profits of the incumbent, or in other words, how much the incumbent would lose by terminating its own proprietary operating system. The following figure illustrates this heuristically. The vertical axis shows the heterogeneity of the incumbent's operating system to Linux (H), and the horizontal axis shows the importance of the business with the operating system (S), e.g. the share of the incumbent's operating system business in its overall profits.

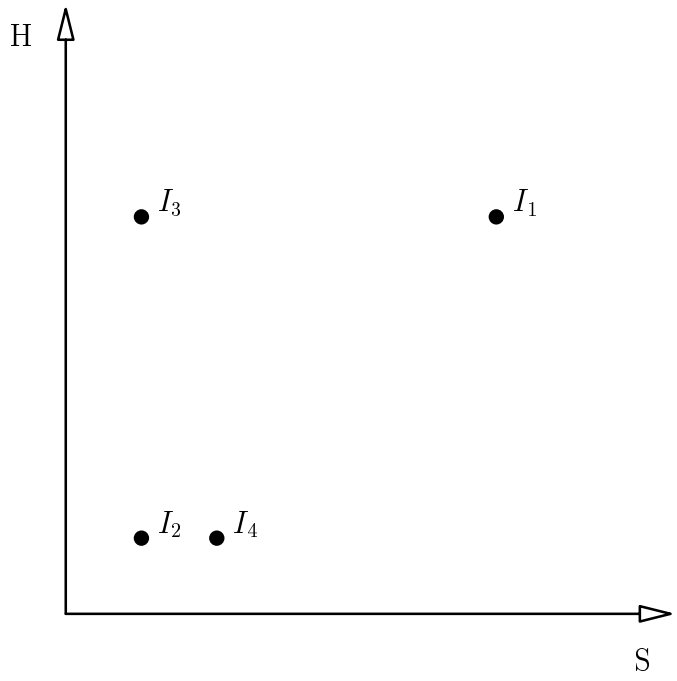

Figure 3: Starting points for the incumbent's decision problem

The closer the incumbent is located to the origin, the higher the likelihood that it will terminate its own product development and engage in supporting Linux. The four cases marked in the figure present different starting points for the decision to either go ahead or terminate the development of the business's own operating system.

The decision for incumbent one (I_1) is straightforward. The current product's heterogeneity is still great enough for the incumbent to cover its average costs and the operating system accounts for an important share of its business. Therefore, it will go ahead with the development of its proprietary operating system, keeping in mind that the heterogeneity between its own product and Linux will have to be maintained.[29]

The situation for incumbent two (I_2) shows the other extreme, but leads to a similarly easy decision. The heterogeneity of its product to Linux is low and the same is true for the contribution of the operating system business to its total business.[30] It is therefore most likely that this incumbent will terminate development of its own proprietary product, leading inevitably to this

[29] Adding software components or interlace application software with the operating system to benefit from network effects is an often-used strategy to increase product differentiation. Microsoft's strategy points in this direction.

[30] An example of an incumbent in this situation is IBM, which is developing its proprietary UNIX AIX, a system which has a low heterogeneity to Linux and accounts only for a very small share of IBM's total IT business.

incumbent supporting Linux. There are two main reasons why it would do so. First, this support guarantees participation in the support services business around Linux. Thus, if the market for the incumbent's own proprietary product collapses, the enterprise could keep earning money with the remaining service business. Due to the fact that the support of the new operating system requires specific knowledge which has to be accumulated in advance, the incumbent will start this accumulation process even while its own operating system is still being sold. Second, if the incumbent is at the same time a hardware producer, supporting Linux guarantees the reliability of the computer systems it offers. In particular, if complete computer networks are delivered, the common maintenance contracts require that the enterprises offer the customer a high availability of the system, which is dependent on software and hardware working together faultlessly.[31]

Incumbent three occupies the most comfortable position (I_3). This incumbent is developing an operating system which is very different from Linux and does not account for an important share of its total business. Examples of such enterprises are producers of supercomputers. They develop single unit production operating systems which account, in comparison to the cost of the hardware, only for a very small part. The continuation of the development is therefore possible and likely in this case. But even if the future development of Linux does reduce the heterogeneity between the products, the harm to the incumbent will be limited due to the small share of the operating system business. The decision will then be the same as in the case of incumbent two.

Incumbent four (I_4), which faces low heterogeneity between its product and Linux and a significant importance of its business with its operating system, is in the most difficult situation. Further development of its product will generate additional sunk costs and bear the risk that the incumbent will not be able to retrieve the pay-off. Termination of the development of its own operating system will lead to the loss of a significant part of its business.

Most of the current incumbents fall into cases two and four. As described above, most developers of operating systems are also producers of the hardware. Therefore the importance of the operating system in comparison to the total business is usually not very high. Furthermore the majority of the operating systems developed by incumbents are proprietary variants of UNIX. They are, due to the fact that Linux is also a variant of UNIX, very similar to Linux (e.g. same commands). Thus, the already-mentioned increasing support of Linux by huge IT enterprises which develop a proprietary UNIX operating system and at the same time offer proprietary computer systems

[31] Cf. Bitzer (1997b).

can be considered as a preparation for the worst-case scenario: the collapse of their operating system market segments.

Microsoft, as the exception in the operating system business, is represented by case one in figure 3. The refusal to support Linux is logical in the light of the analysis above. Microsoft would lose a large part of its business if Linux were widely established. Furthermore, any support of Linux whatsoever would furthermore decrease the heterogeneity between Microsoft's operating systems and Linux.

In the years to come, the increasing support of Linux by the huge IT enterprises will also have a significant impact on the business of the Linux distributors. The distributors will face increasing competition from the huge IT enterprises in their main business field, the support services for Linux.

7 Conclusions

The paper has shown that the emergence of Linux may potentially bring about significant changes in the market structure for operating systems with far-reaching effects on the former monopolistic incumbents.

Even if Linux as a good cannot be traded and a market for it does not exist, the offer of related professional services allows the introduction of Linux to professional customers. As a result, former monopolistic non-contestable markets turn oligopolistic with the foreseeable consequences, e.g. decreasing profits. In addition this change in the market structure even threatens the entire business of the former monopolist in its market segment. The reason for this can be found in the no-cost development of Linux, which leads to considerable cost advantages on the side of the entrants. In the case of low product heterogeneity of the incumbents' and entrants' products, their prices approach marginal costs and the incumbents will therefore no longer be able to cover their fixed costs, which are their development costs. In the long run, this can lead to the incumbents stopping the development of their operating systems. But when this happens, the product market segment vanishes as well, due to the above-mentioned fact that the new entrants offer only services in connection with Linux. Therefore in the most extreme scenario, the market for operating systems could totally collapse and only support services in connection with Linux would remain as a source of business income. The recent support announcements of former monopolists could be interpreted as preparations in anticipation of this scenario.

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Appendix

Proof that the Stackelberg price is higher than the Nash price

The following derivations show that the use of a Stackelberg strategy by the former monopolist in the applied model leads to higher prices and higher profits for both competitors. The Stackelberg leader will take the reaction function of the entrant into consideration when maximizing its profits. Its profit function and the associated first-order-condition therefore has the following form. [32]

$$\pi_1^S = (p_1 - c_1^v) \cdot (\gamma_1 + \alpha_1(\frac{\alpha_2}{2\beta_2} \cdot p_1 + \frac{\gamma_2}{2\beta_2} + \frac{1}{2} \cdot c_2^v) - \beta_1 p_1) - C_1^F$$

$$\frac{\partial \pi_1^S}{\partial p_1} = \gamma_1 + \frac{\alpha_1\alpha_2}{\beta_2} p_1 - \frac{\alpha_1\alpha_2 c_1^v}{2\beta_2} + \frac{\alpha_1\gamma_2}{2\beta_2} + \frac{\alpha_1 c_2^v}{2} - 2\beta_1 p_1 + \beta_1 c_1^v = 0$$

Solving for p_1 results in the Stackelberg price p_1^S. This is now compared with the Nash equilibrium price p_1^N to show that the Stackelberg price is higher than the Nash price.

$$\begin{aligned} p_1^S &= \frac{1}{4\beta_1\beta_2 - 2\alpha_1\alpha_2} \underbrace{(2\beta_2\gamma_1 + \alpha_1\gamma_2 + \alpha_1\beta_2 c_2^v + 2\beta_1\beta_2 c_1^v}_{\Omega} - \alpha_1\alpha_2 c_1^v) \\ p_1^N &= \frac{1}{4\beta_1\beta_2 - \alpha_1\alpha_2} \underbrace{(2\beta_2\gamma_1 + \alpha_1\gamma_2 + \alpha_1\beta_2 c_2^v + 2\beta_1\beta_2 c_1^v)}_{\Omega} \end{aligned}$$

For $p_1^S > p_1^N$ it must be true that,

$$\begin{aligned} \frac{p_1^S}{p_1^N} &= \frac{4\beta_1\beta_2 - 2\alpha_1\alpha_2}{4\beta_1\beta_2 - \alpha_1\alpha_2} \cdot \frac{\Omega - \alpha_1\alpha_2 c_1^v}{\Omega} > 1 \\ &= \frac{1 - \frac{\alpha_1\alpha_2 c_1^v}{\Omega}}{1 - \frac{\alpha_1\alpha_2}{4\beta_1\beta_2 - \alpha_1\alpha_2}} > 1 \end{aligned}$$

or

[32] The second-order-condition $\alpha_1\alpha_2 < 2\beta_1\beta_2$ is obviously satisfied for $\alpha_1 < \beta_1$ and $\alpha_2 < \beta_2$. Cf. assumptions in footnote 25.

$$
\begin{aligned}
1 - \frac{\alpha_1\alpha_2 c_1^v}{\Omega} &> 1 - \frac{\alpha_1\alpha_2}{4\beta_1\beta_2 - \alpha_1\alpha_2} \\
\Leftrightarrow \frac{\alpha_1\alpha_2 c_1^v}{\Omega} &< \frac{\alpha_1\alpha_2}{4\beta_1\beta_2 - \alpha_1\alpha_2} \\
\Leftrightarrow \frac{c_1^v}{\Omega} &< \frac{1}{4\beta_1\beta_2 - \alpha_1\alpha_2} \\
\Leftrightarrow c_1^v &< \frac{1}{4\beta_1\beta_2 - \alpha_1\alpha_2} \cdot \Omega \\
\Rightarrow c_1^v &< p_1^N
\end{aligned}
$$

Thus, if the price p_1^N exceeds the variable costs c_1^v the Stackelberg-price p_1^S is higher than the Nash-price p_1^N.

Illustration of the long-term profitability problem of the former monopolist

Due to the fact that the fixed costs are not considered in the Short-term profit maximization, the difference between the former monopolist and the Linux distributor does not enter into the model. A statement on the profitability of the former monopolist has to be derived from another observation. In the long term, the price of the former monopolist has to cover the total average costs so that the enterprise does not make losses. Whether or not the former monopolist will be able to get a price above the average costs depends in the end on the preferences of the customers for its product.

$$
\begin{aligned}
\pi_1 &= p_1 \cdot y_1(p_1, p_2) - C_1^F - c_1^v \cdot y_1(p_1, p_2) \geq 0 \\
&\Leftrightarrow (p_1 - c_1^v)(\gamma_1 + \alpha_1 p_2 - \beta_1 p_1) \geq C_1^F \\
&\Leftrightarrow \underbrace{(\gamma_1 + \alpha_1 p_2 + c_1^v)}_{\Omega} p_1 - \underbrace{c_1^v(\gamma_1 + \alpha_1 p_2)}_{\Phi} \geq C_1^F + \beta_1 p_1^2 \\
&\Rightarrow \Omega \cdot p_1 - \Phi \geq C_1^F + \beta_1 p_1^2
\end{aligned}
$$

Figure 4 shows that the former monopolist is only able to make profits as long as the price lies between p_1^* and p_1^{**}. Furthermore it can be seen that with a decreasing preference for its product ($\gamma_1 \downarrow$) and/or an increasing preference for Linux ($\alpha_1 \uparrow$) the straight line $\Omega \cdot p_1 - \Phi$ rotates to the right (negative intersection and slope decreases). In addition, with a decreasing preference

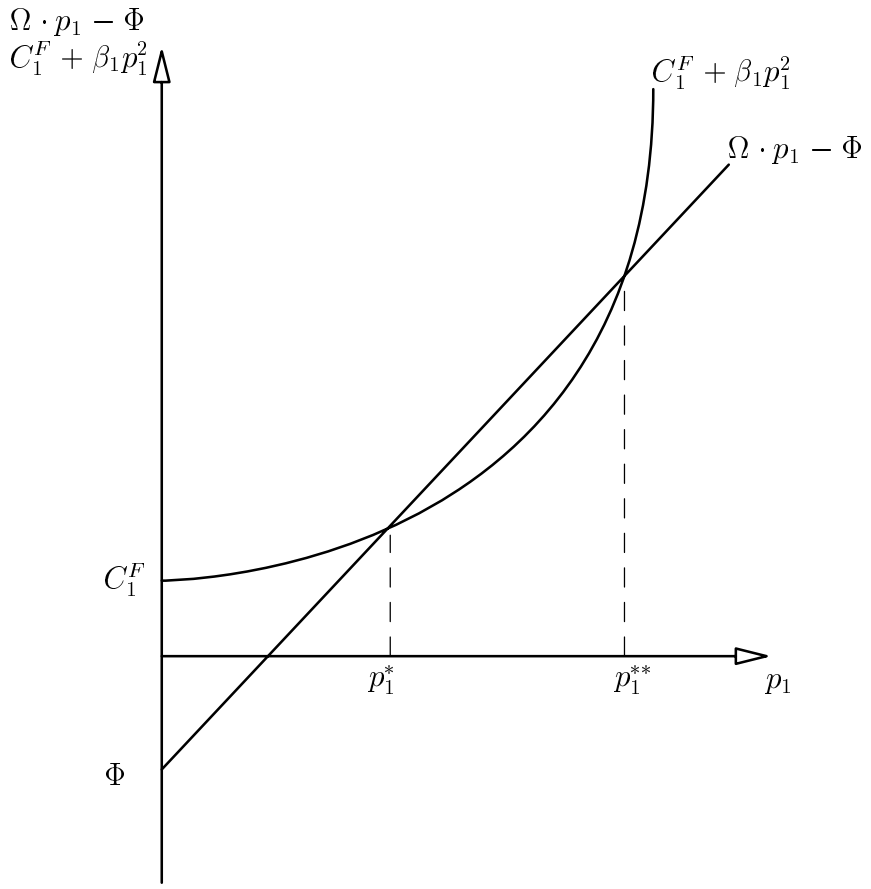

Figure 4: Profitable price area for the former monopolist

for the product of the former monopolist, it is likely that β_1 will increase and with it the slope of the quadratic function $C_1^F + \beta_1 p_1^2$ will increase. The result is that the profitable price area p_1^* to p_1^{**} decreases and could even vanish completely.