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LINUX AND WINDOWS -
A CASE OF MARKET FAILURE?

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Abstract

The topic of this dissertation is economic efficiency in the consumer market for operating systems, which is characterised by rapid and dynamic innovation, a decisive interrelation with hardware and application programs, network externalities, and a crucial impact of intellectual property rights. In addition to desk based research, three research studies were conducted, largely in a positivist framework, aimed at exploring the particular characteristics of the market, especially information levels regarding Windows and Linux, and availability of the systems. A focus group was conducted in order to establish which of the systems is the technically superior one.

The results indicate considerable information imperfections on the consumers' part, as well as inefficiencies stemming from network externalities and the legal framework established by current intellectual property rights law. Further research into the phenomenon is needed, especially in the context of information economics perspectives, as well as psychological and sociological frameworks. State intervention appears to be a feasible remedy in correcting some of the principal inefficiencies stemming from the monopoly power that Microsoft derives from its intellectual property and contractual rights.

Miscellany

I declare that this dissertation is all my own work and the sources of information and material I have used have been fully identified and properly acknowledged as required in the guidelines given in the Programme Handbook which I have received.

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Soli Deo Gloria — To God alone be glory ★

Matthias Bärwolff

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1 Introduction

*Problems cannot be solved at the same level of awareness
that created them.
— Albert Einstein*

The present paper deals with economic efficiency in the consumer market for personal computer operating systems, with a focus on Windows and Linux, a subject characterised by distinguishing features that render it unique in a number of respects.

The importance of efficiency considerations stems from the significance of operating systems in computing, for operating systems are the principal foundation of modern computing, forming the intermediary layer between hardware and application programs. Their complexity is unprecedented, exceeding any other human engineering constructs, and giving rise to virtually insuperable difficulties in making them error-free. As pure information goods they are represented by strings of noughts and ones, the cost of duplication is effectively zero, and returns are of an increasing nature.

In itself an operating system has little value, as it derives utility from the hardware it runs on, and the applications that it is capable of executing. The IBM-compatible personal computer has emerged as the principal hardware platform in the consumer market, as its technical specification has been made publicly available. By contrast, Microsoft has been holding a monopoly in the operating systems consumer market ever since their first contract with IBM in 1981, and its operating systems have been the principal platforms for application programs. There are, at present, no fully compatible operating systems to Windows, which holds an overwhelming monopoly position in the consumer market.

Linux has very recently emerged as a viable alternative to Windows. Its development is exceptional in that it cannot be positioned in the predominant framework of monetary exchange economics. Due to the licence under which the operating system's code as such is distributed, Linux has effectively no exchange value, yet it constitutes a value in money terms that springs from its utility.

The case of Windows and Linux presents an interesting research topic, due to the marked differences between both systems, raising a whole host of issues, not all of which can be exhaustively dealt with in this treatise. This paper aims

to establish the particular characteristics of the market, and attempts to address the issues of economic efficiency, market failure, and potential policy implications. Moreover, important areas for future research into the phenomena are identified.

The research consists of two major parts: the literature review, and three related research studies into different aspects of the problem. The literature review deals with economic and legal foundations of the operating systems market, as well as its specific current structure. After a section on methodological issues, the results of my research studies are presented. Next, the principal findings are laid out, and discussed in conjunction with issues raised in the literature review, addressing the advanced hypotheses. Last, conclusions as to policy implications are drawn. A brief section about the special characteristics of large software in general has been put into the appendix, along with a glossary and various complementary items which are referenced in the main text.

2 Literature Review

I know nothing except the fact of my ignorance.

— *Socrates*

2.1 Background

At present, Windows and Linux are the most important operating systems (OSs) in the software market, Windows being the most widely used in both the server and the desktop market, and Linux being its most serious contender.¹ Microsoft holds a monopoly position in virtually all important consumer segments: operating system, desktop productivity applications, and internet browsers, hence they have an enormous market power whose exertion has repeatedly given rise to antitrust actions against the company. The company have been declared an unlawful monopolist that has repeatedly violated antitrust laws and which has “illegally used its monopoly position in the personal computer operating systems market through a series of anticompetitive license restrictions and other agreements with computer makers, software vendors and Internet service providers [ISP’s]”.² Yet the policy implications from Microsoft’s overwhelming command are far from clear, as a monopoly in itself does not *per se* give rise to antitrust

¹See Appendix C, Tables 6 and 7. Current and historic information about Linux can readily be found on the internet. A good starting point is <http://www.kernel.org>. As for a brief history of MS-DOS and Windows see, for example, <http://inventors.about.com/library/weekly/aa033099.htm> and <http://inventors.about.com/library/weekly/aa080499.htm>.

A Microsoft internal memo by the vice president of the Windows division, leaked to The Register, states: “Linux is the long-term threat against our core business. Never forget that” (Brian Valentine, as quoted in Thomas C. Greene, *MS promotes Linux from threat to ‘the’ threat*, The Register, November 12, 2001, available from <http://www.theregister.co.uk/content/4/22770.html>).

²Stephen Labaton, *Court Rejects Microsoft’s Request for Delay*, NY Times, August 18, 2001. For the time being, in declining to accept an appeal by Microsoft to completely dismiss the findings and conclusions of the District Court, the Supreme Court has effectively upheld the findings of Judge Thomas Penfield Jackson of the Federal District Court in the District of Columbia (Stephen Labaton, *Supreme Court Rejects Microsoft Appeal*, NY Times, October 11, 2001). For an overview of the epic antitrust dispute between the US Department of Justice and Microsoft see also <http://news.ft.com/ft/gx.cgi/ftc?pagename=View&c=Article&cid=FT3ZU5IX9OC&live=true>.

liability, and the likely effects of intervention largely evade reliable prediction. Deriving their monopoly power from the virtually perfect ownership of intellectual property rights over proprietary computer programs which are being licensed to consumers under restrictive contractual agreements regarding their use and redistribution, the principal policy question arises of whether consumers are harmed by Microsoft's dominance and conduct, and if there are possible remedies to enhance consumer welfare.

The legal process of dealing with potentially harmful conduct of Microsoft has thus far proven ineffective and futile in imposing any remedies to impact noticeably on the company. A consent decree reached in a dispute over exclusionary licensing practices with the US Department of Justice³ proved ineffective.⁴ As yet, the latest antitrust case against Microsoft has produced no results at all, neither regarding the lawfulness and effects of bundling, nor its impact on consumer welfare. The economic foundations of 'high-tech markets', being subject to network externalities, dynamic and fast-moving competition, information imperfections on the part of the consumers, and a decisive impact of intellectual property rights as a crucial means of protecting proprietary software products are not conclusive in its implications for antitrust policy.⁵ As yet, no unambiguous economic theory has emerged regarding innovation-related issues in a monopoly context. Hence the extraordinary difficulties in antitrust cases which are generally understood to aim primarily at promoting economic efficiency.⁶ Moreover,

³*United States v. Microsoft Corp.*, 56 F. 3d 1448 (D.C. Cir. 1995). See also Baseman et al. (1995), and Sheremata (1997).

⁴Judge Sporkin, who was thrown off the case when he rejected the decree, opined that: "[T]he U.S. government is either incapable or unwilling to deal effectively with a potential threat to this nation's economic well-being... [If the deal was approved] the message will be that Microsoft is so powerful that neither the market nor the government is capable of dealing with all its monopolistic practices". In the current antitrust lawsuit structural remedies are now unlikely to be imposed, and it is questionable whether behavioural remedies will prove effective (Stephen Labaton, *U.S. vs. Microsoft: Going Back to Square One*, NY Times, September 9, 2001).

⁵The chairman of the US Federal Trade Commission, Pitofsky (2001), laments that:

Because areas of the economy characterized by intellectual property are usually dynamic rather static, reliable predictions are difficult, thereby making effective remedies hard to formulate. From the point of view of antitrust enforcement, remedial questions are a particular challenge in addressing intellectual property issues in a way that alleviates competitive problems without unduly interfering with innovation incentives. (pp. 546-7)

⁶The US Court of Appeals for the DC Circuit in its recent decision to dismiss the remedies

the long duration of court proceedings has proven a serious problem as the market is likely to have changed dramatically by the time any remedies are imposed.⁷

Microsoft, being a publicly held corporation, is naturally concerned about maximising wealth for its residual claimants,⁸ an objective which due to their power in the market is at odds with public interest and consumer welfare.⁹ The special nature of software as a pure information good which finds its manifestation in a digital medium that can be perfectly and infinitely duplicated at virtually zero cost makes the marginal cost effectively zero,¹⁰ and results in astonishing margins

imposed by District Court Judge Jackson had to submit that they did not know which remedies would be appropriate in the case and said that it is unclear how the “current monopolization doctrine should be amended to account for competition in technologically dynamic markets” (see appeals court opinion, *infra* note 118 at 12). The final judgement of the District Court had ordered the breakup of the company and the full disclosure of all APIs, communication interfaces and technical information in a ‘timely manner’. In view of the appeals court decision the US Justice Department has abandoned its efforts to break Microsoft apart (Stephen Labaton, *U.S. Abandoning Its Effort to Break Apart Microsoft*, NY Times, September 7, 2001).

However, the appeals court has expressed its disapproval for the company’s conduct, and the argument that the “subsequent exercise of their lawfully acquired intellectual property rights cannot give rise to antitrust liability”, saying that this argument “borders upon the frivolous” (see appeals court opinion, *infra* note 118 at 33).

⁷The appeals court expressed their concerns: “What is somewhat problematic, however, is that just over 6 years have passed since Microsoft engaged in the first conduct plaintiffs allege to be anticompetitive. As the record in this case indicates, six years seem like an eternity in the computer industry” (p. 10). It remains to be seen whether the latest agreement by the Justice Department and 9 of the 18 stated suing Microsoft to settle the antitrust case will be approved by the courts, and whether the sanctions will prove effective to remedy Microsoft’s illegal conduct. There are a number of exceptions and potential loopholes in the agreement which effectively render it futile (Stephen Labaton, *U.S. and Microsoft in Deal, but States Hold Back*, NY Times, November 3, 2001; Anonymous, *An unsettling settlement*, The Economist, November 10, 2001, pp. 83–4; and Michael Kanellos et al., *The agreement: Devil’s in the detail*, CNET News.com, November 5, 2001, available from <<http://news.cnet.com/news/0-1003-200-7765151.html>>). Meanwhile, the European Commission is preparing its antitrust case against Microsoft (Anonymous, *The next battleground*, The Economist, November 10, 2001, pp. 84–6; and Anonymous, *EU to Hold Microsoft Hearing Next Month*, Reuters, November 21, 2001, available from <<http://www.nytimes.com>>).

⁸See Easterbrook and Fischel (1991, pp. 67–8) for the argument that shareholders as the principal bearers of risk are the owners of a company.

⁹The mission statement on their website, however, suggests otherwise: “Microsoft’s vision is to empower people through great software – any time, any place and on any device”. And: “Our managers and employees must always act with the utmost integrity, and be guided by what is ethical and right for our customers. We compete vigorously and fairly”.

¹⁰Due to the ease with which software can be duplicated the piracy rates have always been very high. The Business Software Alliance (BSA) estimates a world piracy rate of 37 percent

and according profits for Microsoft, making it one of the richest companies in the world¹¹ and its main shareholder Bill Gates the world's richest man.¹²

By contrast, Linux has taken the world by surprise by its utterly unconventional nature, and challenges some of the most basic economic notions of how the firm emerges, incentives, and the structure of cooperation, as well as the basic assumptions of opportunism and rational choice, and questions the incentive argument in the justification for intellectual property rights. Some of its features are truly surprising and inclined Kollock (1999) to call it “the ‘impossible’ public good”, as it is developed and maintained by volunteers all over the world, without formal contractual relations and in complete absence of any profit motive.¹³ Thus

and losses to the global software industry of \$11.7 billion in the year 2000 (Anonymous, *Global software industry loses more than \$11.7 billion to piracy*, BSA UK Press Release, May 21, 2001, available from <<http://www.bsa.org/uk/press/newsreleases//2001-05-21.609.phtml>>), calling software piracy “one of the most under-reported business scandals of the last decade (Andrew Fisher, *Businesses count the cost of digital pirate raids*, Financial Times – FT IT, March 7, 2001, p. 1). However, these figures are based on the assumption “that everyone who ever copied a program would have otherwise bought it at retail” (Carlton and Perloff 2000, p. 509). See also Gopal and Sanders (2000), and Wagner and Sanders (2001). Incidentally, until 1998 it was perfectly legal to copy software in Argentina (Julia Scheeres, *Argentina mulls open-source move*, Wired, May 4, 2001, available from <<http://www.wired.com/news/print/0,1294,43529,00.html>>).

¹¹According to its 2001 Annual Report (available from <<http://www.microsoft.com/msft/ar01/>>) this year Microsoft has generated revenues of \$25.3 billion, \$8.0 billion of which come from the licensing of Windows desktop platforms, and a net income of \$7.3 billion. It is holding a total of \$31.6 billion in cash and short-term investments, and its total assets amount to more than \$59.3 billion. Microsoft has the highest returns on revenues of all the world's companies, according to Anonymous, *The world's largest corporations*, Fortune – European Edition, July 23, 2001, p. F-14. According to the Business Week Microsoft has a brand value of \$65 billion, making it the world's second most valuable brand (Anonymous, *The best global brands*, FT dynamo, August 6, 2001, available from <<http://www.ftdynamo.com>>). See also Various authors, *FT 500 – The world's largest companies (Supplement to The Financial Times)*, Financial Times, May 11, 2001.

¹²The founder and chairman of Microsoft has amassed a personal fortune of almost \$60 billion (Anonymous, *Want to be a billionaire? Be born a Walton*, FT dynamo, June 22, 2001, available from <<http://www.ftdynamo.com>>). As of September 28, 2001, he holds 12.3 percent of Microsoft shares outstanding. CEO Steve Ballmer owns 4.4 percent of the company as of June 30 (data from Hydra database). See also <<http://moneycentral.msn.com/investor/invsub/ownership/ownership.asp?Symbol=MSFT>> for the major institutional and mutual fund shareholders of Microsoft.

¹³This seemingly contradictory pattern can largely be explained by the utility that contributors appear to derive from their work on Linux, which is only possible when private intellectual property rights are waived. In addition, reputation and gift exchange mechanisms likely play a role.

the focus lies almost entirely with the product, a possible advantage over a more marketing orientated approach regarding the quality of the operating system, given the inherent difficulties in creating large error-free computer programs.¹⁴

Even though the Linux project has no formal legal existence it can be considered a firm in an economic sense.¹⁵ The institutional foundations differ markedly from that of ordinary firms, most of which adopt a ‘standard form’ contract: an incorporated structure and formal written contractual arrangements.¹⁶ By contrast, the relation between those who contribute to Linux can be regarded as one shaped by psychological contracts.¹⁷ Conventional approaches to analysing the Linux project as a firm are largely rendered futile as the basic assumption for virtually all economic considerations, opportunism in the shape of quantifiable and tradeable rewards considerations, appears not to be fulfilled. The most promising approach should be based on the the resource-based view of the firm and an information cost perspective.¹⁸

¹⁴See Appendix B. Linus Torvalds, the initiator and undisputed leader of the Linux project stated in an interview: “I want to make the technical decisions based solely on the technical issues. I want my priorities to be extremely obvious and always straight” (Michael Vizard, *Linus Torvalds talks economics and operating systems*, InfoWorld, April 9, 1998, available from <http://www.infoworld.com/cgi-bin/displayStory.pl?/interviews/980409torvalds.htm>).

¹⁵No such considerations have been made, as far as I am aware. The Linux project has largely been analysed from an organisational theory perspective, which has been proven extraordinarily difficult, and most authors have fallen short of duly appreciating all relevant aspects. Unfortunately, Raymond’s (1998) influential paper has introduced the notorious and often uncritically quoted metaphor of the bazaar in open-source development projects, as opposed to the cathedral in traditional software engineering, a notion which is misleading and not even half-right. For example, says Ljungberg (2000): “I believe that the bazaar mode of open source projects will influence the future of knowledge organizations both in terms of organising, customer relations and business models” (p. 216). Eunice (1998) remarked that the cathedral/bazaar dichotomy “assumes an open-is-good/closed-is-bad worldview” and Raymond confuses “development mechanisms and methodology with goals and philosophy”. The cognitive dissonance (Festinger 1957) most authors have been subject to has resulted in a number of unduly simplified analyses. Examples of scholarship that avoid much of the obfuscation brought on by confusing normative and positive considerations include Kuwabara (2000) and Tuomi (2001).

¹⁶See Hart (1989, p. 1764).

¹⁷Rousseau (1989) defines such a contract as: “[A]n individual’s beliefs regarding the terms and conditions of a reciprocal exchange agreement between that person and another party”, a notion which is fully compatible with the economic understanding of contracts as “relationships characterized by reciprocal expectations and behavior” (Hart 1989, p. 1764, n. 30). See also Farmer and Fedor (1999).

¹⁸For the notion of the resource-based view of the firm see Barney (1991), Wernerfeld (1984, 1995), and Medcof (2000). For some of the particular problems and implications in human-asset-intensive firms see Coff (1999), and Ouchi (1980, 1993). As regards collective action,

The most important underlying foundational structure that makes the cooperation and organisation possible on a big scale is the internet in that it crucially contributes to lowering the costs that arise in the course of cooperation.¹⁹ The willingness of a sufficient number of programmers all over the world to collaborate in the effort of creating large software, a flexible hierarchical organisation, a degree of peer review that contributes to the quality of the code, and the internet as an institutional foundation, along with the inherent characteristic of software as an information good contribute to the feasibility and surprising success of the Linux project in the absence of commercial considerations. A further important foundation of Linux is the General Public License (GPL),²⁰ a contractual means by which intellectual property is placed once and for all in the public domain by prohibiting appropriation of the copyrighted software code into proprietary software.²¹ It allows unrestricted use of the software, including changing of the code and redistribution, as long as the copies or derivatives are being distributed under the terms of the GPL, and requires the source code to be published, thus it puts a far greater weight on the input side of intellectual creations as opposed to the output side, and fully satisfies the public interest in the creation and building upon it.

As regards complementary software, from the very inception of the project software from the GNU project has been available for Linux and contributed decisively to the acceptability of Linux.²² A large number of open-source projects, viewed from a sociological perspective, see Kollock (1998), Heckathorn (1998), and Dawes and Messick (2000).

¹⁹It is common to regard the internet as lowering transaction costs. However, I deliberately avoid the term here as it is inextricably linked to the notion of transaction cost economics (TCE) and the “cost of using the price mechanism” (Coase 1937).

²⁰The GNU GPL is available from <http://www.gnu.org/copyleft/gpl.txt>. GNU is a recursive acronym that stands for GNU’s not Unix, and name of a project started in 1983 by Richard Stallman which was supposed to result in a free “complete Unix-compatible software system”, but, however, failed to create an operating system kernel. Linux is now the principal kernel for the GNU system. See also Stallman (1999), and Stallman’s “The GNU Manifesto” (available from <http://www.fsf.org/gnu/manifesto>).

²¹As yet, no one has brought a legal action in respect of infringement of the GPL, hence its legal enforceability has not yet been clearly established by the courts.

²²Credits for some important preconditions for the Linux project accrue to Richard Stallman, the founder of the Free Software Foundation (FSF), creator of the GPL and a large number of crucial applications including the GCC and the emacs text editor which were all licensed under the GPL and hence freely available to Linus Torvalds and other contributors to Linux. Richard Stallman has been the first computer scientist to be awarded a fellowship by the John D. and Catherine T. MacArthur Foundation in 1990, an honour that in 1998 was also given to Tim Berners-Lee, the inventor of the world wide web. See also Stallman (1999), and Torvalds (1999).

run in the same way as the Linux project, contribute higher level layers of software to Linux, making it a full scale system comprising the operating system kernel (Linux), graphical user interfaces (GUIs), and productivity applications. Since recently Linux has been enjoying crucial backing from some major commercial companies. IBM has committed resources of \$1 billion for the year 2001 to backing Linux, adding to the credibility of the project,²³ and a number of commercial applications have been ported to Linux,²⁴

Microsoft is not backing Linux and has thus far not ported any of its applications to Linux. Their increasing concerns about Linux are obvious from a recent series of aggressive attacks against Linux, open-source in general, and the GPL, characterised by bold claims, finding its climax in a statement of Microsoft president and CEO Steve Ballmer: “Linux is not the public domain. Linux is a cancer that attaches itself in an intellectual property sense to everything it touches”.²⁵ By contrast, Microsoft, as Linus Torvalds puts it in a recent interview, “has traditionally been, and pretty much continues to be, a nonissue for Linux development”.²⁶

Linux’s POSIX conformity has been a key factor in facilitating porting of existing UNIX software. See Daniel Quinlan, *The Past and Future of Linux Standards*, Linux Journal, June 1999 (available from <<http://www2.linuxjournal.com/lj-issues/issue62/3417.html>>).

²³Joe Wilcox, *IBM to spend \$1 billion on Linux in 2001*, CNET News.com, December 12, 2000 (available from <<http://news.cnet.com/news/0-1003-202-4111945.html>>). See also Stephen Shankland, *IBM expands Linux marketing push*, CNET News.com, July 24, 2001 (available from <<http://news.cnet.com/news/0-1003-202-6662643.html>>) and Steve Lohr, *Some I.B.M. Software Tools to Be Put in Public Domain*, NY Times, November 5, 2001.

²⁴Amongst others, Oracle’s ported its Oracle8 database management system, and IBM its DB2 Universal Database and WebSphere e-commerce software (Phil Hochmuth, *Linux against the odds*, Network World, December 25, 2000).

²⁵Anonymous, *Microsoft CEO takes launch break with the Sun-Times*, Chicago Sun-Times, June 1, 2001 (available from <<http://www.suntimes.com/output/tech/cst-fin-micro01.html>>). See also Anonymous, *Microsoft exec calls open source a threat to innovation*, Bloomberg News, February 15, 2001 (available from <<http://news.cnet.com/news/0-1003-200-4833927.html>>), Ben Charny, *Microsoft raps open-source approach*, CNET News.com, May 3, 2001 (available from <<http://news.cnet.com/news/0-1003-200-5813446.html>>), Mike Ricciuti, *Gates wades into open-source debate*, CNET News.com, June 19, 2001 (available from <<http://news.cnet.com/news/0-1003-200-6322264.html>>), Craig Mundie’s recent speech in the NY University Stern School of Business (available from <<http://www.microsoft.com/presspass/exec/craig/05-03sharedsource.asp>>), and Stephen Shankland, *Microsoft license spurns open source*, CNET News.com, June 21, 2001 (available from <<http://news.cnet.com/news/0-1003-200-6352301.html>>). For a brief analysis as to the precise strategic reasons for the attacks see also Joe Wilcox and Stephen Shankland, *Why Microsoft is wary of open source*, CNET News.com, June 18, 2001 (available from <<http://news.cnet.com/news/0-1003-202-6291224.html>>).

²⁶Joe Barr, *An interview with Linus Torvalds: Free, as in beer*, LinuxWorld, February, 2001

2.2 Economic and Legal Foundations

2.2.1 The Market

The notion of the market has been used for centuries in a whole host of manifold senses and contexts. One theme, however, above all, is recurrent: the mutually beneficial voluntary transaction, stemming from two most basic human traits, the striving for survival, that is, the desire to satisfy certain basic and higher level needs, and the ability to form beliefs about rights and wrongs, and to judge one's own performance from an impartial perspective, impacting on individuals' behaviour in a social context. The former gives rise to transactions, and the latter creates a sense of reciprocity accompanying those transactions, rendering them mutually beneficial.²⁷

The Oxford English Dictionary traces the use of the word back to the 12th century, however, it was not until Adam Smith's "The Wealth of Nations" that the notion was forcefully introduced into theoretical economic thinking.

The great Scottish philosopher never gave a precise definition of the market, effectively leaving the issue open to interpretation,²⁸ but made a strong statement in favour of the market as an institutional mechanism, which under conditions of 'free competition' or 'perfect liberty' resulted in maximised overall social welfare. His rhetorics were principally aimed at policymakers at the time, in view of a general indifference towards social welfare as a desirable goal of policy, and a widespread scepticism towards trade as a means of increasing welfare.²⁹ Implicit and important to his argument is the recognition that transactions are of a voluntary nature and economic actors are opportunistic, hence all the parties

(available from <http://www.linuxworld.com/lw-2001-02/lw-02-linux.html>). It is a very popular misconception that Linux has chiefly been a countermovement to Microsoft fuelled by political and ideological sentiment. A recent FT article by a columnist known for her self-serving and unsound claims states: "An important element of the Linux spirit was rebellion against 'big business' interests – and in particular Microsoft, as it came to dominate the desktop" (Louise Kehoe, *The spirit of Woodstock struggles on*, Financial Times, August 29, 2001, p. 11).

²⁷See Gouldner (1960) who argues that reciprocity as a 'universal norm' contributes substantially to the 'stability of social systems', a notion that has been reinforced by the game-theoretic approach and its implications (Axelrod 1984).

²⁸Cairnes (1888, p. 100) criticised him because "it is not quite clear ... in which sense he [Smith] uses the word 'market'."

²⁹In the 18th century commerce was regarded as highly suspicious in the Christian and civic republican tradition, both of which were based largely on ancient Greek thought. Recall that Aristotle considered 'trafficking in goods' as hazardous to the moral well-being of individuals.

to a transaction should be better off after the transaction.³⁰ To him the decentralised market mechanism was in many instances vastly superior to any type of centralised administrative system.³¹

However, he was also aware that “from the point of view of the individual producer or group of producers it was most beneficial to circumvent the competitive

³⁰As he put it forcefully:

[M]an has almost constant occasion for the help of his brethren, and it is in vain for him to expect it from their benevolence only. He will be more likely to prevail if he can interest their self-love in his favour, and show them that it is for their own advantage to do for him what he requires of them. . . . It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest. We address ourselves, not their humanity but to their self-love, and never talk to them of our own necessities but of their advantages. (Smith 1910, p. 13)

³¹He puts it:

He generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it. . . . [H]e intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention. . . . The statesman who should attempt to direct private people in what manner they ought to employ their capitals would not only load himself with a most unnecessary attention, but assume an authority which could safely be trusted, not only to no single person, but to no council or senate whatever, and which would nowhere be so dangerous as in the hands of a man who had folly and presumption enough to fancy himself fit to exercise it. (Smith 1910, pp. 400–01)

Incidentally, he only used the notion of the “invisible hand” once in his work, and there is, in fact, nothing mystical to it.

Most neoclassical writers have anxiously defended and elaborated this market notion, and reject outright any state intervention going beyond the legal recognition and enforcement of private property rights (Friedman 1962; Becker 1962; Liebowitz and Margolis 1999). An exemplary statement by Liebowitz and Margolis (1999) reads:

An inefficiency is a profit opportunity. By definition, an inefficiency means that there is some feasible change for which the benefits outweigh the costs. That is to say, there exists a possible surplus. The person who can figure out a way to bring about the necessary reallocation and capture some of the net benefit will enjoy a profit. Where property rights are clear and freedom of contract is broad and secure, inefficiencies will face assault from profit-seeking entrepreneurs. . . . The abstract possibility of market failure is an inadequate basis for the making of real-world policy. (pp. 239–40)

For a summary of critical accounts of a market-based and voluntaristic society see Shearmur and Klein (1997). See also Copp (2000) for an interesting treatment of the inherent conflict

market with its attendant risks, and use all available means to prevent competition, in order to obtain the highest possible price for their wares”, as Muller (1993, p. 77) points out. Therefore, the market had to be designed in a way that encourages “self-control and the channeling of the passions in socially beneficent directions” (p. 131).

The notion of the market, it appears, is a crucial yet highly ambiguous concept at the very core of economics. It is often used in different contexts and its usual definition is relatively broad. A recent definition (Pearce 1986, p. 263) reads: “[G]enerally, any context in which the sale or purchase of goods or services take place. There need be no physical entity corresponding to a market”. A more narrow definition, linking the market explicitly to the exchange of goods, is the one by Hardwick, Khan, and Langmead (1999, p. 51): “The market for a good can be thought of as the area in which buyers and sellers of the good come in to contact with each other to transact their business”.

Understandably, sociologists feel generally uneasy about such definitions. Lie (1997, p. 342) remarks: “[T]he neoclassical market is shorn of social relations, institutions, or technology and is devoid of elementary sociological concerns such as power, norms, and networks”,³² and continues: “The very abstraction of the market – its ontological indeterminacy – allows for its universal applicability”.

The application of axiomatic propositions to economic modelling, and the dispensing with factors that apparently evade reliable abstraction may be justified as it facilitates a basic understanding of economic processes, yet the economic concept of the market is not universally applicable to a universe of human relations.³³ As Schumacher (1973, p. 42) puts it: “There are boundaries to the applicability of the economic calculus”, and “[T]o undertake to measure the immeasurable is absurd and constitutes but an elaborate method of moving from preconceived notions to foregone conclusions” (p. 41).

Antitrust policy, in making normative considerations about social welfare, builds largely on economic considerations regarding efficiencies of markets. By virtue of the government’s coercive power it seeks to correct market inefficiencies

between capitalism and freedom, stemming from inequalities in economic power.

³²To be sure, these concerns are not entirely new. Marshall (1920, p. 182) wrote: “Everyone buys, and nearly everyone sells. . . in a ‘general’ market. . . . But nearly everyone has also some ‘particular’ markets; that is, some people or groups of people with whom he is in somewhat close touch: mutual knowledge and trust lead him to approach them. . . in preference to strangers”.

³³See also Kindleberger (1986, pp. 1–3).

by imposing remedies on corporations which are considered to abuse their market power and thereby lower social welfare.³⁴

Whilst ‘the market’ in most economic considerations is generally a rather broad concept, the point of departure from an antitrust perspective is the product, and “the interest is in market power” (Faull and Nikpay 1999, p. 44). Part of the legal test that is being applied in judging allegations of market power that prejudices consumers is the notion of the ‘relevant product market’, which “includes all the products and firms that in fact do or could easily offer reasonable substitutes to the customers if the firm in question were to raise prices or supply inferior products” (p. 45).³⁵ The difficult issue in defining the market is that the boundaries usually cannot be decided satisfactorily precisely. Implementing antitrust guidelines in reality is far from straightforward and may pose many pitfalls. Assessing all relevant contingencies regarding demand and supply substitutes and potential competition is prone to misjudgements or may simply be infeasible,³⁶ questioning the reasonable justification of any policy measures.

This tends to be an especially serious issue in industries undergoing a rapid pace of product and technological innovation, which is certainly the case in software markets, as Katz and Shapiro (1998, p. 13) note: “Market boundaries shift over time along with technology and marketing practices”.³⁷ The ongoing Microsoft lawsuit has shown that already the determination of what constitutes a product is notoriously difficult and depends on the standing. One may consider an operating system a distinct product.³⁸ Microsoft has been arguing that its Internet Explorer is an integral part of its Windows operating system.³⁹ Whatever the standing, software products are strongly complementary and can be described as forming systems (Katz and Shapiro 1994), which tend to be subject to signifi-

³⁴Exploring the notion of antitrust or competition policy is beyond the scope of this paper. But see Carlton and Perloff (2000, ch. 19–20), Van Cayseele and Van den Bergh (2000), and Faull and Nikpay (1999).

³⁵This notion can be found in American and European legislation. See Faull and Nikpay (1999, pp. 45–6).

³⁶For an elaboration see, for example, Froeb (1994) and his references.

³⁷The US DOJ and FTC Antitrust Guidelines for the Licensing of Intellectual Property (1995, available from <<http://www.usdoj.gov/atr/public/guidelines/ipguide.htm>>) take this to a certain extent into account. See especially § 3.2.3 which treats innovation markets.

³⁸In 1993 upon receiving a complaint from Novell about Microsoft’s licensing practices, the European Commission made the finding that the three layers of software, operating system, graphical user interface (GUI), and software applications, constituted separate markets. (XXIVth Report on Competition Policy, 1994, Annex II at 364-5)

³⁹See also the appeals court opinion, *infra* note 118 at 79.

cant network effects, potentially creating both direct and indirect externalities.⁴⁰ This complicates an appropriate determination of relevant markets considerably. Moreover, price discrimination between different consumer segments may further narrow the relevant market.⁴¹

Some authors have argued that the relevant market definition is too narrow in that it puts unduly little emphasis on the dynamics of the market and the importance of future-generation products. However, the analytic difficulties in reliably predicting future-generation product markets are obviously considerable, as “all that we presently can observe is the current generation goods market, existing assets, and the research and development efforts proposed or in progress” (OECD 1997, p. 13). Hruska (1992) elaborates:

[I]n a rapidly evolving high-technology market, it is hard to define a product which continually changes both in its internal characteristics (such as the speed and fluidity of the operating system) and its interaction with other similarly developing products (such as the interaction of OS software and continually advancing microprocessor hardware). (p. 330)

In an antitrust context an appropriate definition of the product market in operating systems is, due to the uncertainties of development and the ambiguity of economic models, highly difficult.⁴²

2.2.2 Transaction Costs

The recognition of property rights is central to the capitalist system.⁴³ It is a widely accepted notion among economists that private property enhances social welfare due to the incentives associated with diverse kinds of property relation-

⁴⁰See section 2.2.4.

⁴¹This is explicitly recognised in the 1992 US DOJ/FTC Horizontal Merger Guidelines (available from <<http://www.antitrust.org/law/US/mg.html>>).

⁴²OECD (1997) states:

Product market definition poses severe difficulties in a context where research and development efforts continuously change the nature of products, the possible substitutes for those products, and the identity of suppliers of the products and their substitutes. (p. 9, footnotes omitted)

For an excellent survey of relevant economic and legal literature in this field see OECD (1997, pp. 7-39).

⁴³In fact, property rights and the freedom to utilise properties as desired are the defining characteristics of the capitalist system.

ships.⁴⁴ However, those rights are not natural, but depend upon the existence and enforcement of legal rules.⁴⁵ Only the establishment of private property rights gives rise to potential mutually beneficial transactions in a market.⁴⁶ Indeed, the concept of property had been expanded from a purely physical conception to one which takes exchange value into account. The differential between individuals' valuations (or costs) of goods and services which gives rise to 'clearing' in a market place is recognised and legally protected. That is, "the *expected earning power* of those things is property" and thus "[t]o deprive the owners of the *exchange value* of their property is equivalent to depriving them of their property" (Commons 1924, p. 16, emphasis in original).

The recognition and protection of property rights gives rise to costs, and so does the exchange of properties rights. Throughout the history of economics this has been widely recognised. Adam Smith repeatedly points at the costs of maintaining property rights,⁴⁷ the costs of transferring properties,⁴⁸ as well as "concepts of costly information and the ability of individuals to exploit others' ignorance to their own advantage" (Allen 2000, p. 912).

⁴⁴See for example Usher (2000), and Olstrom (2000).

⁴⁵It is a fallacy to believe that property rights can be solely designed according to economic efficiency considerations. As Schmid (1989, p. 59) puts it nicely: "[The economy is] a universe of human relations" and not merely "a universe of commodities". And Samuels (1981, p. 155) remarks: "There is no independent test by which the law's solutions can be said to be the efficient solution". Institutional economics holds that a purely efficiency driven approach to institutional change is too narrow and somewhat misleading, given the evolving and interdependent character of law and economics. For "owing to human interdependence and scarcity, each individual's opportunity set is constrained and shaped by the opportunity sets of others in society" (Medema, Mercuro, and Samuels 2000, p. 437), property rights are constantly evolving and changing. "Since each individual desires to make choices from a set that is as unconstrained as possible, individuals will wish to control the choices and hence opportunity sets, of others who may constrain their choice." This conflict is especially severe with respect to intellectual property. See section 2.2.5.

⁴⁶Allen (2000, p. 898) puts it: "Given that trade is the transfer of property rights, there can be no trade (and hence no gains from trade) in the absence of property rights".

⁴⁷"He [the rich man] is at all times surrounded by unknown enemies, whom, though he never provoked, he can never appease, and from whose injustice he can be protected only by the powerful arm of the civil magistrate continually held up to chastise it" (Smith, as cited in Muller 1993, p. 147).

⁴⁸"If the two countries are at a great distance, the difference may be very great; because though the metals naturally fly from the worse to the better market, yet it may be difficult to transport them in such quantities as to bring their price nearly to a level in both. If the countries are near, the difference will be smaller, . . . *because in this case the transportation will be easy*" (Smith 1910, p. 173, emphasis added).

It was not until Coase's (1937) famous article that the concept of transaction costs was explicitly introduced to economic thinking. Coase did not define transaction costs with any precision, simply calling it "[the] cost of using the price mechanism" (p. 391), which he considered in the context of institutional choice, effectively arguing that positive transaction costs were both necessary and sufficient for an explanation of the firm. Only much later he provided some elaboration of the concept (Coase 1960), yet the notion was to remain a vexed one. Whereas the existence of transaction costs is undisputed, its implications are obscure to the present day. It has proven an insufficiently powerful tool of analysis in explaining institutional choice,⁴⁹ and its assumptions limit its predictive value.⁵⁰

Allen (2000) makes a useful distinction between two approaches to the notion of transaction costs: property rights and neoclassical approach. For the former "the two concepts of property rights and transaction costs are fundamentally interlinked" (p. 897) and transaction costs are defined as "the costs establishing and maintaining property rights" (p. 898). Thus, if property rights were complete, no transaction costs would occur.⁵¹ Alternatively, departing from the Coase theorem,⁵² transaction costs may be defined as the "costs that cause the Coase theorem not to apply" (Allen 2000, p. 905)

Beginning with Hicks (1935) the neoclassical approach defines transaction costs more narrowly as the "costs resulting from the transfer of property rights" (Allen 2000, p. 901). Hence "in the neoclassical approach, enforcement type costs *within* the firm are *not* transaction costs (p. 902, emphasis in original).

Regarding the causes of transaction costs, both approaches are relatively similar. Parties must:

find each other, they have to communicate and to exchange information . . . goods must be described, inspected, weighted and measured.

Contracts are drawn up, lawyers may be consulted, title is trans-

⁴⁹For a seminal criticism see Alchian and Demsetz (1972), and for a summary of approaches to the theory of the firm see Hart (1989) and Foss, Lando, and Thomsen (2000).

⁵⁰For two articles challenging major assumptions and implications of transaction cost economics see Norderhaven (1995), and Zajac and Olsen (1993).

⁵¹Cheung (1992, p. 52) states: "[T]he dual specifications of clearly delimited rights and zero transaction costs are redundant. If transaction costs are truly zero, the delineation of rights can be ignored".

⁵²The Coase theorem states that in the absence of transaction costs the outcome of private bargaining will be Pareto-efficient regardless of the distribution of property rights. For an extensive review and discussion of literature on the Coase theorem see Medema and Zerbe Jr. (2000).

ferred and records have to be kept. In some cases, compliance needs to be enforced through legal action and breach of contract may lead to litigation. (Niehans 1987, p. 676)

Defining transaction costs poses significant difficulties. Demsetz (1988) pointed out that applying the term too broadly threatens to make it tautological and useless. Schlag (1989) summarises: “an overly expansive view of transaction costs threatens to make the Coase theorem tautological. On the other hand, an overly restrictive view of transaction costs can effectively invalidate the theorem” (p. 1675). Moreover, the notion of transaction costs draws on the assumption that economic actors behave opportunistically whenever they engage in market transactions. It remains inevitably silent on the nature and origins of its causes.

2.2.3 Information Costs

The principal cause of transaction costs are information imperfections. If information was perfect no transaction costs would arise (Barzel 1977). The classic article calling for a more rigorous treatment of information was that by Stigler (1961), but it was mainly Stiglitz who formalised and elaborated the notion of the economics of information. From an information costs perspective imperfect information rather than transaction costs are at the heart of economic problems.

Grossman and Stiglitz (1980) showed that informationally efficient markets are impossible, due to the fundamental conflict between the incentives to produce costly information and the efficiency with which it is disseminated.⁵³ The only information that could be efficiently distributed was costless information. Hence “the idea of a perfect market in information is internally contradictory even in theory” (Boyle 2000, p. 2013).

In the context of consumer decision making the problem of limited information can have severe impacts on the market structure and equilibrium. Consumer welfare may as a result be affected. Carlton and Perloff (2000, pp. 421–2) identify five chief reasons for limited consumer knowledge: differing reliability of information; cost of collecting information; limited ability to store and recall information; bounded rationality, i. e. the use of simplified rules to process information; and differing ability to process information correctly due to education and intelligence.

It has been argued that limited quality information about goods or services on the part of the consumer may result in the non-existence of a market, or

⁵³They put it: “There is a fundamental conflict between the efficiency with which markets spread information and the incentives to acquire information” (p. 405).

only the lowest-quality good may be sold (Akerlof 1970).⁵⁴ The inefficiencies resulting from asymmetric information may be prohibitively expensive to remedy by means of government intervention. However, there are ways of equalising information levels or efficiently remedying the prejudices to consumers resulting from ignorance, to alleviate the information imperfections.⁵⁵ Guarantees and liability laws may serve as an assurance to consumers that the quality accords with the claims of the seller. Reputation as a signal of quality in markets where sellers expect repeated purchases and hence have a strong incentive not to sell defective goods may constitute a similar check. Independent parties may provide reliable information to consumers if the resulting increase in consumer welfare outweighs the costs of provision.

Limited price information may result in the disappearance of a market or in a multi-price equilibrium (Carlton and Perloff 2000, p. 431). A single-price equilibrium can occur at the monopolistic price (or at least above the marginal price) (p. 433), which may cause the market to disappear, depending on the search costs and the number of sellers (Stiglitz 1979). The nature of the equilibrium is understood to depend upon the number of informed and uninformed consumers, which determines the loss of business to sellers that raise their price above the competitive equilibrium price, and hence their ability to profitably do so.⁵⁶

The result of these distortions relative to the theoretical optimal market with a hypothetical Walrasian auctioneer is that the fundamental law of supply and demand and the law of one price do not hold in markets where information is limited. “[M]arkets with limited information differ from those with perfect information” (Carlton and Perloff 2000, p. 447). Moreover, “market prices are not the only signals which convey information about scarcity, and prices do convey information other than that about scarcity”. There are a variety of other ways being utilised to convey information (Stiglitz 2000, p. 1449). The hope that information imperfections could be treated with conventional tools in the neo-classical framework (Stigler 1961) has largely proved futile, since “many of the standard results – including welfare theorems – do not hold even when there are small imperfections of information” (Stiglitz 2000, pp. 1443–4).

⁵⁴Carlton and Perloff (2000) put it tersely: “*There is no market for good-quality used cars*” (p. 425, emphasis in original).

⁵⁵The remainder of this paragraph draws heavily on Carlton and Perloff (2000, pp. 426–7).

⁵⁶Generally speaking, the more informed consumers there are, the higher the probability that competitive prices prevail. See Carlton and Perloff (2000, pp. 431–41) for an elaboration.

With special respect to high tech markets Sirgy and Su (2000) argue that “[t]he complexity of technological innovations has increasingly undermined the foundations of perfect competition” (p. 1) and “consumers in an increasing world of high tech have less knowledge about what constitutes quality, let alone the ability to compare and contrast the quality of two or more high tech products. . . preventing the average consumer from making wise and informed decisions” (p. 7). Consumer sovereignty, resting on the notion that people *know* what is good for them and can value it accordingly, is becoming a fiction rather than a useful assumption.⁵⁷ Hence, they argue, businesses have to implement the stakeholder concept (Freeman 1984), and behave in a socially responsible manner. However, it is clear that profit-maximising companies will capitalise on information differentials where possible.⁵⁸ Stiglitz (2000) puts it: “Firms know that it is costly for customers to search, and will exploit that. Managers know that it is costly for shareholders to monitor them, and will exploit that” (p. 1455). Economic actors have an incentive to create noise or take actions to increase the level of asymmetries of information (Edlin and Stiglitz 1995; Stiglitz 2000).

2.2.4 Network Externalities

The notion of externalities can be traced back at least to Pigou (1938) who argued that possible spillover effects could create unpriced externalities, affecting the socially optimal allocation of resources.⁵⁹ His taxation solution had subsequently

⁵⁷Uncertainty, information imperfections and bounded rationality potentially render them unfit to make rational decisions. See also marketing textbooks (for example Adcock et al. 1998, pp. 71–2, Kotler et al. 1999, pp. 243–51) for the notions of selective attention, selective distortion, and selective retention.

⁵⁸To be sure, the empirical evidence that ‘socially responsible’ companies do on average perform better than other companies due to the impact of ‘socially responsible’ investors and consumer activism is mounting (Heal 2001). From an orthodox CAPM perspective this seems puzzling, but see also for example Chatterjee, Lubatkin, and Schulze (1999) who contend that markets are imperfect and ‘strategy matters’.

⁵⁹Says Pigou:

[T]he essence of the matter is that one person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders a service or disservice to other persons (not producers of like services), of such a sort that payment cannot be extracted from the benefited parties or compensation enforced on behalf of the injured parties. (p. 183)

Pigou himself owed a fair amount to Marshall:

We must call to mind the fact that the struggle for survival tends to make those methods of organisation prevail, which are best fitted to thrive in their environ-

been largely rejected by proponents of the public choice and the property rights approach. Coase (1960) in his celebrated article rearticulated Knight's (1924) critique, arguing that taxation is rigid and arbitrary, and would simply create another externality, foreclosing the possibility of the affected parties to strike a mutually advantageous bargain. Not only is the precise tax impossible to compute, it also creates incentives that render the tax as a means to achieve efficiency futile:

... to do so would require a detailed knowledge of individual preferences and I am unable to imagine how the data needed for such a taxation system could be assembled. ... [E]ven if the tax is exactly adjusted ... [it] would not necessarily bring about optimal conditions. ... Without the tax, there may be too much smoke and too few people living in the vicinity of the factory; but with the tax there may be too little smoke and too many people living in the vicinity of the factory. (Coase 1960, pp. 41–2)

From his perspective the externality problem is essentially one of transaction costs. Therefore the remedy has to focus on property rights rather than taxation. Dahlman (1979) carries this point further, stating that the concept of externalities is a highly normative one, and deeming the economy to be in a Pareto-efficient equilibrium. Due to the associated costs and uncertainties government intervention is not justified.⁶⁰

ment; but not necessarily those best fitted to benefit their environment, unless it happens that they are duly rewarded for all the benefits they confer, whether direct or indirect. And in fact this is not so. ... [A]nd as a result many businesses languish and die, which might in the long run have done good for society if only they could have obtained a fair start. (1916, pp. 596–7)

⁶⁰Says Dahlman (1979):

If we include the costs of transacting in the constraints that describe the conditions under which economic agents perform their individual wealth maximization, we would then describe an attainable optimum, and this is one we should use in judging optimality and welfare problems. ... The conclusion ... would seem to be that if it exists it must be optimal, and if it does not exist it is because it is too costly, *so that is optimal too*. If you do not like the smell of the air, seek comfort in the knowledge that it would cost you more than it is worth to you to do away with the stench, for, otherwise, would you not do it? (pp. 153–4, emphasis added)

and continues:

There is no proof that the market, in the presence of costs of transacting, does

A considerable shortcoming of both Pigou and his critics is their representation of the allocation problem in a partial equilibrium context rather than in one of dynamic generation and resolution, as Dragun and O'Connor (1993) point out. Coase's (1960) "formal symmetry in any situation of externality", they argue, "is highly problematical (not to say self-serving) in a properly dynamic view of externality generation and resolution". Incidentally, according to a study by economists at St Andrews University 19,500 Britons die prematurely due to air pollution every year,⁶¹ and it is doubtful that there is any perceptible immediate symmetry in cause and effect and a reasonable opportunity for the affected parties to remedy the situation themselves, not only due to transaction costs but due to highly imperfect information. The absence of symmetry in a large number of externality cases is crucial, and suggests that property rights approaches to phenomena like environmental degradation and pollution are not as academically sound as its proponents purport.⁶²

Network externalities are of a fundamentally different nature than Pigovian externalities, yet they pose the same set of challenges regarding the warrant and nature of government intervention. The concept of network externalities has been receiving increasing attention over the last decades by economists and policy makers. Courts have in recent cases largely accepted that software markets are subject to considerable network externalities, justifying the potential need for antitrust enforcement actions. Unfortunately, the policy implications are less clear.⁶³ Whilst some argue that the purported welfare loss due to possible 'lock-in' effects and inefficient network size is largely unproven, and advocate a

not attain an optimum, but a simple assertion: the market leads to an inoptimal solution *relative to what the government can attain*. To make this a reasonable proposition we must *assume* that the government can do better than the market can – and this is the implicit point of reference according to which we judge market performance. (p. 155, emphasis in original)

⁶¹Jim Pickard, et al., *Pollution 'kills 19,500 a year'*, Financial Times, January 15, 2001, p. 6.

⁶²See also, for example, Gorringer (1999, ch. 3), and Schumacher (1973).

⁶³Say Katz and Shapiro (1994):

[I]t is theoretically possible for government intervention to improve market performance. But ... the extent of the market inefficiency is unclear, ... [and] even if policy-makers try to maximize total surplus, they may lack the information needed to do so. ... [W]e are far from a general theory of when government intervention is preferable to the unregulated market outcome. (pp. 114–5)

hands-off approach because of the highly dynamic nature of software markets and the uncertainties and costs of antitrust measures (Liebowitz and Margolis 1999), others see a strong need for government intervention to promote social welfare.

Network externalities stem from the characteristic of certain products to derive some of their value from the number of others using the same or a compatible product, that is, the users of these products form a network, and the utility of each single product depends partly on the size of the network, the classic example being a telephone network. The more people are connected to the network, the higher the potential individual benefit. This ‘positive feedback effect’ (Arthur 1990) may result in unpriced externalities and possible ‘lock-in’ into a Pareto-inferior equilibrium, which potentially affect social welfare.

Katz and Shapiro (1985) make a useful and widely accepted distinction between direct and indirect network externalities. The former is “generated through a direct physical effect of the number of purchasers on the quality of the product” (p. 424).⁶⁴ The latter is given rise to by ‘indirect effects’, commonly referred to as the ‘hardware–software paradigm’, (Katz and Shapiro 1985, p. 424) and applies to complementary products which form systems.⁶⁵ The owners of these systems can be considered to form a ‘virtual network’. Indirect consumption externalities arise when complementary components to a system are purchased at different times (Page and Lopatka 2000, p. 955), for example cars and various postpurchase services; hardware and software; video players and tapes. The costs and availability of complementary products to a base product, and hence the value of the base product and the *whole* system, may depend upon the number of users of the same or a compatible base product.⁶⁶

Liebowitz and Margolis (1994) make a distinction between network *effects* and network *externalities* in order to discriminate between ‘merely pecuniary externalities’ and true network externalities, which in their view are far less common than network effects generally. They argue that most indirect network exter-

⁶⁴Note, however, that direct network externalities might also arise in the absence of a physical network, consider for example human languages.

⁶⁵Page and Lopatka (2000) define a system as “any combination of a durable good and associated goods or services that perform some desired function” (p. 955).

⁶⁶The classic example here is that given by Katz and Shapiro (1985):

[A]n agent purchasing a personal computer will be concerned with the number of other agents purchasing similar hardware because the amount and variety of software that will be supplied for use with a given computer will be an increasing function of the number of hardware units that have been sold. (p. 424)

nalities are, in fact, pecuniary externalities, “external effects that work through the price system”, and reserve the term network externality for “a specific kind of network effect in which the equilibrium exhibits unexploited gains from trade regarding network participation”.⁶⁷

As mentioned earlier, networks that exhibit direct externalities may have a sub-optimal size, since the private marginal benefit of participating in the network is lower than the total social benefit. That is, there are ‘adaption externalities’ which the individual is unlikely to consider upon making a decision. The equilibrium size of the network may be smaller than the social optimum (Katz and Shapiro 1994). Further, future expectations on the part of the individual and coordination problems resulting in a ‘social dilemma’ situation may affect network size. At the extreme, two markedly different equilibria are possible, depending on the expectations of every individual.

Property rights that allow the internalisation of consumption externalities may solve the problem of inefficient network size (Katz and Shapiro 1994; Liebowitz and Margolis 1994). Single ownership of the network may allow pricing that reflects the the overall benefit derived from an additional user, and the owner may deploy a whole host of different strategies to attract users. However, in the case of inexhaustible economies of scale, as is typically the case with software products, a monopoly may exacerbate inefficiencies. When cooperation is viable, possibly facilitated by intermediary organisations, internalisation of externalities may be possible without single ownership.

The inefficiencies in networks with indirect externalities stem largely from uncertainty about future availability and price of the software⁶⁸ in the presence of significant switching costs. That is, a user may be ‘locked in’ to a product, due to sunk pecuniary and learning costs. If a monopolist supplies both hardware

⁶⁷Note, however, their point of departure:

[B]oth by name and by some of the explicit results of the network literature, network externalities are asserted to constitute market failure. If almost every aspect of the economy exhibits network externality, and if externalities presumptively are market failures, then our most basic results about the efficiency of markets may be in error and dramatic policy changes might be warranted. We believe such changes would be misguided. (p. 134)

Their work in general may be seen in the context of the general propensity of the Chicago school to defend basic neoclassical assumptions and concepts. See also Freedman (1998).

⁶⁸I am using the word software here in the context of the ‘hardware–software paradigm’.

and software, there is a danger that he will exploit ‘locked in’ consumers (Katz and Shapiro 1994). To remedy those problems a sponsor of a hardware–software network can make binding commitments regarding future software availability and pricing. Since this is not always a feasible option, the sponsor may open the market to independent software suppliers, thereby assuring customers they will not be exploited (Farrell and Gallini 1988). Leasing hardware can lower the sunk cost commitment of the consumer (Katz and Shapiro 1994).

The existence of network externalities can have significant effects on the nature of competition between incompatible systems (Arthur 1990; Katz and Shapiro 1994). Due to increasing returns to scale an early standard may ultimately dominate the whole market. It has been suggested that the resulting equilibrium may be suboptimal, a superior standard may not be adopted by the market due to prohibitively high switching costs and coordination dilemmas (David 1985; Arthur 1990). Katz and Shapiro (1994, p. 106) state that “standardizing on a single system can be very costly if the system turns out to be inferior to another system”. The tendency of network markets to tip towards one standard can result in particularly intense competition in the early phase, leading competitors to employ aggressive strategies like penetration pricing in a bid for future profits from the de facto standard (Katz and Shapiro 1994).

Liebowitz and Margolis (1994, 1995a, 1999) strongly dispute that those effects lead to market failure, especially that of inferior choice among discrete networks. They contend that value-increasing transitions do occur, submitting, however, that the nature of these transitions is poorly understood in economics. Liebowitz and Margolis (1999) maintain that software markets are subject to Schumpeterian competition (Schumpeter 1942), that is, rapid innovation is a major source of creation and destruction in the economy and monopolies are of a serial nature. Further they contend that most industries are subject to decreasing returns to scale, and therefore multiple networks can exist (Liebowitz and Margolis 1994).⁶⁹

A considerable shortcoming of the literature on network externalities is the lack of empirical support for the possibility of market failure. It is unfortunate that the example most often cited by proponents of the concept is the notorious QWERTY case (David 1985). Liebowitz and Margolis (1990) have argued forcefully that the story is factually incorrect. Similarly, Liebowitz and Margolis (1994) show

⁶⁹Although it is generally understood that software markets exhibit increasing returns to scale, Liebowitz and Margolis (1999) argue that these markets may also be subject to decreasing returns, with a, however, tenuous example (pp. 81–2). For a brief critique see Brown (2000).

that the Beta videotape format is no better than VHS, as was asserted by Arthur (1990).⁷⁰

A further important limitation to models of network externalities is the assumption that network value functions rise without limit (see for example Katz and Shapiro 1986). Moreover, heterogeneous consumer preferences may allow multiple competing networks to coexist (Katz and Shapiro 1994; Liebowitz and Margolis 1998).

Closely related to the notion of network externalities is that of path dependence. It has been asserted that the existence of network externalities in markets with increasing returns may cause ‘path dependence’ (Arthur 1989), that is, insignificant historical events may result in an inefficient and unremediable equilibrium. The classic paradigm setting case, again, is that of the QWERTY keyboard, which, as mentioned above, was proved flawed by Liebowitz and Margolis (1990).

Liebowitz and Margolis (1995b) draw a distinction between three progressively increasing degrees of path dependence, the first two of which occur commonly and do not affect efficiency. Rather, they merely reflect ordinary durability. Third-degree path dependence relates to an inefficient outcome, where there exists a preferable outcome which is not obtained, albeit feasible. This inefficient ‘lock in’ is commonly ascribed to ‘interactive behaviour’ problems. The empirical evidence for the existence of third-degree path dependence is weak and no clear policy implications can be drawn (Liebowitz and Margolis 1995b, 2000).

However, switching costs, including learning and transaction costs, and co-ordination problems can impede the transition to a superior standard and reduce social welfare. Firms may have an incentive to increase switching costs through incompatible proprietary standards and contractual means (Klemperer 1987; Katz and Shapiro 1994; Shapiro 1999), thwarting competition.⁷¹ Compatibility of competing products can be welfare enhancing, leading to intense

⁷⁰To be sure, the evidence that the QWERTY keyboard arrangement is as good as the Dvorak or any other arrangement is, in fact, not conclusive. The mere exposure of flaws in Dvorak’s research is not sufficient for the conclusion that there exist no adverse and insuperable network externalities. See for example MacKenzie and Zhang (1999), and Marmaras and Lyritzis (1990).

⁷¹Says Shapiro (1999, p. 10):

[L]ack of compatibility can be the death-knell of a new technology, even if it is superior in some absolute or stand-alone sense. And incumbent firms often have the incentive to exert their intellectual property rights to deny such compatibility to would-be entrants.

competition in the mature stage of the market and substantially lower switching costs. There are two principal mechanisms to achieve compatibility (Katz and Shapiro 1994):

standardization, whereby systems are designed to have interchangeable components; and adapters, which attach to a component of one system to allow it to interface with another system. With adapters, the principal cost is that of the adapters themselves, *plus the fact that adapters may work imperfectly*. By contrast, the primary cost of standardization is a loss of variety: consumers have fewer differentiated products to pick from, especially if standardization prevents the development of promising but unique and incompatible new systems. (emphasis added, footnotes omitted)

Firms tend to prefer incompatibility and spend resources to block compatibility if they have a “distinctly superior overall package, including its product offering, its installed base, and its reputation” (Katz and Shapiro 1994). If that is not the case, firms may prefer compatibility.

In software markets firms can employ intellectual property rights and contractual means to block compatibility and thereby increase switching costs. Regulatory policies that encourage standardisation and make compatibility possible may thus be welfare enhancing.

2.2.5 Intellectual Property Rights

Intellectual property “continues to be one of the law’s more obscure and esoteric fields” (Millard 2000, p. 177). It is an area of unusual conceptual difficulties, and is justified on a whole host of different theories, non of which provides a fully satisfactory framework, and conclusive justification and guidelines for policy measures.⁷² Rather, intellectual property constitutes a trade-off between a host of

⁷²Menell (2000) captures the problem neatly:

Economic theorists have produced multiple plausible models for which empirical distillation will remain elusive and unlikely to be of much predictive value due to the heterogeneity of inventive activity, the diversity of research environments, the complexity of technological diffusion, the richness and changing nature of real world institutions and the obvious measurement problems in conducting empirical research of this type. . . . [T]he holy grail of a perfectly calibrated incentive system is unattainable. (p. 163)

stakeholders, shaped by social welfare considerations and rent seeking activities.⁷³

The principal argument in favour of private intellectual property rights is that they provide crucial incentives for the creation of ideas, the principal framework being that of utilitarianism.⁷⁴ Says Bentham (1839, p. 71):

[T]hat which one man has invented, all the world can imitate. Without the assistance of the laws, the inventor would almost always be driven out of the market by his rival, who finding himself, without any expense, in possession of a discovery which has cost the inventor much time and expense, would be able to deprive him of all his deserved advantages, by selling at a lower price.

Effectively, the conferment of intellectual property rights renders inherently non-rivalrous information goods claims on the rivalrous good money in a monetary exchange context, endowing it with a legally recognised and protected exchange value.⁷⁵ The chief trade-off regarding the extent of intellectual property rights protection is that between creating incentives for innovation and the deadweight loss of monopoly exploitation.⁷⁶ The point of departure for intellectual property rights has traditionally been the recognition that information is a public good,⁷⁷

⁷³Note the rhetoric quality of the metaphor ‘intellectual property’, obfuscating the fact that *a priori* there are no natural exclusive rights whatsoever to ideas, and implicitly shifting the focus from public to private benefit.

⁷⁴For an account of the principal arguments against utilitarianism as a framework for public policy see Brown (1992).

⁷⁵It may be argued that contractual measures can serve the same purpose. However, absent a clear legal understanding of its merits as private property, this has proven somewhat difficult.

⁷⁶Lord Mansfield in *Sayre v. Moore* (1785) stated:

We must take care to guard against two extremes equally prejudicial; the one, that men of ability who have employed their time for the service of the community, may not be deprived of their just merits, and the reward of their ingenuity and labour; the other, that the world may not be deprived of improvements, nor the progress of the arts be retarded.

⁷⁷Jefferson (1813), reflecting upon the public goods attributes of information, non-excludability and inexhaustibility, put it:

It is agreed by those who have seriously considered the subject, that no individual has, of natural right, a separate property in an acre of land, for instance. By an universal law, indeed, whatever, whether fixed or movable, belongs to all men equally and in common, is the property for the moment of him who occupies it; but when he relinquishes the occupation, the property goes with it. *Stable ownership is the gift of social law*, and is given late in the progress of society. It

which gives rise to a principal conflict between the creation of knowledge and social welfare, recognised by Arrow (1962):

[A]ny information obtained... should, from the welfare point of view, be available free of charge... This insures optimal utilization of the information but of course provides no incentive for investment in research. In a free enterprise economy, inventive activity is supported by using the invention to create property rights; precisely to the extent that it is successful, there is an underutilization of the information. (pp. 616–7)

Proponents of the property rights approach have questioned the appropriateness of the public good attribute of information as a starting point for economic thinking about intellectual property, arguing that strong intellectual property rights should be provided (Demsetz 1969, 1970), drawing on the principal property rights approach claim that the distribution of property rights does not affect the efficiency of the outcome (Coase 1960). However, allocative and productive efficiency are largely static concepts which are not readily applicable to innovations and creative works in an intrinsically dynamic context, ‘marked by persistent evolutionary pressures’ (Gastle and Boughs 2001).

Arriving at reasonable assumptions for and conceptualisations of the notion of intellectual property is inherently difficult,⁷⁸ yet does not pose entirely new

would be curious then, if an idea, the fugitive fermentation of an individual brain, could, of natural right, be claimed in exclusive and stable property. If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called idea, which an individual may exclusively possess as long as he keeps it to himself; but the moment it is divulged, it forces itself into the possession of everyone, and the receiver cannot dispossess himself of it. Its peculiar character, too, is that no one possesses the less, because every other possess the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lites his taper at mine, receives light without darkening me. That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them... Inventions then cannot, in nature, be subject of property. (emphasis added)

See also Stiglitz (1999) for a discussion of knowledge as a public good.

Incidentally, tribes in the highlands of Papua New Guinea still have an understanding of property which coincides with Jefferson’s conjecture that “whatever, whether fixed or movable, belongs to all men equally and in common” (pers. comm. Philip Briggs).

⁷⁸Global traditions on intellectual property differ significantly. See for example CSTB (2000,

problems. Boyle (1992) sharply noted that:

[I]ntellectual property... actually presents exactly the same problems as the liberal conception of property generally. It merely does so in a more obvious way and in a way which is given particular spin by our fascination with information. All systems of property are both rights-orientated and utilitarian, rely on antinomical conceptions of public and private, and present insuperable conceptual difficulties when reduced to mere physicalist relations.

The empirical evidence that the granting of intellectual property rights is, in fact, needed to stimulate inventive activity and investment is not conclusive. The seminal papers questioning the validity of the economic efficiency argument in intellectual property are those of Plant (1934a, 1934b). He contended that much creative activity is of a spontaneous nature, and that first-mover advantages and other factors provide sufficient rewards to create.

There are four major areas in intellectual property: patents, copyrights, trademarks,⁷⁹ and trade secrets.⁸⁰ Patents can be considered the strongest form of intellectual property since they grant property right or a limited monopoly over an idea, provided it is sufficiently useful, novel and non-obvious, and hence also any manifestation of that idea, and its commercial exploitation.⁸¹ Although traditionally regarded as not applicable to software products, patent protection has been granted in some recent cases.⁸²

pp. 56–7) on the traditional differences between America and Europe regarding moral rights of authors, and the tradition in Asian countries where the expression of an idea is regarded as a social one, not an individual one. See also Alford (1995) and Gilligan (1996, p. 119). In fact, it was not until 1991 that the Republic of China passed a formal copyright law. For a critique of the basic romantic concepts of ‘the author’ and ‘the inventor’, underlying intellectual property, see for example Boyle (1992, 2000) and the references in Menell (2000, p. 162).

⁷⁹I will not deal with those, but see Menell (2000, pp. 149–50).

⁸⁰Trade secret law affords “formal legal protection to those who make reasonable efforts to maintain trade secrecy”, however, “the rightholder may have little effective recourse if a trade secret becomes widely known or if a user of the information acquired it without knowledge of its having been misappropriated” (Menell 2000, p. 150–1). See Coleman (2000). It is worth noting that there may be a public interest in disclosure which can potentially override trade secret law and render an act of disclosure exempted from liability under rules of confidentiality.

⁸¹The economics of patents has been principally debated in the industrial organisation literature. There is a strong divergence of opinions as regards the economic effects of patent protection. See for example Carlton and Perloff (2000, ch. 16).

⁸²The dual nature of software as both a literary work and a machine has challenged the

Copyrights provide exclusive rights to reproduce and publish an original expression to the creator of a literary work for a limited time period. Further, particular rights to the creation under the ‘fair-use’ doctrine are left in the public domain. There is an ongoing discussion about the appropriateness of criteria regarding originality in copyright law. Whilst some argue that “at least some minimal degree of creativity” should be satisfied,⁸³ others claim that “what is worth copying is *prima facie* worth protecting”.⁸⁴ The scope of copyright has been considerably broadened throughout the 20th century. Originally devised to promote literary and artistic creativity and the diffusion of works, which at the inception related solely to books,⁸⁵ it was subsequently applied to sound

traditional patent concept. It was not until *Diamond v. Diehr*, 450 U.S. 175 (1981), in which a computer program was part of a process which was claimed patentable, that the first patent for a computer program was granted (CSTB 2000, p. 193). Patenting of software products is a highly controversial issue, which I will not further explore here. As a means of protecting intellectual property it is not as widely used as copyright, due to the disclosure requirements, and the danger that a granted patent may be invalidated at a later point on grounds of originality requirements. But see Press (2000), Hart, Holmes, and Reid (1999), and also CSTB (2000, pp. 192–8), Lloyd (2001, pp. 293–4), and Moens (2000, pp. 422–6). For the current European patent law harmonisation debate see PbT Consultants (2001).

⁸³In the US copyright does not extend to mere collections of facts such as telephone directories, notwithstanding the fact that they might be expensive to compile. In *Feist Publications, Inc. v. Rural Telephone Service Co. Inc.* 111 S.Ct 1282, 18 U.S.P.Q. 2d 1275 (1991) the Supreme Court rejected the former ‘sweat of the brow’ standard. However, as regards computer programs the requirement coincides with the European notion of originality which was stated in Article 1.3 of the EU Software Directive (91/250): “A computer program shall be protected if it is original in the sense that it is the author’s own intellectual creation”. See Derclaye (2000a, pp. 15–6). Millard (2000, p. 187) concludes:

The low level at which the originality threshold has tended to be fixed by the courts means that even relatively simple and utterly mundane works can be protected by copyright. This is very important in the computer context where programs and other functional works may lack aesthetic appeal and display little creativity yet be of tremendous commercial value. Were a higher threshold to be set for the originality test, it is probable that much computer software and data would fall completely outside copyright. (footnotes omitted)

In Europe copyright has been extended to databases, provided they achieve a certain level of originality. At present, however, the standard of originality remains untested before courts. See Chalton (2000) for the current European legislation.

⁸⁴Peterson J. in *University of London Press Ltd v. University Tutorial Press Ltd* (1916) 2 Ch. 601 at 610, as cited by Attridge (2000, p. 563).

⁸⁵The Statute of Anne (1709, passed in 1710, available online from <<http://edge.net/~flowers/statute%20of%20anne.htm>>) was confined to books, and titled: “An act for the encouragement of learning, by vesting the copies of printed books in the

recordings, films, broadcasts, and most controversially, computer programs and databases. A long-standing principal characteristic of copyright is that it does not extend “to ideas, procedures, methods of operation or mathematical concepts as such”.⁸⁶ The idea/expression dichotomy is, however, not always a satisfactory tool of analysis.

As indicated above, neither legal nor economic arguments for copyright are entirely convincing. A judge at one occasion opined that it approaches “nearer than any other class of cases belonging to forensic discussions, to what may be called the metaphysics of law, where the distinctions are, or at least may be, very subtle and refined, and, sometimes, almost evanescent”.⁸⁷ Although the marginal costs of copying have fallen significantly over the last decades,⁸⁸ which has by some been taken as an argument for the tightening of copyright law, the principal arguments of Plant (1934a), calling copyright into question from an economic perspective, remain largely valid. He makes an explicit distinction between authors for whom writing constitutes their profession and those who write for other *non-financial reasons*. The former may depend upon royalties, although this need not necessarily be the case, whilst the latter are *antedate* indifferent towards royalties, for whatever reason.⁸⁹ Further, he points out that

authors or purchasers of such copies, during the times therein mentioned”. Some have argued that it was not the pressure from authors, but rather the lobbying efforts of the stationers, that led to the enactment of what is considered the world’s first copyright law. Kretschmer (2000, p. 216) concludes: “The history of copyright can be characterised as a continuous expansion of owners rights, favouring in general investors over creators”. Moreover, authors were required to register their works with and pay a fee to the Stationer’s Company in order to obtain copyright protection. Attridge (2000, p. 563) points out that the rationale behind copyright law prior to the Act was public censorship, which, however, with developments in the printing industry, was rendered futile, and shifted to the commercial interests of stationers and the Crown. That is, rent seeking rather than economic efficiency considerations brought about modern copyright law. Boyle (2000, p. 2037) puts it tersely: “Intellectual property policy has consistently under-valued the public domain”.

⁸⁶Article 2 of the WIPO Copyright Treaty (1996). This principle is embodied in the EU Software Directive (91/250) Article 1.2 and Recital 14, and in the US Copyright Act 1976 § 102 (b).

⁸⁷*Folsom v. Marsh*, 9 F. Cas. 342, 344 (C.C.D. Mass. 1841)(No. 4,901), as cited in Boyle (1992, n. 16 and accompanying text).

⁸⁸In fact, the digital nature of a large number of today’s works challenges the foundational legal and conceptual notion of copying as the fundamental perspective that underlies copyright in a number of unprecedented ways. The discussion about this controversial issue and its implications is only just beginning (CSTB 2000, pp. 140-3).

⁸⁹*Inter alios* most academics, and artists who comprehend art in a fashion that excludes the immediate symmetry between creation and reward belong to the second group. “Freely

traditionally some of the most important works of art known to man were created under a system of patronage,⁹⁰ and challenges the non-excludability dilemma argument using empirical data from the 19th century. Hurt and Schuchman (1966) and Breyer (1970) coincide with Plant's conclusion that the need of copyright is questionable.⁹¹

Apart from the questionableness of the copyright system encouraging creation better than would be the case in its absence, there are considerable costs to the system. The first and foremost is the social welfare loss due to monopoly pricing if the intellectual property right entails a monopoly. For economic efficiency it is irrelevant to whom the consumer surplus, the difference between marginal cost and individual utility, accrues. Therefore perfect price discrimination would constitute a remedy to the welfare loss (Demsetz 1970), but it has been argued that perfect price discrimination is *impossible* to attain due largely to information imperfections.⁹² Further costs are transaction costs of licensing, and administration and enforcement costs.⁹³ Transaction costs may be prohibitively high, retarding progress built upon the creation in question, which is seen as one justification for the fair use doctrine.⁹⁴ Along with the deadweight social loss, but on a dynamic rather than static level, copyright "increases the cost of borrowing from previous works and thus weakens the incentive to create" (Gordon and Bone 2000, p. 195). It puts a possibly undue emphasis on the output side to the creation as opposed

have I received, freely given, and want nothing in return", Martin Luther said of his writing. Mann (1998) conjectures that only as a result of growing book trade the romantic notion of the artist, a "sovereign being who creates beauty out of nothing but inspiration" has developed in the 18th century. See also Boyle (1992, n. 130 and accompanying text), and *supra* note 78. Note that the reasons for the indifference towards pecuniary rewards largely evade orthodox economic modelling.

⁹⁰This partly applies to the two groups mentioned *supra* in note 89.

⁹¹Following on from these papers a number of studies have been conducted. For an overview see Watt (2000, ch. 4).

⁹²See Boyle (2000) and Gordon and Bone (2000, pp. 194–5). Boyle (2000) makes two important points: "We might believe that surplus in the hand of (generally poorer) consumers was more valuable than surplus in the hands of (generally richer) producers, because of the *diminishing marginal utility of wealth*" (p. 2027, emphasis added), and "[P]erfect state-backed price discrimination. . . would require massive information-gathering on the part of the producers and, perhaps ultimately, on the state. Perfect price discrimination requires more information about customers than can be revealed by mere self-selection and more information-gathering (to prevent illicit arbitrage, lending, or gifts)" (p. 2034).

⁹³See Gordon and Bone (2000, pp. 195–6).

⁹⁴Fair use is generally a statutory right, rendering claims otherwise invalid. Thus notes like: "Not to be quoted without written permission of the authors" are void.

to the input side.⁹⁵ Information is by its very nature cumulative (Landes and Posner 1989). The limitation of exclusivity to the expression, leaving the idea in the public domain, along with the fair use doctrine, is considered the chief characteristic of copyright law attempting to minimise the social cost of exclusivity.

Concerns regarding the warrant of copyright are even more acute in the context of computer programs.⁹⁶ The fundamental difference between software and more traditional creations that fall under the scope of copyright is the nature of the expression which is given protection to. Copyright is automatically given to all levels of software code, that is, the source code as well as the machine-readable binary code “[s]imply by virtue of the fact that they can be symbolically represented in a way which resembles the written word” (Gordon 1998, p. 10), the crucial difference being that the former gives expression to an idea in a human-readable fashion, whereas the latter is of a principal utilitarian nature and *not human-readable*. Hence the analogy to conventional writings is a difficult one to maintain.⁹⁷ The applicability of copyright to software entails considerably strengthened intellectual property rights for their owners. Samuelson (1984) puts it:

The problem is a new one. Until the advent of computer programs, copyrighted works that were sold to the public communicated the ideas they contained. Unpublished works that might have claimed copyright protection had little or no commercial value. Now it is possible both to publish a work and to keep it secret, and keeping it secret is part of the way the commercial value of the work is maintained. Computer programs in machine-readable form are the first type of copyrightable work to have a major commercial value *without* disclosure. (p. 710, emphasis in original, footnotes omitted)

⁹⁵“Intellectual property policy has to focus on the input side of the table as well as the output side of the table” (Boyle 2000, p. 2032).

⁹⁶For an excellent account of European and American case law and legislative regarding copyright in software programs see Derclaye (2000a, 2000b).

⁹⁷Welch (1992) argues:

Notwithstanding the representational similarity of programs to literary works, programs remain the technology for using computers. They are not designed to communicate information, thought, or feeling to human beings, nor are they designed to communicate with, as opposed to physically control, computers... [T]he program is in a fact a technological and not a literal product.

In the US computer programs have been considered copyrightable from 1964, on condition that a readable copy, the source code, was deposited with the Copyright Office. This requirement was effectively dropped with the 1976 Copyright Act (Samuelson 1984, pp. 715–7).

The only logical relation the machine code bears to the source code is an interdependence through a mathematical relation, defined by a compiler program, which transforms the higher level source code into executable binary code.⁹⁸ Absent the availability of the source code, vast reverse engineering efforts are necessitated to derive the idea to the creation,⁹⁹ rendering futile the conventional notion that the subject of copyright is a creation which is intended to express an idea, and hence any conventional notion of fair use.¹⁰⁰

From a legal perspective the line between the idea and the expression in computer programs is an elusive one, giving rise to unprecedented non-literal infringement challenges. *Computer Associates v. Altai*¹⁰¹ was the first case to establish a means of determining which non-literal elements of a program are copyrightable.¹⁰² As non-literal elements were identified: program ultimate func-

⁹⁸Note that this automated transformation is not possible vice versa. In mathematical terms the mapping from the higher-level language domain to the image space of binary code is surjective, but not injective.

⁹⁹European and American law largely accepts reverse engineering as a means “to extract the ideas and structures from computer programs” (Attridge 2000, p. 568) and to achieve interoperability. In *Sega Enterprises Ltd v. Accolade, Inc.* 977 F. 2d 1510 (9th Cir. 1992) it was held that:

Disassembly of copyrighted object code is, as a matter of law, a fair use of the copyrighted work if such disassembly provides the only means of access to those elements of the code that are not protected by copyright and the copier has a legitimate reason for seeking access.

See Attridge (2000, pp. 568–9) for a brief account of recent developments in Europe and the US. See also Faull and Nikpay (1999, pp. 622 ff.).

¹⁰⁰For a seminal political statement for ‘free software’ see Stallman (1992). See also *infra* note 126. Note, however, that even the availability of the source code still necessitates a considerable effort to *understand* the code. One of the contributors to the focus group conducted by the author pointed out: “Having open sources does not mean that everyone will understand them. The intellectual effort to understand the source code is almost akin to that needed to create the code in the first place” (pers. comm. Jochen Witte).

¹⁰¹*Computer Associates International v. Altai* 982 F. 2d 693 (2nd Cir. 1992).

¹⁰²The first case to recognise non-literal elements as copyrightable was *Whelan Associates, Inc. v. Jaslow Dental Laboratory, Inc.* 797 F. 2d 1222, 1238 (3d Cir. 1986), *cert. denied*, 479 U.S. 1031 (1987), in which the structure of the defendant’s program was substantially similar to that of the claimant’s. However, no rigid test was established. For a detailed account of the US and the UK position as regards non-literal infringement see Millard (2000, pp. 205–20).

tion or purpose, modules, organisational or flow charts, parameter lists, structure, and macros. The *Altai* ‘abstraction-filtration-comparison test’ was devised to determine whether the allegedly copyright infringing program is ‘substantially similar’ to the original. The non-literal elements are to be determined, unprotectable components, including ideas and features that are dictated by efficiency considerations, required by external factors, or taken from the public domain, are to be removed, and the remaining components to be compared. In subsequent cases the test was further developed.¹⁰³ It is clear that the application of a rigid legal test to complex software may be infeasible or at least very problematic, a limitation that the *Altai* court was aware of, noting that the test “would have to be adapted to the particular circumstances of the case” (Derclaye 2000b, p. 58). European courts have thus far not adopted a structured approach to copyright infringement cases.¹⁰⁴ However, Jacob J. in *Ibcos Computers v. Barclays* (1994) opined that the copyrightability of an idea hinges upon how detailed it is:

The true position is that where an “idea” is sufficiently general, then even if an original work embodies it, the mere taking of the idea will not infringe. But if the “idea” is detailed, then there may be infringement. It is a question of degree.¹⁰⁵

At present, copyright does not seem to extend to software interfaces since “functionality is the realm of patent law protection, whereas copyright law protects non-functional works” (Derclaye 2000a, p. 12, n. 50).¹⁰⁶ Further, recent US cases have considered user-interfaces, as regards functional aspects, not to be copyrightable.¹⁰⁷ However, whilst copying a user-interface does not present

¹⁰³See Derclaye (2000b, pp. 58–9).

¹⁰⁴See Derclaye (2000b, pp. 63–5).

¹⁰⁵*Ibcos Computers Ltd v. Barclays Mercantile Highland Finance Ltd* (1994) F.S.R. 497, at 291.

¹⁰⁶Article 6 of the Software Directive allows reverse engineering in order to obtain “information necessary to achieve interoperability”, and American case law has been firmly upholding the *Sega* precedent (see *supra* note 99). In *Sony v. Connectix* 203 F. 3d 596 (9th Cir. 2000) it was held that emulating an interface does not infringe copyright. In the absence of a patent the functional results of a copyrighted program are not protected (Fitzgerald 2001, pp. 123–4). Warren-Boulton, Baseman, and Woroch (1994) point at strong economic arguments against the copyrightability of interfaces. An interface which constitutes a *de facto* standard is the result of “the efforts of many sponsors” and can be an extremely valuable asset in the presence of network externalities. “Besides the original developer, there are the users that purchase the program, the makers of complementary hardware and software, and even suppliers of compatible substitutes” (p. 7).

¹⁰⁷See Gordon (1998, pp. 12–3), and Derclaye (2000b, pp. 60–1). In *Apple Computer, Inc.*

any severe difficulties as it is visible to the user, implementing the functionality of an existing API (software-software-interface) in the absence of specification or source code necessitates considerable reverse engineering efforts, and may effectively be impossible.¹⁰⁸ Hence the perfect ownership of the source code in the absence of disclosure requirements regarding APIs potentially creates a *de facto* ownership over the software interface stemming from the copyright protection of the software.¹⁰⁹

Distribution of software is generally different from that of more conventional copyrighted information goods. It is licensed to a consumer rather than sold, allowing the producer to impose greater restrictions and limitations on the consumer than would be possible under a sales arrangement. The rights granted by the licence, not the program as such constitute the software product. This profoundly affects the rights of the consumer in most instances. He may be prohibited from transferring the program to someone else, or from doing certain things with the program.¹¹⁰ The enforceability of such contracts is still a relatively open issue.¹¹¹ There may be overreaching provisions in software li-

v. Microsoft Corp. 94 CDOS 7160 (9th Cir. 1994) it was held that Apple’s user-interface, being a ‘purely functional feature’, deserves no copyright protection. The court also recognised the desirability of “the adoption of compatible standards”. A similar reasoning was applied in *Lotus Development Corp. v. Borland International, Inc.* 49 F. 3d 807 (1st Cir. 1995), identifying a menu-command hierarchy as a ‘method of operation’ and therefore excluded from copyright protection. Judge Boudin did even go further, wondering why customers of Lotus should remain “captives of Lotus because of an investment in learning made by the users and not by Lotus” (quoted in Gesmer 1995).

¹⁰⁸See *infra* note 126.

¹⁰⁹Social welfare may, as a result, be affected. Says Millard (2000):

Where... a *de facto* industry standard has emerged... the possibility of copyright being used to monopolise the specification of interfaces... has enormous policy implications. Much of the rapid growth and diversity that has characterised the computer industry in the last two decades has resulted from the widespread development of hardware and software products that are ‘compatible’ with those most popular in the market. Such compatible products frequently improve substantially on the products offered by the company that initiated the standard both in terms of price and performance, and often also in terms of innovation. (p. 205, emphasis in original)

¹¹⁰Some economists argue that restrictive licensing enhances social welfare since it allows moving closer to perfect or first degree price discrimination, but the argument is neither innocent nor conclusive. See *supra* note 92, and also Carlton and Perloff (2000, pp. 280–90).

¹¹¹See Ravicher (2000) for an account of recent US cases.

cences which are not enforceable, especially if there is no equal bargaining power as is the case in most mass market software licence agreements.¹¹² Provisions attempting to circumvent the fair use doctrine are generally considered void.¹¹³ Most mass market licence agreements have been considered enforceable, provided certain procedural requirements were met: “proper notice of the licence before purchase, adequate time to review and assert whether to assent to the licence’s terms, and the opportunity to return the software for a full refund if the licence is unacceptable” (Ravicher 2000). However, the state of law regarding this matter is not fully conclusive at the present moment.

A restrictive licence may add to the strong protection of proprietary rights in software granted by copyright and trade secret protection of the underlying source code.¹¹⁴ Yet a licence may also be utilised to turn the conventional intellectual property rights notion on its head, and be designed to attain the exact opposite effect, not restricting the use of the software, claiming no proprietary rights, and leaving the intellectual property once and for all in the public domain.¹¹⁵

¹¹²Mass market licence agreements are generally fixed and not negotiable, and come either in the shape of ‘shrink-wrap’ or ‘click-wrap’ licenses. By opening the package or clicking an affirmative label respectively the licence is deemed to be a binding contract.

¹¹³See discussion above.

¹¹⁴See for example the Windows end user license agreement (EULA).

¹¹⁵See for example the GNU GPL. A list of GPL compatible licences is available from <http://www.gnu.org/philosophy/license-list.html>.

2.3 The Structure of the Operating Systems Market

The market for operating systems is special in a number of respects, alluded to in the preceding sections. It is characterised by increasing returns to scale as regards the core product, which is the digitally coded information and can be of tremendous commercial value. Property rights over computer programs are established through intellectual property rights law, particularly copyright, and strengthened by legal contractual means in licensing agreements with customers. The extent of intellectual property rights has largely been shaped by rent seeking activities and normative considerations regarding welfare and progress. The arguably most disturbing feature of the operating systems market is its exhibition of positive consumption externalities on different levels: indirect externalities stemming from the number of applications available,¹¹⁶ direct externalities from proprietary communication and document format standards,¹¹⁷ and the differing availability of postpurchase services. We can also readily include “the more subtle ones” mentioned by Katz and Shapiro (1985, p. 424, n. 1): “[T]he fact that product information is more easily available for more popular brands; . . . the role of market share as a signal of product quality; and . . . purely psychological, bandwagon effects”.

Microsoft has been a monopolist in the market for Intel-compatible PC operating systems ever since their first non-exclusive contract with IBM to market the operating system MS-DOS with their PCs. In the ongoing lawsuit¹¹⁸ it was established that Microsoft has been holding an overwhelming monopoly position for the last decade.¹¹⁹

¹¹⁶Also, the number of supported hardware platforms may potentially entail indirect externalities.

¹¹⁷Computer network communication standards are largely public. However, there are a number of widely used proprietary document standards, which, even though related to applications, may affect the OS market if the applications that produce and read those formats are not available for all operating systems.

¹¹⁸*United States v. Microsoft Corp.*, 84 F. Supp. 2d 9 (D.D.C. 1999). The Findings of Fact, the Conclusions of Law, and the proposed final judgement are available from http://www.usdoj.gov/atr/cases/ms_index.htm. The appeals court opinion is available from <http://msft.cadc.uscourts.gov/cadc/00-5212a.pdf>. See also <http://www.cadc.uscourts.gov/ecf/Microsoft/Microsoft.asp>.

¹¹⁹Findings of Fact, § 35 states:

Microsoft possesses a dominant, persistent, and increasing share of the worldwide market for Intel-compatible PC operating systems. Every year for the last decade, Microsoft’s share of the market for Intel-compatible PC operating systems has stood above ninety percent. For the last couple of years the figure has been

The value of Windows as an operating system in the consumer market is partly a function of the network size, a certain degree of proprietary quality of functional aspects of the software, sunk learning costs of users and familiarity with the system, and the availability of a large number of applications for Windows. Microsoft is understandably capitalising on its intellectual property rights, and is against compatibility, even if welfare would be increased by the move to compatibility.¹²⁰

The absence of feasible substitutes and the virtually perfect ownership of intellectual property rights over its products, along with *de facto* standards which are largely kept proprietary,¹²¹ have been creating insuperable long-run barriers to entry.¹²² There have been no feasible demand substitutes,¹²³ and due to indirect

at least ninety-five percent, and analysts project that the share will climb even higher over the next few years. Even if Apple's Mac OS were included in the relevant market, Microsoft's share would still stand well above eighty percent.

According to a recent article in the New York Times, "Microsoft holds 95 percent of the market for PC operating systems and there are 400 million Windows-based computers in use worldwide" (Steve Lohr, *Microsoft introduces new operating system*, NY Times, October 26, 2001).

¹²⁰See Katz and Shapiro (1985), and *supra* section 2.2.4.

¹²¹As a monopolist Microsoft has little incentive to share standards with competitors. It has also been known for its notorious propensity to attempt to appropriate public standards. In 2000 it implemented the Kerberos authentication protocol for Windows 2000 extending the Kerberos standard administered by the Internet Engineering Task Force (Mary Jo Foley, *Microsoft in the hot seat in new Net flap*, ZDNet, May 11, 2000, available from <<http://www.zdnet.com/filters/printerfriendly/0,6061,2568294-2,00.html>>). As has been clearly established in the ongoing lawsuit they made substantial efforts to "contain and subvert Java technologies". A Microsoft document, quoted in the appeals court opinion (p. 56) states as a strategic goal: "Kill cross-platform Java by grow[ing] the polluted Java market... [as] [c]ross platform capability is by far *the* number one reason for choosing/using Java" (emphasis in original).

¹²²In the US, since 1998, copyrights to businesses last 95 years (Carlton and Perloff 2000, p. 503) which in the case of software renders the property right over the creation virtually perfect as the commercial value of a software product is highly unlikely to stretch over that time frame. Arguably, the latest concessions by the legislature to owners of intellectual property are the result of intense lobbying efforts throughout the 1990's "by companies like Walt Disney, which wanted to keep the 73-year-old Mickey Mouse from slipping into the public domain alongside the works of Shakespeare and Victor Hugo" (Amy Harmon, *Suddenly, 'idea wars' take on a new global urgency*, NY Times, November 11, 2001).

¹²³Findings of Fact, § 18 states: "Currently there are no products, nor are there likely to be any in the near future, that a significant percentage of consumers world-wide could substitute for Intel-compatible PC operating systems without incurring substantial costs".

network externalities¹²⁴ there have been no supply substitutes.¹²⁵

Perfect cloning of the Windows API would remove this barrier to entry, but appears to be effectively impossible, as the Windows API is ever changing and only partly disclosed to the public.¹²⁶

As the Microsoft monopoly is not contestable¹²⁷ it entails a significant market power, which is exacerbated by an arguably relatively inelastic demand curve, and has recently been emphasised by changes in Microsoft's licensing schemes for business customers. Large customers, in the absence of alternatives on the desktop, are facing considerable increases in their costs for Microsoft software.¹²⁸

Being effectively a government-created monopoly subject to no significant competition in the consumer market for Intel-compatible PC's, the welfare costs are possibly substantial, encompassing not only the deadweight loss of monopoly

¹²⁴The Microsoft monopoly entails a large number of applications for Windows which far exceeds that available for any other operating system. A further indirect externality is the expertise available for Windows and the familiarity of people with the system.

¹²⁵An exemplary case is that of Be, Inc., which offered an operating system called BeOS that, despite its quality and favourable reviews, never gained widespread acceptance with consumers or hardware makers. The company had to sell themselves recently to Palm, Inc. (Michael Kanellos, *Be: A long history of almost*, CNET News.com, August 17, 2001, available from <<http://news.cnet.com/news/0-1006-200-6893683.html>>).

¹²⁶Findings of Fact, § 52 states:

IBM discovered this to its dismay in the mid-1990s when it failed, despite a massive investment, to clone a sufficiently large part of the 32-bit Windows APIs. In short, attempting to clone the 32-bit Windows APIs is such an expensive, uncertain undertaking that it fails to present a practical option for a would-be competitor to Windows.

However, despite the difficulties to achieve full compatibility with the Windows API, as it is not fully documented, a number of projects are running, the most important of which is Wine (<<http://www.winehq.com>>). Wine is an implementation of the Windows APIs, that does not require Microsoft Windows, and allows Windows binaries to run under Linux, FreeBSD, and Solaris. For a current list of further projects see <<http://www.winehq.com/others.html>>.

¹²⁷For the notion of contestable markets see Baumol, Panzar, and Willig (1988). The theory of contestable markets has been challenged on a number of academic grounds, and effectively lacks empirical evidence. In particular, the assumption of zero sunk costs, or a complete lack of asset specificity, renders the model futile in the context of software markets.

¹²⁸Joe Wilcox, *New Microsoft licenses may increase costs*, CNET News.com, May 10, 2001 (available from <<http://news.cnet.com/news/0-1003-202-5887975.html>>), Joe Wilcox, *Microsoft customers balk at license changes*, CNET News.com, September 20, 2001 (available from <<http://news.cnet.com/news/0-1003-202-7238508.html>>), Alan Cane, *Microsoft terms anger IT chiefs*, Financial Times, September 24, 2001, p. 9.

but also the costs stemming from the efforts to maintain the monopoly (Posner 1975).¹²⁹ Moreover, innovation, which in software markets tends to be of a sequential nature, is possibly being retarded by Microsoft's enclosing its source codes, treating them as trade secrets.¹³⁰ The often quoted argument that these losses might be outweighed by the incentive "to invest in research and development"¹³¹ is somewhat questionable as it is not readily obvious that Microsoft's innovations are of a somewhat superior nature than those of their competitors.¹³²

¹²⁹In 2001 Microsoft's sales and marketing expenses amounted to almost \$5 billion. It also spent considerable amounts on lobbying the government to drop the antitrust case, and hiring lobbyists, economists and lawyers. Apart from donating more than \$10 million to politicians and parties (Joel Brinkley, *Microsoft's Huge 4-Year Crusade Gets Credit for a Coup*, NY Times, September 7, 2001) it has been funding a group called Americans for Technology Leadership (ATL) which "engaged telemarketers to make unsolicited calls seeking permission to use selected citizens' names on letters to the Congress demanding that Justice drop its antitrust case" (Dan Carney and Richard S. Dunham, *Outreach, Microsoft Style*, Business Week, July 23, 2001). See also Rampton and Stauber (2001), Joel Brinkley, *Unbiased Ads for Microsoft Came at a Price*, NY Times, September 18, 1999, and Ted Bridis et al., *When Microsoft's Spin Got Too Good, Oracle Hired Private Investigators*, Wall Street Journal, June 29, 2000 for the involvement of Microsoft with the Independent Institute and the promotion of the book "Winners, Losers & Microsoft" by Liebowitz and Margolis. One observer commented: "An independent research group that takes money from the people it's supposed to be researching is either accepting bribes or stupid, neither of which says anything good about their conclusions" (available from <http://www.geocrawler.com/archives/3/525/2000/6/100/3955135/>).

¹³⁰Microsoft has recently introduced a 'shared source' scheme, in which big customers get access to the source code. However, they are not permitted to change the code (David. F. Gallagher, *Helping Software Companies Be as Open as They Want to Be*, NY Times, November 5, 2001).

¹³¹See for example Carlton and Perloff (2000, p. 98).

¹³²Their first operating system MS-DOS was based on Q-DOS, a CP/M clone created by the Seattle Computer Company, which Microsoft bought in 1981 (Jonathan Erickson, *MS-DOS R.I.P.*, Byte, October 29, 2001, available from <http://www.byte.com/print/documentID=19770>). The GUI that they introduced with Windows was based on research by Xerox and prior commercial implementations by competitors. The arguably most important recent development in computing, the world wide web (WWW) and its underlying protocols, the hypertext transport protocol (HTTP) and the uniform resource locator (URL) protocol, as well as the hypertext markup language (HTML) were conceived and designed by Tim Berners-Lee, and are maintained by the world wide web consortium (W3C, <http://www.w3.org>), a non-profit organisation. The first commercial web browser which made the WWW a popular mass medium was developed by Netscape Communications, and a number of mission-critical software that run the internet are open-source developments, for example, the Apache webserver (<http://www.apache.org>), bind and sendmail. The much touted .NET framework for business applications resembles Sun's J2EE, and Microsoft's new programming language C# is conceptually equal

Moreover, despite its virtually inexhaustible cash resources, Microsoft's products are subject to the universal difficulties in creating error free software.¹³³ There is little indication that a competitive operating systems market would be less innovative than one dominated by Microsoft.¹³⁴

Linux has traditionally been a system renowned for its reliability, performance, portability,¹³⁵ and affordability, rather than its usability and user-friendliness.¹³⁶

to Sun's hugely successful Java. See also Anonymous, *Not invented here*, available from <<http://www.vcnet.com/bms/departments/notinvented.html>>. It is probably fair to say that most of the innovations regarding fundamental technologies underlying the computing revolution have been made under systems of patronage, most notably, research sponsored by universities and governments.

To be sure, Microsoft has been innovative and successful in adopting technologies, and developing them to marketable products. For example, Microsoft's COM technology that was derived from CORBA has been the first coherent commercial implementation of a object oriented component communication architecture (pers. comm. Manuel Mang and Jochen Witte). Also, Microsoft deserve credits for the widespread adoption of the PC, as they retained their rights to license MS-DOS to other parties than IBM.

¹³³A leaked document from Microsoft revealed that one week before the launch of Windows 2000 there were "over 63,000 potential know defects", despite the goal to have 'zero bugs'. A spokeswoman for Microsoft had to submit: "Bugs are inherent to computer science. All software ships with issues" (Mary Jo Foley, *Somebody Call An Exterminator*, ZDNet, February 11, 2000, available from <<http://www.zdnet.com/filters/printerfriendly/0,6061,2436920-2,00.html>>). See also <http://www.nthelp.com/50/windows_2000_sp1_buglist.htm> for a current list of Windows 2000 bugs, and Appendix B.

¹³⁴Recall that the utility of Windows in the presence of network externalities stems from the efforts of many sponsors, including users, and providers of complementary software. That said, Microsoft is fully aware of the importance of third party application developers to their business, and commits significant resources to support Windows developers (Wylie Wong, *Microsoft realigns software developer units*, CNET News.com, October 17, 2001, available from <<http://news.cnet.com/news/0-1003-200-7546924.html>>)

¹³⁵Largely due to the availability and modularity of the source code Linux has been ported to virtually every conceivable hardware platform, from wristwatches to supercomputers, making it the most widely ported operating system. See also Stephen Shankland, *Chipmakers angle for Linux support*, CNET News.com, September 1, 2001 (available from <<http://news.cnet.com/news/0-1003-200-7026026.html>>).

¹³⁶It has been increasingly adopted in the server market. See Appendix C, Table 6. For an interesting, albeit slightly outdated, empirical study into businesses see Anonymous, *The economics of Linux (II)*, Computer Finance, January 4, 2000. Linux is understood to be used in a number of mission critical settings. See, for example, Guillermo Ortega, *Linux for the International Space Station Program*, Linux Journal, March, 1999 (available from <<http://www2.linuxjournal.com/lj-issues/issue59/index.html>>). Due to its performance and affordability it also enjoys a growing popularity in the field of supercomputing (Anonymous, *The penguin gets serious*, The Economist, January 27, 2001). The scalability, performance and

The principal problem of Linux as an alternative to Windows on the desktop has been the absence of GUIs that match and resemble Windows' ease of use, and a lower number of applications for Linux.¹³⁷ However, over the last years the number and maturity of complementary applications, making Linux more suitable for the desktop, has risen sharply. KDE and Gnome¹³⁸ are the most important and widely used GUIs, and a number of productivity applications have been developed. A variety of office suites are available, KOffice, and most notable Sun's StarOffice¹³⁹ which has become the most viable competition to Microsoft's Office package, especially as it is capable of reading and producing documents in the ubiquitous Word format, and runs on Linux, Sun Solaris and Windows platforms. Several internet browsers are available, the most promising of which are Mozilla, an open derivative of Netscape's Navigator,¹⁴⁰ and Opera, a commercial alternative, which enjoys increasing popularity.¹⁴¹ Despite the prevailing opinion that Linux is not suitable for the desktop, it is emerging as a viable alternative to Windows.¹⁴² The Linux kernel being understood to be stable, fast and mature,

the obvious cost-effectiveness have proved compelling reasons for financial service institutions to adopt Linux for complex performance and risk analysis (Emily Brayshaw, *Penguin farming pays off*, Banking Technology, February 2001). The New York Stock Exchange is adopting Linux for certain operations (Geoff Nairn, *Upstarts' Progress*, Financial Times, Survey – FTIT, November 7, 2001). Governments have recently been showing an increasing interest in Linux as a cost-effective alternative to their dependence on Microsoft, and a number of legislatures have passed laws giving preference to free software where feasible (Paul Festa, *Governments push open-source software*, CNET News.com, August 29, 2001, available from <<http://news.cnet.com/news/0-1003-202-6996393.html>>).

¹³⁷For example, Microsoft Word and the Microsoft Internet Explorer command dominant market shares due, in part, to network externalities. Both are somewhat proprietary as regards their functional aspects, and are not available for Linux.

¹³⁸KDE stands for K Desktop Environment, and GNOME for GNU Network Object Model Environment. Both resemble Windows and Macintosh interfaces. See also Stephen Shankland, *Linux moves slowly onto the desktop*, CNET News.com, December 11, 2000 (available from <<http://news.cnet.com/news/0-1003-202-4101018.html>>), and TÜViT (2000).

¹³⁹See Stephen Shankland, *Sun shows new version of StarOffice*, CNET News.com, August 31, 2001 (available from <<http://news.cnet.com/news/0-1003-200-7018328.html>>), and <<http://www.sun.com/products/staroffice/>>. The related OpenOffice suite is the open source branch, and effectively freely available (<<http://www.openoffice.org>>).

¹⁴⁰See Hamerly and Paquin (1999), and <<http://www.mozilla.org>>.

¹⁴¹See Paul Festa, *Opera releases new Windows beta*, CNET News.com, November 14, 2001, available from <<http://news.cnet.com/news/0-1005-200-7864843.html>>.

¹⁴²The author submits with all due respect that most articles which argue that Linux is not suitable for the desktop are poorly researched, and make factually wrong and misleading statements, like: "Most computer users don't want to worry about compiling programs before running or writing their own device drivers – operations that take place under the hood in Windows

the focus is now increasingly shifting toward making Linux more usable.¹⁴³

Creating and marketing a Linux based desktop system that challenges Microsoft's longstanding monopoly, in that it sufficiently alleviates switching costs for, and gains awareness, acceptability, affordability, and availability with consumers, has thus far proven unsuccessful. Commercial Linux distributors have been more profitably focusing on the enterprise market with subscriptions and support services.¹⁴⁴

However, a number of current developments contribute to Linux based systems as an alternative to Windows in the consumer market. The perceptual gap between Windows and Linux based systems in hiding the complexity of the operating system is narrowing. As Linux based systems are becoming more complete, the adverse effects of network externalities stemming from the availability of application programs should weaken. Also, the Wine project is advancing,¹⁴⁵ making it possible to run Windows applications without having to pay Windows licensing costs,¹⁴⁶ thus lowering the effect of network externalities created

but sometimes rear their ugly heads on Linux systems" (Anonymous, *Linux Not Ready for Desktop Move*, The Associated Press, June 3, 2001, available from <<http://www.nytimes.com>>). A recent article in the Financial Times, very much in line with the "recent rash of 'Linux is not for the desktop' punditry in the mainstream media" (Nicholas Petreley, *Stop the desktop insanity*, InfoWorld, July 9, 2001), advances similarly tenuous arguments and concludes: "The 'Linux threat' to Windows on the desktop has dissipated... [O]nly diehard Microsoft foes now use it on the desktop" (Louise Kehoe, *The spirit of Woodstock struggles on*, Financial Times, August 29, 2001, p. 11).

If an internal Microsoft email leaked to The Register is to be believed, Microsoft is considering Linux a threat to its desktop dominance: "Linux is not only a threat to Microsoft's server business – it is increasingly becoming a threat to the desktop in a number of key areas" (as quoted in John Lettice, *MS moves to head off Linux desktop 'threat'*, The Register, September 27, 2001, available from <<http://www.theregister.co.uk/content/4/21899.html>>).

¹⁴³Stephen Shankland, *Making Linux usable tops Torvalds' list*, CNET News.com, August 29, 2001 (available from <<http://news.cnet.com/news/0-1003-200-7008296.html>>).

¹⁴⁴Dell, for example, has recently ceased selling computers preinstalled with Linux to private customers because of low demand (Anonymous, *Dell ends Linux offering*, NY Times, August 3, 2001). The companies Corel and Eazel, have failed in their recent attempt to make Linux suitable for mainstream use.

¹⁴⁵See *supra* note 126.

¹⁴⁶Recently, a commercial effort has been launched to create a Linux and Wine based system that runs Windows and Linux programs and offers Windows comparable usability and user-friendliness. Lindows.com, a Californian start-up, hopes to release the first version of LindowsOS early next year (Geoff Nairn, *Upstarts' Progress*, Financial Times, Survey – FTIT, November 7, 2001 and Stephen Shankland, *Start-up creating Linux-Windows combo*, CNET News.com, October 24, 2001, available from <<http://news.cnet.com/news/0-1003-200-7630640.html>>).

by the abundance of applications for Windows.¹⁴⁷ Moreover, the ever increasing importance of the internet and open communication protocols may lower that of operating systems as the principal platforms for applications.¹⁴⁸ With Windows XP Microsoft recently introduced a ‘product activation’ feature, aiming to reduce piracy rates.¹⁴⁹ This, in turn, would reduce welfare,¹⁵⁰ increase the dead-weight loss of monopoly, and possibly lower the extent of positive consumption externalities stemming from the size of the Windows network.¹⁵¹ Depending on Microsoft’s ability to price discriminate, and satisfy demand of those who would otherwise acquire a pirated copy of Windows, would-be competitors may benefit from a significantly more competitive market.¹⁵² Another factor that may affect the dominance of Microsoft is its severely shaken image and reputation in the industry and with consumers, largely as a result of the high-profile antitrust lawsuit against the company.¹⁵³

¹⁴⁷See *supra* note 71 and accompanying text.

¹⁴⁸This is why Microsoft has been so anxious to drive its Internet Explorer to the market at all costs, and attempting to appropriate the HTML standard. For a recent exemplary incident see Sandeep Junnarkar and Joe Wilcox, *Microsoft backpedals on MSN browser block*, CNET News.com, October 26, 2001 (available from <<http://news.cnet.com/news/0-1005-200-7660935.html>>), and Sandeep Junnarkar and Joe Wilcox, *MSN lockout stirs antitrust rumblings*, CNET News.com, October 28, 2001 (available from <<http://news.cnet.com/news/0-1005-200-7667367.html>>). See also John Naughton, *Why Microsoft is fighting a free and open exchange*, The Observer, February 25, 2001. Were the technical specification for a common platform for applications publicly available, there would be no private *de facto* monopoly over the platform simply by virtue of its being protected by intellectual property rights. To quote Ken Wasch, president of the Software & Information Industry Association: “[I]t is safe to say that Microsoft shares certain, but not all Application Programming Interfaces (APIs), and only does so when it is in the best interests of the company, not the interest of dynamic innovation within the industry” (Anonymous, *SIIA Responds to Microsoft Statement on Open Source*, SIIA Press Release, May 3, 2001, available from <<http://www.spa.org/sharedcontent/press/2001/5-3-01.html>>).

¹⁴⁹The extent to which these measures will be successful remains to be seen. Before the official launch of Windows XP, pirated copies have been available in Thailand and China, trading for a fraction of the official retail price (Anonymous, *Thai pirates crack Microsoft’s New Windows System*, Reuters, November 12, 2001, available from <<http://www.nytimes.com>>, and Anonymous, *Phonies galore*, The Economist, November 10, 2001, p. 84). However, casual copying will likely be hindered by those measures.

¹⁵⁰Software piracy increases welfare on Pareto-efficiency grounds. In Microsoft’s case it arguably also increases welfare on distributional efficiency grounds. See *supra* note 92. See also Boyle (2000, pp. 2010 ff.).

¹⁵¹Boyle (2000, p. 2017) makes a similar consideration.

¹⁵²The same holds for complementary Windows applications like Office XP, which themselves create network externalities.

¹⁵³See, for example, Lawrence Lessig, *The limits of credibility*, The Industry Standard, July

2.4 Prior Research Studies

The author is not aware of any research papers or essays which explicitly address the issue of market failure in the operating systems market. A number of papers discuss the ongoing antitrust lawsuit against Microsoft, and the economic and legal arguments surrounding the case.¹⁵⁴ Some attempts have been made to address the economic aspects of open source development.¹⁵⁵

Gartner and IDC are commercial research institutes which frequently deal with Windows and Linux, mainly in the server market, assess the state of the market, and give indications as to future developments.¹⁵⁶

A study by SuSE Linux AG, a German Linux distributor, earlier this year merits explicit mention.¹⁵⁷ The quantitative study, conducted by TNS EMNID which interviewed 5,000 individuals, presumably in Germany, regarded levels of awareness and interest in Linux compared to Windows.

It found that 23 percent of PC users interviewed will consider switching to Linux when they upgrade their equipment. Linux is generally considered more stable than Windows, with 46 percent of Linux users regarding stability of their system as an ‘outstanding asset’, compared to 13 percent of Windows users. Moreover, the study found that Windows users associated stability more often with Linux than they did with Windows. 56 percent of the respondents have heard of Linux, and 10 percent are using it at home or at work. The study suggests that lack of experience on the users’ part and the limited range of application programs are the chief reasons for not switching.

23, 2001 (available from <<http://www.thestandard.com/article/0,1902,28036,00.html>>).

¹⁵⁴See, for example, Baseman, Warren-Boulton, and Woroch (1995), Sheremata (1997), Page (1999), Gifford and McGowan (1999), Carstensen (1999), Hazlett, Litan, and Rockefeller (2000), and Gastle and Boughs (2001).

¹⁵⁵See, for example, Sawhney and Prandelli (2000), Ljungberg (2000), and von Hippel (2001). See also <<http://firstmonday.org>>.

¹⁵⁶See, for example, George Weiss, *What’s the future of Linux*, ZDNet, October 23, 2001 (available from <<http://www.zdnet.com/filters/printerfriendly/0,6061,2819787-92,00.html>>).

¹⁵⁷The following figures draw upon a short article about the study (Michael Hall, *Survey Results from SuSE: Users Believe Linux is more stable, 23% Will Consider Switch*, LinuxToday, March 28, 2001, available from <http://linuxtoday.com/news_story.php3?ltsn=2001-03-28-004-20-NW-MR-SS>).

3 Methodology

A great many people think they are thinking when they are merely rearranging their prejudices.

— *William James*

3.1 Introductory Notes

The principal research paradigm in economics has been that of positivism, as economic theory is largely an axiomatic system,¹⁵⁸ and its chief attraction is its apparent soundness as a scientific method. It is understood to produce relatively reliable results, in contrast to phenomenological approaches which arguably produce more valid but less reliable results. However, *a priori* propositions are much harder to maintain in economics than they are in natural sciences, as they are the manifestation of actions of human individuals in a societal setting. Medema et al. (2000) put it:

[T]he unique determinate optimal solutions of the neoclassical research protocol are both presumptive and forced, heuristically useful for analytic exercises but not representative of actual economic processes in all their evolutionary complexity. (pp. 437–8)

The allocation of resources is shaped by arguably unpredictable actions of individuals rather than universal laws. Schumacher (1973) points out that: “The judgement of economics... is an extremely *fragmentary* judgement; out of the large number of aspects which in real life have to be seen and judged together before a decision can be taken...” (p. 38, emphasis in original). Moreover, the normative power of economics is limited as desirable and purposeful ends to economic considerations are not given, and only partly approximated by economic quantifications.¹⁵⁹ The pursuit of happiness is not merely an economic matter, and there is little evidence that economic theorising based on simplified assumptions has been producing valid results, or making mankind better off.¹⁶⁰

¹⁵⁸See also Hardwick, Khan, and Langmead (1999, pp. 12–4).

¹⁵⁹For example, growth in a nations GDP is but an arguably poor indicator of its wealth and well-being.

¹⁶⁰See Easterlin (2001).

On the other end of the methodological continuum (Morgan and Smircich 1980, p. 492) lies a far more cautious ontological assumption of the nature of reality. Whereas the ‘positivist’ takes the reality to be an external and concrete structure, the ‘phenomenologist’ regards reality as a projection of human imagination. The arguably most useful assumption from a sociological viewpoint can be considered somewhere in between these two extremes and stresses the importance of symbolic discourse. According to Kumar (1987):

Our reality is, first and perhaps most of all, a linguistic reality. Or, since language is one kind of symbolic system, a set of conventionalized sounds and signs, we can say that our reality is primarily based on symbols. The world ‘out there’ is for us a world clothed in symbols. These symbols identify or ‘indicate’ certain aspects of the environment to us and also structure our responses to them. (p. 41)

The notion of reality as a concrete structure may well be valid, but it does not exclude that of reality as a human imagination. As our reality is essentially a social reality, there is no ‘pure’ physical reality that we can so recognise.¹⁶¹

3.2 Hypotheses and Research Design

The research conducted for this paper can be positioned mainly in the positivist framework, even though triangulation of different research methods and data has been employed. The starting point for subsequent considerations is the following null hypothesis, which somewhat coincides with the assertion made by Liebowitz and Margolis (1999).

H0: The operating systems consumer market is not subject to significant and remediable market failures.

It is submitted that the notion of market failure is a definitionally difficult one, and can be tautological in that it is effectively ubiquitous, rendering the advanced

¹⁶¹To quote Kumar (1987), whose account is indebted to Ludwig Wittgenstein, again:

We endow the world with symbols and respond to the meanings contained in them. So there are as many things in the world, and only such things, as we have meanings for at any given time... Without a word to describe a thing, it remains unintelligible – to all intents and purposes, non-existent. (pp. 42–3)

null hypothesis *a priori* invalid.¹⁶² In the context of this paper, however, a pragmatic approach to the notion of market failure has been adopted. The market is considered to fail, where there is a feasible substantially Pareto-superior equilibrium, and where government intervention or entrepreneurial effort are possible means to remedy that failure.

The literature that has been reviewed for this paper suggests that the operating systems market is subject to a number of phenomena that possibly result in inefficiencies amounting to market failure of a significant magnitude. Thus three alternative hypotheses are advanced, leading to a fourth summary hypothesis:

H1: The operating systems consumer market is subject to inefficiencies stemming from the design of intellectual property rights with respect to software.

H2: The operating systems consumer market is subject to inefficiencies stemming from direct and indirect network externalities.

H3: The operating systems consumer market is subject to inefficiencies stemming from information imperfections on the consumers' part.

H4: The operating systems consumer market exhibits market failure that warrants state intervention.

The hypotheses have been investigated in three related studies which were confined to the consumer market. Naturally, the author has been subject to time and budget constraints, and the relatively broad nature of the hypotheses did not allow for a fully exhaustive analysis. Moreover, the issue under research somewhat evades a 'rigorous' quantitative statistical hypothesis testing. Rather, it has to be considered in the context of the inevitable normativeness of the market failure concept, the elusiveness of the economic framework, and the intrinsic difficulties in measuring imperfections and welfare losses.¹⁶³ However, the pertinent issues are being addressed, and areas of future research identified. The approach taken

¹⁶²Say Zerbe Jr. and McCurdy (1999, p. 563): "Market failures disappear only when the cost of operating the price system is zero. In the real world, however, this never occurs". See also Baumol (1979).

¹⁶³As regards economic efficiency, it is worth recalling Medema et al. (2000):

[T]here is no unique efficient result... [E]fficiency is a function of rights and not the other way around... Relying solely on the Pareto-efficiency criterion serves to obfuscate and impede the normative choice process that is necessarily at work in the legal-economic nexus. (p. 440–6)

by the author is not merely deductive, but to an extent also inductive, as the triangulation of data and research methods has been employed to derive a more valid and robust picture.

The first study was a focus group with three experienced computer experts, and was conducted in order to determine which operating system is the technically superior, an issue which due to the complexity of software is extraordinarily difficult to address, and hence poses precisely the intelligibility problem outlined above. Effectively, quality and performance of software are not ascertainable in an absolute sense, rendering the positivist approach futile to a certain extent.¹⁶⁴ As subjective views are diverse, the focus group as a means of research has the advantage of evening out individual biases by immediate feedback dynamics. It also provides “a ready means, through subtle pitting of one against the other, for distinguishing between shared and variable perspectives” (Schatzman and Strauss 1973, p. 82). The author knew the participants personally from previous work experience, a factor that decisively contributed to the feasibility of the study. They have all studied computer science in Germany and have a longstanding experience in different fields of computer science and applied computing.¹⁶⁵ Their different attitudes, preferences, and subjective views resulted in a heated discussion extending far beyond the initial set of subjects.

The second study was a quantitative questionnaire survey among students at the Humboldt-University in Berlin regarding the level of satisfaction with the used operating system, and awareness and assessment of Windows and Linux.¹⁶⁶ A sample size of 100 was chosen, and an individual distribution was adopted. Participants were selected on a random basis, and approached personally by the author. The principal advantage of this method over other distribution methods is that response rates are very high, in my study more than 99 percent, rendering the non-response bias very low, and hence the validity and reliability of the obtained data very high. The author completed the questionnaires in the presence

¹⁶⁴The same holds for other aspects of software. Usability and user-friendliness are effectively undecidable (Thimbleby 1990).

¹⁶⁵Frank Bourier has been developing business applications for Windows, and teaching Windows programming. Jochen Witte has been working chiefly as a system administrator for several small enterprise networks, and an intimate experience with different operating systems. Manuel Mang has been working mainly in the field of database management and middleware development.

¹⁶⁶See Figure 1 on page 52 for the questionnaire design. The rating scales were designed as continua whose two ends were represented by opposing terms. The questions were asked in German, and have, for the purpose of this paper, been translated into English by the author.

of the individual respondents, asking the questions and giving explanations where necessary.¹⁶⁷ No reward was given for answering the posed questions. The study was conducted in July 2001 on two consecutive sunny days in the inner courtyard of the university's main campus. The results may thus be biased towards students with a propensity to have a break on the courtyard, but this should have only an arguable low impact on the results. An obvious limitation of the study regarding generalisability of the findings to the broader population of consumers is its restriction to a sample of students.¹⁶⁸

A third, quantitative, study was concerned with the availability and cost of Linux as opposed to Windows when purchasing a new computer. Nine computer vendors in Berlin were contacted by telephone, and questioned about their ability to deliver a computer in the price range of about £700 with Linux installed rather than Windows. An additional inquiry into four highstreet vendors in Bournemouth was undertaken. The sample of vendors was somewhat dictated by the feasibility of different options. For the survey in Berlin the vendors were selected from advertisements in a popular events magazine. In Bournemouth the author personally questioned four computer shops in the town centre. The relatively small sample size and an obvious and possibly significant selection bias render the results only indicative of the availability and cost of Linux when purchasing a new computer.

The analysis of the research studies is largely of an exploratory nature. As regards the first study, the principal findings, especially shared opinions, are stated. Exploratory and confirmatory data analysis have been applied to the data derived from the quantitative studies.

¹⁶⁷For example, some respondents did not know what an operating system is, and had to be given a short explanation.

¹⁶⁸The author considered conducting a telephone survey to obtain a random sample of the whole population. However, there are drawbacks regarding generalisability to this method, and it was somewhat impracticable to conduct.

1	Do you have a computer?	(yes/no)
2	Which operating system are you using?	(open question)
3	How satisfied are you with the system?	(on a scale of 1 to 5, very unsatisfied to very satisfied)
How high do you consider your system's:		
4	– stability?	(on a scale of 1 to 5, very low to very high)
5	– user-friendliness?	(idem)
6	– technical quality?	(idem)
7	Was the system installed when the computer was acquired ?	(yes/no)
<i>If question 2 was answered with Linux, go to Question 13.</i>		
8	Have you heard of Linux?	(yes/no)
How high do you consider Linux':		
9	– stability?	(on a scale of 1 to 5, very low to very high)
10	– user-friendliness?	(idem)
11	– technical quality?	(idem)
12	Would you consider switching to Linux?	(yes/no)
<i>Go to Question 18.</i>		
13	Have you heard of Windows?	(yes/no)
How high do you consider Windows':		
14	– stability?	(on a scale of 1 to 5, very low to very high)
15	– user-friendliness?	(idem)
16	– technical quality?	(idem)
17	Would you consider switching to Windows?	(yes/no)
18	Your age?	(open question)
19	Your sex?	(male/female)
20	Your course of studies?	(open question)

Figure 1: Questionnaire used in study 2

4 Results

Statistics never prove anything.

— *E. F. Schumacher*

In this section the results of the three studies are being presented. Study 1 refers to the focus group conducted, study 2 was the questionnaire survey among students, and study 3 the inquiry into computer vendors.

4.1 Study 1

As suggested earlier, assessing quality of software products in an absolute sense is *a priori* impossible, and also poses definitional difficulties. Despite the agreement that operating systems are effectively unintelligible in their entirety,¹⁶⁹ the participants of the focus group reached consensus on a number of issues.

Linux is more stable and faster than Windows, and has substantially lower hardware requirements. As regards stability, however, it was also established that Windows NT and Windows 2000 are fundamentally different from, and significantly more stable than Windows 95/98.

The public availability of Linux' source code contributes to its security and stability, and, arguably, the overall quality of the operating system. It was noted that Linux is a relatively mature open source project, in contrast with a large number of other open source projects. That is, Linux is not the 'better' system, simply because it is open source.

A number of further issues that went beyond the initial set of subjects were being discussed. Those involved the causes of Microsoft's monopoly, different consumer preferences, submarkets, the appropriation of standards by Microsoft, strategic issues, and possible resulting benefits and adverse effects of Microsoft's

¹⁶⁹This was neatly captured in one argument regarding the quality of both systems on a source code level:

FRANK: Have you seen the sources [of Linux]?

MANUEL: No, of course not.

FRANK: Neither have I. So how should I then tell which is the better code?

See also the comment of Jochen, regarding the intelligibility of source code, *supra* note 100.

dominance. However, no unanimous consensus was reached about these points, and the discussion was influenced by differing subjective views and perceptions.

4.2 Study 2

For the raw data collected see Appendix E. The respondents to the questionnaire survey were all students at the Humboldt-University Berlin in Germany, predominantly aged 20 to 27. 55 respondents were male, and the remaining 45 female. One approached person declined to participate in the survey, rendering the response rate 99.01 percent. Another four persons did not have a computer which excluded them from the targeted population.

As expected, the vast majority of respondents were using Windows. Four percent were using MacOS, and a mere two percent Linux.¹⁷⁰ The two persons that were using Linux, were also using Windows for certain tasks, both utilising VMware for Linux to run the systems simultaneously on the same hardware.¹⁷¹

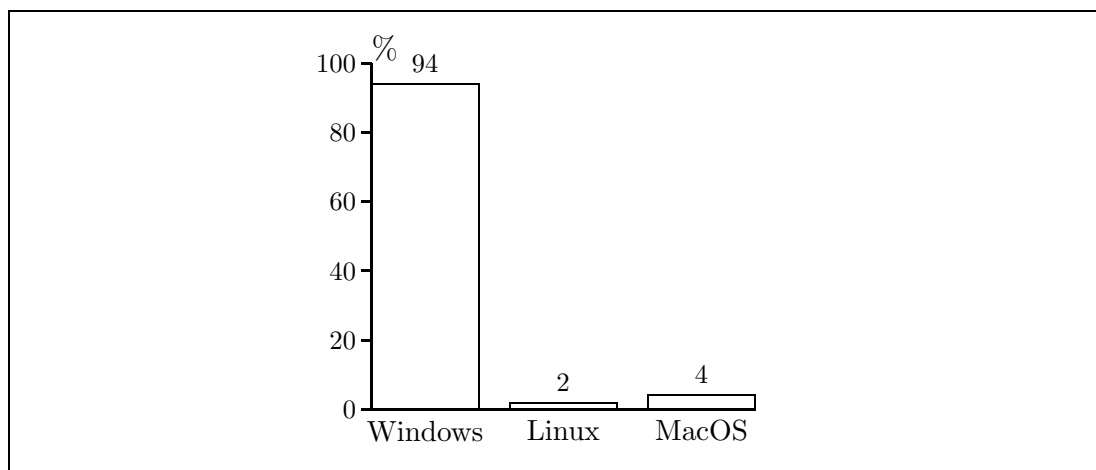


Figure 2: Operating systems shares in the sample

¹⁷⁰This finding parallels the latest figures from IDC, which are displayed in Table 7 on page 81. Assuming the IDC figures reflect the true percentages, the probability of obtaining the same result is approximately

$$0.94^{94} 0.04^4 0.02^2 \binom{100}{94} \binom{6}{2} = 0.05454$$

and is higher than that for any other possible result.

¹⁷¹VMware is a virtual machine, emulating the computer's hardware, allowing multiple operating systems to run at the same time, sharing the underlying hardware. See also <<http://www.vmware.com>>, and Stephen Shankland, *VMware riding on Windows XP coattails*, CNET News.com, November 3, 2001 (available from <<http://news.cnet.com/news/0-1003-200-7763850.html>>). It was not established whether the two respondents were using a licensed copy of Windows.

The following results are confined to the subset of those respondents who use Windows, as for the four MacOS and the two Linux users no reliable results can be derived. The number of valid and missing responses, as well as the means and standard deviations for the most relevant questions are listed in Table 1. Except for rows 5 and 6 where the answers were coded with 1 and 0, the image space for the rating scale questions consists of natural numbers from 1 to 5. Frequencies of valid responses of selected questions are shown in Figures 3, 4, 5, 6, and 7.

	N valid	N missing	Mean	σ
Level of overall satisfaction	94	0	3.18	0.93
Windows' stability	94	0	3.09	1.11
Windows' user-friendliness	94	0	3.61	0.81
Windows' technical quality	87	7	3.25	0.82
System installed ^a	94	0	0.64	–
Awareness of Linux ^a	94	0	0.80	–
Linux' stability	28	66	4.18	0.72
Linux' user-friendliness	26	68	3.00	0.94
Linux' technical quality	27	67	4.07	0.68
Switching considered ^a	91	3	0.36	–

^a1 stands for yes, 0 for no.

Table 1: Selected exploratory statistics for the sample

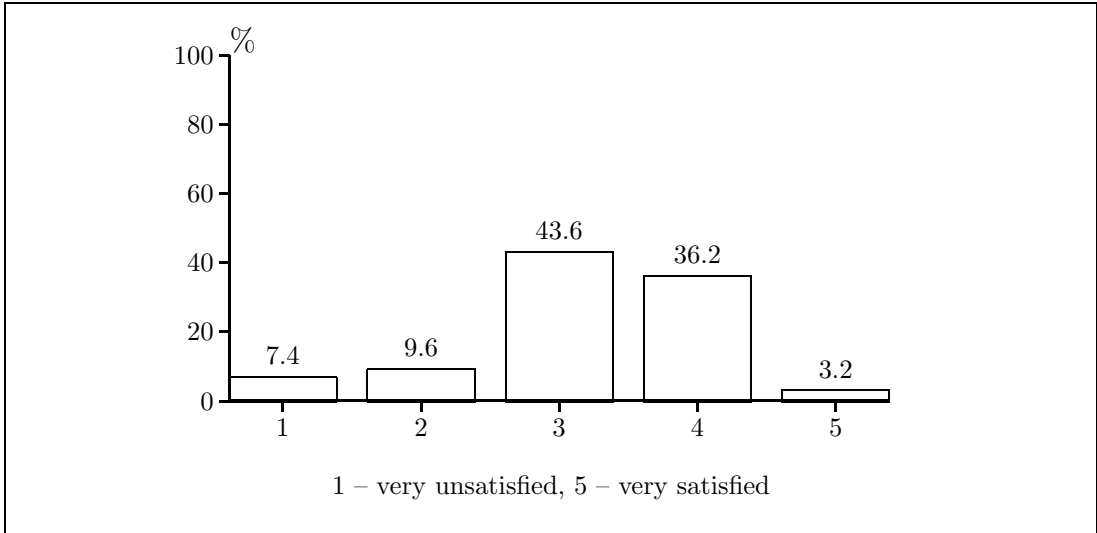


Figure 3: Overall satisfaction with Windows

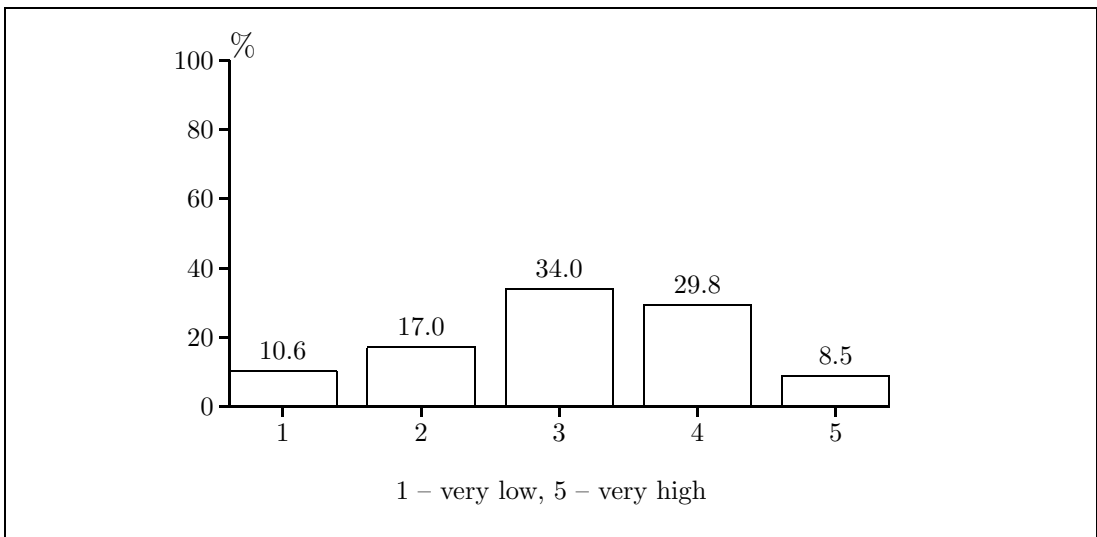


Figure 4: Assessment of Windows' stability

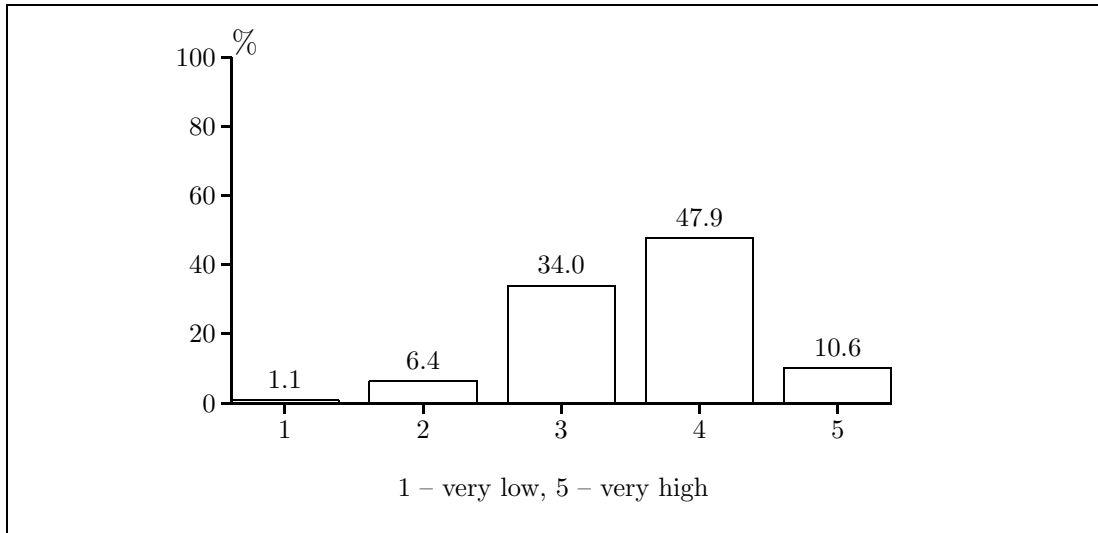


Figure 5: Assessment of Windows' user-friendliness

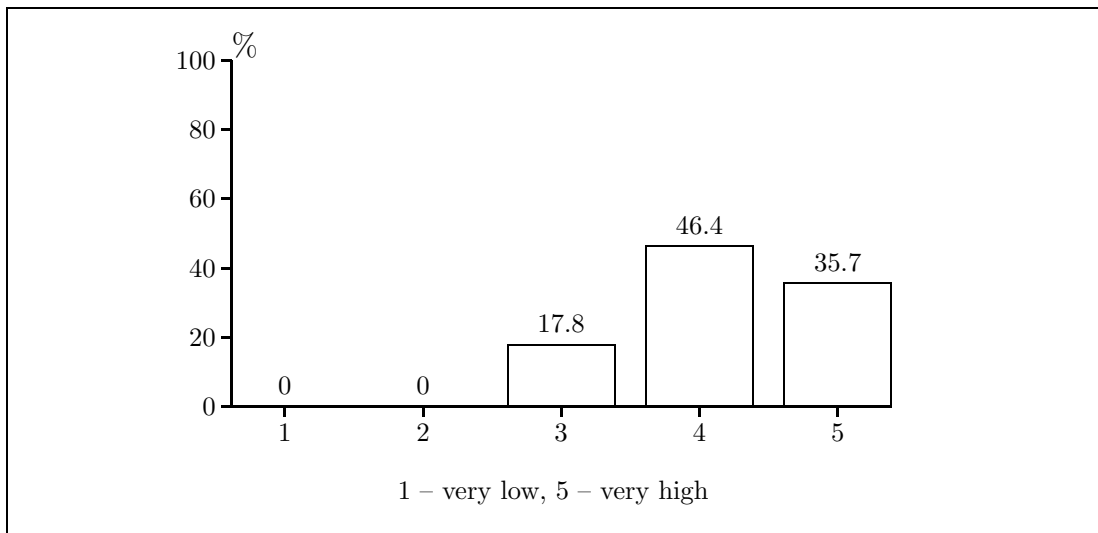


Figure 6: Assessment of Linux' stability

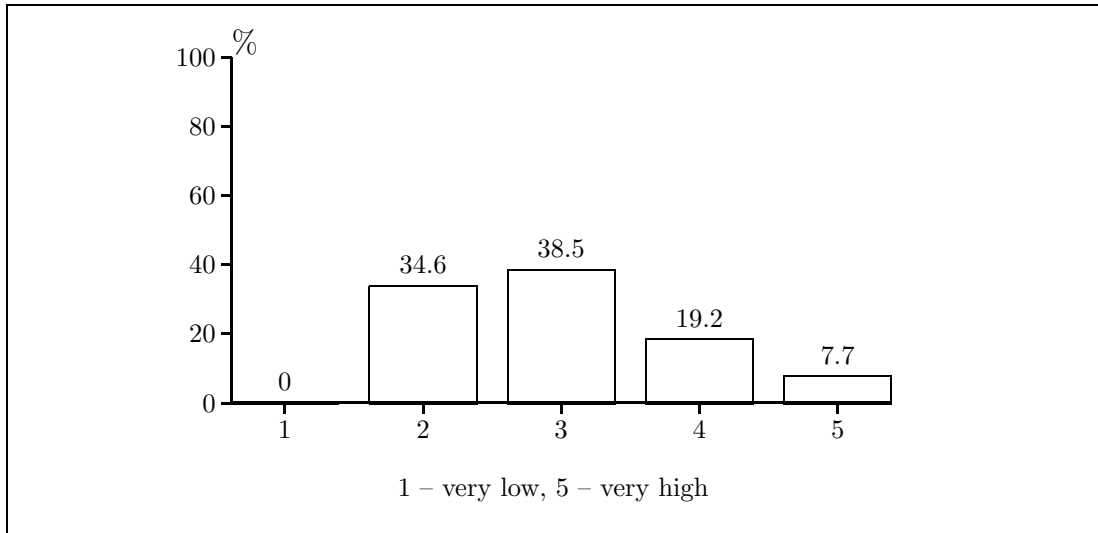


Figure 7: Assessment of Linux' user-friendliness

The average level of overall satisfaction can be described as medium, and is below that of those respondents who were using MacOS and Linux, respectively. 36 percent of the respondents would consider switching to Linux. However, the vague nature of the question posed suggests that the percentage of respondents who seriously consider switching in the near future might be significantly lower. 64 percent of the Windows users had their system installed when they acquired the computer. 80 percent had heard of Linux, however, only about 30 percent could answer the Linux related questions.

In relation to Linux, Windows was regarded less stable and of lower technical quality, but as more user-friendly. Linux' stability was, on average, considered more than one category higher than that of Windows. By contrast, the difference of the means regarding user-friendliness was 0.61 units.

Statistically significant associations and correlations have been found between a number of value sets, the most relevant of which are displayed in Tables 2 and 3. To satisfy the preconditions for conducting the chi square tests¹⁷² the data from the rating scale questions had to be regrouped into three categories: low (1, 2), middle (3), and high (4, 5). For measuring the correlation between two variables Spearman's rank correlation coefficient was used, as the collected data is of a categorical nature.¹⁷³ Even though some data is descriptive rather than ordinal, it has been treated as ordinal data for the purpose of the analysis.

¹⁷²See Saunders, Lewis, and Thornhill (1997, p. 317).

¹⁷³The application of Spearman's rank correlation coefficient, Kendell's tau-b, and Pearson's product moment correlation coefficient to the data resulted in virtually the same correlation coefficients and significances, indicating a high robustness of the results.

	Pearson chi square	Significance (2-tailed)	N
Overall satisfaction Windows' stability	12.615 ^a	0.013	94
Overall satisfaction Windows' user-friendliness	16.235 ^b	0.003	94
Overall satisfaction Windows' technical quality	17.152 ^c	0.002	87
Overall satisfaction Willingness to switch	17.389 ^d	0.000	91
Overall satisfaction Awareness of Linux	1.072 ^e	0.585	94
Willingness to switch Awareness of Linux	2.404 ^f	0.121	91
Sex Awareness of Linux	18.347 ^g	0.000	94

^a1 cell (11.1 %) has an expected count less than 5. The minimum expected count is 4.43.

^b3 cells (33.3 %) have an expected count less than 5. The minimum expected count is 1.19.

^c1 cell (11.1 %) has an expected count less than 5. The minimum expected count is 2.24.

^d0 cells have an expected count less than 5. The minimum expected count is 5.08.

^e1 cell (16.7 %) has an expected count less than 5. The minimum expected count is 3.23.

^f0 cells have an expected count less than 5. The minimum expected count is 6.89.

^g0 cells have an expected count less than 5. The minimum expected count is 8.69.

Table 2: Selected chi squares (Pearson's chi square)

	Correlation coefficient	Significance (2-tailed)	N
Overall satisfaction Windows' stability	0.363 ^a	0.000	94
Overall satisfaction Windows' user-friendliness	0.227 ^b	0.028	94
Overall satisfaction Windows' technical quality	0.405 ^a	0.000	87
Linux' stability Linux' user-friendliness	0.592 ^a	0.001	26
Linux' technical quality Linux' user-friendliness	0.397 ^b	0.049	25
Overall satisfaction Willingness to switch	-0.431 ^a	0.000	91
Overall satisfaction Awareness of Linux	-0.005	0.960	94
Willingness to switch Awareness of Linux	0.163	0.124	91
Sex Awareness of Linux	-0.442 ^a	0.000	94
Overall satisfaction Linux' stability	0.494 ^a	0.008	28
Overall satisfaction Linux' user-friendliness	0.432 ^b	0.027	26

^aCorrelation is significant at the .01 level (2-tailed)
^bCorrelation is significant at the .05 level (2-tailed)

Table 3: Selected correlations (Spearman's rho)

The results from the chi square tests, where feasible, and the correlation computations are largely consistent.

There is a weak positive, statistically significant correlation between the level of overall satisfaction and the assessment of Windows' stability, user-friendliness and technical quality. Also, significant correlations were found between the three sets of values regarding Linux. However, no chi square test could be conducted

due to the small sample size.

Not surprisingly, level of overall satisfaction and willingness to switch to Linux are statistically significantly associated variables with a negative correlation. However, neither between overall satisfaction and awareness of Linux, nor between willingness to switch and awareness of Linux, is there a significant association or correlation. Female respondents show a lower level of awareness of Linux than their male counterparts.

Rather surprisingly, there is a relatively strong positive correlation between the level of overall satisfaction and the assessment of Linux' stability and user-friendliness. Due to the small number of respondents no meaningful chi square test to reject independence of these variables could be conducted.

4.3 Study 3

The findings of the survey into computer vendors in Berlin and Bournemouth are shown in Tables 5 and 4. The price figures in Table 5 were converted from Deutschmark into Pounds by applying an exchange rate of 3.20, and rounded to multiples of five.

The general pattern that emerged indicates a low level of availability of Linux as part of a computer package. Only in two cases it was possible to have Linux installed on the purchased computer. Even though the price for Linux is well below that for Windows, the mark-up for the installation of Linux raises its price significantly above that effectively charged for Windows in these two cases.

Name of vendor	Price reduction when waiving Windows 98	Availability and cost of Linux
Dixons	no reduction	not available
Tiny	no reduction	not available
Ashton Waverley	£75	not available
Creative Computers	£60	not available

Table 4: Results of the inquiry into computer vendors in Bournemouth

Name of vendor	Price reduction when waiving Windows 98	Availability and cost of Linux
Indat	no reduction	not available
Eteque	£80	£15 ^a
Picad Computer	£80	not available
HD-Computer	£85	not available
HD-Computer II	£80	£40 ^a
I-Motion	no reduction	£25 ^b
Axxess	£85	£35 ^c
Westmark Computer	£85	not available
Bilgi-Interface	£80	not available

^aNo installation.
^bPlus £50 per man-hour for the installation.
^cPlus £110 for the installation.

Table 5: Results of the inquiry into computer vendors in Berlin

5 Analysis and Discussion

*The outcome of any serious research can only be to make
two questions grow where one question grew before.*

— *Thorstein B. Veblen*

The purpose of the research project was to establish whether or not the operating systems consumer market is subject to market failure, to explore its nature and particular characteristics, and to draw conclusions as to possible remedies and policy implications. The findings that have been made in the research studies conducted largely coincide with and complement the indications from the literature reviewed. Addressing the advanced hypotheses, the discussion draws on the literature review and the principal findings that have been made in the research studies.

Study 1 reinforces the concerns about the meaningful definition of an operating system, and the difficulties in assessing its quality and performance. The principal finding of the study, which corresponds with the indications from the server market and the general picture that is drawn in the current literature, is that there are strong indications that Linux as an operating system in a stand-alone sense is superior to Windows in performance and stability.

The second study indicates that there are significant information imperfections on the consumers' part. Even though 80 percent of the Windows users in the sample were aware of Linux, less than 30 percent had a more detailed conception. In other words, more than 70 percent of the respondents did have virtually no specific conceptual notion of Linux. If this is true of a sample of students, it is likely that the percentage for a broader population is even higher, assuming that students are somewhat more knowledgeable than average citizens.

The correlation that has been found between the level of overall satisfaction and the assessment of Linux' stability and user-friendliness suggests that respondents may have been subject to cognitive dissonance (Festinger 1957) in forming their opinions.¹⁷⁴ However, further research in exploring this phenomenon is needed

¹⁷⁴Possibly, those respondents who indicated a lower level of satisfaction with Windows conceive Linux to be less stable and user-friendly in order to match differing conceptions and perceptions. This would likely be facilitated by information imperfections regarding quality of the systems.

to derive valid and reliable conclusions.

The vast majority of respondents were using Windows. All those who did not use MacOS were using Windows, indicating that Microsoft's command of the Intel-compatible PC operating systems market is virtually perfect. The fact that the two respondents that were using Linux did also use Windows suggests that, at present, certain Windows applications make Windows indispensable.¹⁷⁵

Linux was regarded as the more stable but less user-friendly system.¹⁷⁶ In conjunction with the low level of awareness of Linux this suggests a low level of knowledge about the current state of Linux based desktop systems, and a high level of familiarity with Windows and Windows applications, particularly the Office suite. The author sees a strong need for a research study that compares the usability and user-friendliness of a Windows and a Linux based desktop system in a laboratory staged non-participant observation, in order to properly assess the feasibility of Linux as a desktop system compared to Windows at the present moment. Such a study could also establish to which extent perceptions of Linux change after participants have been introduced to and experienced a Linux based desktop system.¹⁷⁷

64 percent of the Windows users had their operating systems installed on acquiring the computer.¹⁷⁸ This may somewhat obfuscate the cost of Windows, when it is perceived as an integral part of a package rather than a complementary product to the computer hardware.¹⁷⁹

Predictably, an interdependence between the level of satisfaction and the willingness to switch has been found. However, only a weak and insignificant relation between willingness to switch and awareness of Linux has been found. This appears to indicate that lower satisfaction with Windows and increased willingness

¹⁷⁵This appears to be especially true of Microsoft Office, as substitutes like Sun's StarOffice do not yet achieve full compatibility with Microsoft's proprietary document formats. However, it has not been established if the Windows software used was properly licensed. If not, the obvious question arises whether Windows and Windows applications would be dispensed with by the two respondents, had they had to pay the full licence costs.

¹⁷⁶Note that the generalisability of those results is somewhat restricted by the small number of respondents who answered the Linux related questions.

¹⁷⁷The author strongly considered conducting a research study along these lines, however, due to practical restraints refrained from doing so.

¹⁷⁸It is likely that a significant percentage of the remainder installed a pirated copy of Windows, or violated licence restrictions of other copies. However, this issue was not addressed in my survey due to its sensitive nature.

¹⁷⁹The author acknowledges that this point could have been raised in the survey, to establish whether those who purchased a computer with Windows installed were aware of the costs for the operating system.

to switch do not entail a higher level of awareness of Linux, possibly because of the low level of information available.

The existence of significant information imperfections regarding quality, performance and prices calls for more focused research into their nature, causes and dynamics. Further related research should be conducted on prejudices and preconceived opinions towards Linux.

Despite the limitations of study 3 due to its small size, it forcefully points at the low availability and high cost of Linux in the consumer market. In most cases Linux is not available at all, and where it is, the costs to consumers of installing Linux on the vendor's side are substantial, whereas they are effectively zero for Windows in all cases.¹⁸⁰ In case the consumer has access to Linux expertise, the cost of installation on the consumer's side could be relatively low in terms of money.¹⁸¹ However, it appears that the costs and uncertainties that arise in the course of creating the hardware-OS system in the case of Linux are relatively high, despite the fact that the software itself is effectively free. In addition to those costs, as computer and operating system form a system which is more of a usable and perceptible consumer product than the separated two, this arguably contributes to the information imperfections, in that potential buyers of a computer system are highly unlikely to be exposed to a Linux system in the absence of prior knowledge.

Consumers are understandably concerned not only about the features and utility of the operating system they adopt, but the utility of the overall system they are using, including the availability of applications and expertise. The impact of network externalities regarding applications and expertise appears to be decisive. Effectively, most consumers are indifferent toward the quality and performance of the operating system, as it is but a part of the perceptible consumer product comprising hardware, operating system, GUI, and applications. As long as Windows is the foundation of the "distinctly superior overall package" (Katz and

¹⁸⁰The cost of installation depends on the level of available expertise and economies of scale. Also, low demand for Linux will arguably contribute to the high price charged for installing Linux.

¹⁸¹In fact, costs could be effectively zero. There are no restrictions as to the number of installation that can be made from a typical Linux distribution (for example, Red Hat or SuSE), hence the effective cost of the software approximates to zero. The costs for installing Linux depend on the availability and cost of expertise. It would be an interesting research project to study the extent to which people are able to install Linux themselves, possibly in comparison to Windows, and in the light of their prejudices against Linux.

Shapiro 1994) Microsoft has a great incentive to keep the Windows API proprietary to the maximum possible extent, and encourage developers to create software exclusively for Windows.

Furthermore, the vast majority of consumers have only restricted knowledge about computers and software, preventing them from making rational and informed decisions.¹⁸² These information imperfections are aggravated by a whole host of signals that shape the consumers' preferences.¹⁸³ In particular, Microsoft has an incentive to 'make noise' and increase asymmetric levels of information by persuasive and false advertising,¹⁸⁴ as operating systems and software in general are experience goods with very few search qualities, making a judgement about the validity of claims prior to the purchase virtually impossible.¹⁸⁵ Also, because the Linux developer community cannot be treated like a normal competitor in that it is not a conventional firm with a separate legal identity, since recently Microsoft has been strongly attacking and lobbying against Linux, attempting to induce doubts about its merits.¹⁸⁶

The low level of information disseminated about Linux may be seen in the context of the incentive conflict regarding the provision of information absent rewards for doing so,¹⁸⁷ as the Linux project and many of the complementing projects are largely of a non-commercial nature, but most information channels are embedded in a monetary exchange context. Only economic actors who could capitalise in money terms on an increased information level, had an incentive to

¹⁸²See *supra* note 57 and accompanying text.

¹⁸³Say Carlton and Perloff (2000, p. 465): "[B]uying behavior depends on consumers' perceptions of products rather than on the products' physical characteristics".

¹⁸⁴See, for example, John R. Wilke, *FTC charges Microsoft with deceptive advertising*, WSJ Interactive Edition, February 26, 2001 (available from <<http://www.zdnet.com/filters/printerfriendly/0,6061,2689685-2,00.html>>).

¹⁸⁵Software may be considered a credence good, that is, a good whose quality cannot be determined even after consumption. See Carlton and Perloff (2000, ch. 14) for an introduction to advertising from an economic perspective.

¹⁸⁶See *supra* note 25 and accompanying text. Another exemplary statement (Anonymous, *Microsoft exec calls open source a threat to innovation*, Bloomberg News, February 15, 2001, available from <<http://news.cnet.com/news/0-1003-200-4833927.html>>) reads:

Open source is an intellectual property destroyer, I can't imagine something that could be worse than this for the software business and the intellectual property business... I'm an American, I believe in the American Way. I worry if the government encourages open source, and I don't think we've done enough education of policymakers to understand the threat.

¹⁸⁷See *supra* note 53 and accompanying text.

produce costly information.¹⁸⁸

At present, switching to Linux entails substantial costs to consumers that have been using and are accustomed to Windows and Windows applications. These encompass transaction costs that arise in the course of creating the usable system, a loss of variety of available applications, and learning costs that have to be committed to operate the system. The magnitude of those costs very much depends upon the user's level of expertise or access to such, his preferences regarding applications, and his willingness to commit efforts to learning to use a Linux based system. To the average consumer the costs and benefits of adopting Linux are blurred, and hardly reasonably assessable. Hence there is only little incentive to switch to Linux. In fact, it appears that for most consumers there is hardly any convincing reason to switch to Linux, as long as Windows is perceived to be part of the "distinctly superior overall package", and the benefits of adopting Linux are improbable to outweigh the costs associated with switching.¹⁸⁹

The issue of market failure is essentially one of relative efficiency and welfare increasing transitions between discrete states. In the presence of positive network externalities there may be multiple stable equilibria. Moreover, the design of property rights systems, in particular intellectual property rights, which is not exclusively guided by social welfare considerations, impacts on the efficiency of an equilibrium state,¹⁹⁰ and the magnitude of switching costs between different equilibria.

The complexity of interactions between different layers of software, and the economic actors involved, makes a judgement about the nature and magnitude of market failure regarding operating systems somewhat difficult. Arguably, Linux

¹⁸⁸Since there are no restrictions as to the number of installations that can be made from a typical Linux distribution, very little profits are being made from the software itself. Only the excludable support services create significant profit opportunities for Linux distributors. By contrast, Microsoft can spend substantial monies on promoting its operating systems (Joe Wilcox, *Windows XP marketing tab to hit \$1 billion*, CNET News.com, June 26, 2001, available from <<http://news.cnet.com/news/0-1003-200-6382865.html>>).

¹⁸⁹This conjecture is supported by the low percentage of respondents who considered switching from Windows to Linux in the questionnaire survey conducted by the author.

¹⁹⁰Proponents of the property rights approach, especially those who strongly believe in the Coase theorem, may reject this statement. However, it should be clear that the Coase theorem is a mere theoretical consideration. For a discussion see Medema and Zerbe Jr. (2000). It should also be noted that Coase himself did not actually believe in this formulation attributed to him. See, for example, Farrell (1987). See also *supra* notes 45 and 163, and sections 2.2.3 and 2.2.5.

is the superior operating system to Windows with respect to quality and performance, hence there is a market failure.

Of crucial significance regarding switching costs between the systems is the issue of compatibility, and strategic rent seeking considerations of economic actors preventing compatibility between software components provided by different parties. Strategic opportunistic behaviour can affect social welfare and hence amount to market failure.¹⁹¹ As has been pointed out above, Microsoft is making a conscious and determined effort to obstruct compatibility with its operating systems.¹⁹² Copyright and contractual licensing agreements are the principal legal means by which this is achieved. The design of intellectual property rights regarding software may well affect social welfare in that it allows overprotection for the copyright holders.¹⁹³ Arguably, copyright has never been the appropriate means to protect software programs in binary form, in the absence of mechanisms to prevent an undue emphasis on the rights holder, as opposed to the public interest in dynamic innovation, and the availability of interfaces in order to allow for competition with regard to *de facto* standards which are effectively a mere by-product of innovations.¹⁹⁴ Says Carstensen (1999): “[I]t seems evident that the rewards conferred by the present system of entitlements are excessive in relation to the social gains”. As the *raison d’être* for intellectual property rights is the promotion of social welfare, there appears to be a need for legislative intervention.

The *de facto* monopoly of Microsoft over the Windows APIs entails a possibly welfare lowering effect, stemming from positive consumption externalities of complementary software products. It is largely the network externalities, in particular the availability of a large quantity of applications, and expertise and familiarity with the system that increase the value of Windows as an operating system. This phenomenon is unprecedented, and from a welfare perspective there are no unequivocal policy implications. However, this effect contributes decisively to Microsoft’s monopoly and renders welfare enhancing direct competition with Windows virtually impossible.

¹⁹¹This is especially likely in industries where where entry is difficult. See Carlton and Perloff (2000, ch. 11) for an elaboration.

¹⁹²See *supra* note 126 and accompanying text.

¹⁹³See *supra* notes 95 and 109 and accompanying text.

¹⁹⁴Functional aspects, in the absence of patent protection are not legally protected. For example, functional aspects of more conventional interfaces, like sockets and plugs, are not protected by intellectual property rights. The crucial question arises of whether ownership over an interface by virtue of trade secret protection should be tolerated.

As indicated above, Linux and complementary applications are arguably becoming a feasible competing system to Windows on the desktop. The research conducted suggests that there are severe information imperfections on the consumers' part regarding awareness and knowledge about Linux. This appears to impact on the structure of the market, invalidating the neoclassical assumption of the negligible effect of imperfect information and bounded rationality upon efficiency.¹⁹⁵ The particular nature of the operating systems market regarding the economic actors, imperfection of information, incentive structures of providing information, and the characteristic of operating systems as part of computer system, calls for more focused research and elaboration in a context of information economics.

On the whole, it seems that there are severe imperfections in the consumer market for operating systems, finding its manifestation in the overwhelming monopoly of Microsoft. Average consumers are paying prices well in excess of the marginal or average fixed cost,¹⁹⁶ and have no real alternatives to Windows on Intel-compatible PCs without incurring substantial costs. Apart from the high costs to consumers, which may be considered a welfare lowering market imperfection,¹⁹⁷ the principal welfare cost is the deadweight loss of monopoly.¹⁹⁸ Moreover, innovation, and hence quality and performance of operating systems consumers are using, is possibly being retarded by Microsoft's monopoly and strategical conduct as a wealth maximising company.

¹⁹⁵See section 2.2.3. It is interesting to note that Liebowitz and Margolis, who are strong proponents of the conjecture that Microsoft has no negative impact on the market whatsoever, and there is no welfare loss due to its monopoly in a number of software markets, have thus far shown a complete lack of awareness of Linux. In fact, their paper suffers from severe errors of understanding regarding computer technology, reflected in false statements like: "Unix, or Apache, for example, are flexible standards. Users add features to suit their own purposes. Other users can adopt these revised versions" (1999, p. 88).

¹⁹⁶Recall the findings of study 3 conducted by the author. The cost of Windows as part of a package effectively amount to about 10 percent of the package price.

At present, Microsoft is subject to more than 100 class action antitrust suits, representing 13 million PC users in the US, contending that it overcharges consumers. One economic analysis estimates the overcharges by Microsoft from 1994 to 1999 to be \$15 billion to more than \$40 billion (Steve Lohr, *Microsoft Aims to Settle Suits by Equipping 12,500 Schools*, NY Times, November 21, 2001).

¹⁹⁷See *supra* note 92.

¹⁹⁸Arguably, the monopoly entails X-inefficiencies, constituting a related welfare cost. For the seminal paper, see Leibenstein (1966). See also Rozen (1985), and Frantz and Singh (1988).

State intervention, especially regarding the design of intellectual property rights in software programs appears to be a possible means of remedying these market failures by promoting a higher degree of competition.¹⁹⁹ Operating systems are commodities which are markedly different from other software products, in that they create a commons in the form of APIs that allow the execution of various application programs. The capacity of Microsoft to exclude competition with respect to its APIs gives rise to monopoly power which is not justified by economic efficiency considerations. The Linux project and other open source developments appear to indicate that innovation in software markets does not necessitate strong intellectual property and contractual rights as conferred by the present system at all.

The present legal system regarding intellectual property rights allows for an equilibrium to exhibit unexploitable gains, as entrepreneurial efforts to challenge Microsoft's monopoly in the consumer operating systems market, and possibly establishing a Pareto-superior equilibrium, entail prohibitive costs.²⁰⁰ A redesign of the current legal regime would likely increase welfare, and alleviate the impact of network externalities upon competition in the operating systems market, by allowing for competition with regard to the *de facto* standard API in the market, and the creation of perfect adapters to allow for uninhibited transitions between different systems. Dynamic and sequential innovation should be facilitated, and prices for operating systems should approach marginal costs. There are no indications that a more competitive market structure would retard innovation and progress.

As regards the low level of information about Linux, no clear policy implications can be drawn, due to the trade-off between the costs and benefits of providing information, which is effectively undecidable. However, as soon as commercially exploitable opportunities come into existence, entrepreneurial efforts should contribute to tracing out information differentials. Moreover, the momentum of IBM, Intel, and other major players in the computer industry behind Linux, along with persistent and growing favourable press coverage will likely increase levels of awareness and knowledge with consumers.

¹⁹⁹See also Carstensen (1999).

²⁰⁰See *supra* notes 125 and 126. It remains to be seen whether the recently announced effort to create a Windows compatible operating system based on Linux (see *supra* note 146) will be successful. At the moment, analysts are still treating it as vapourware.

6 Conclusion

The future is not what it used to be.

— *Paul Valery*

The present paper has been an attempt to address the issue of economic efficiency in the consumer market for operating systems with special respect to Windows and Linux. Central economic and legal arguments surrounding the matter, and a number of particularities that set this market apart from more conventional markets have been discussed. The limited space of this paper necessitated some omissions, most notably the issue of bundling and efficiency, and the research conducted inevitably could not address all the pertinent issues exhaustively. Yet the results and conclusions that have been drawn are important, and crucial areas of future research have been identified. The issue at stake is nothing less than economic efficiency regarding the arguably most important recent developments of mankind, concerning humanity and its progress and well-being as a whole.

Due to its highly dynamic nature, the structure and characteristics of the market are likely to continue changing rapidly, especially with the growing importance of the internet and distributed computing, and the development of new consumer appliances. Nevertheless, personal computers are bound to remain consumer devices of significant importance, and so is the issue of quality, performance and costs of operating systems which are an integral and indispensable part of computer systems.

The case of Windows and Linux is unprecedented in its complexity, and raises a whole host of issues that evade comprehensive treatment in a single paper. Moreover, it appears to forcefully call into question some conventional economic concepts and frameworks, and points at the limitations of a one-sided economic approach, as it features a number of characteristics which make it unique and particular in a variety of respects. It should provide a rich playing ground for future research as a case study for the application of theories from the fields of information economics, psychology, and sociology.

This treatise should make clear that economic efficiency cannot be treated merely in Coasian terms, detached from considerations as to the conferment of property rights. In fact, these considerations appear to be crucial in view of

vested interests of powerful opportunistic economic actors as against a public interest in dynamic innovation and competitive markets.

The assertion that the operating systems market is efficient is hard to maintain, and the neoclassical argument that the market will work best when left to itself, rejecting state intervention when the effects are uncertain, is tenuous when we accept that Microsoft's monopoly is founded exclusively on intellectual property rights. Moreover, the dichotomy between the market and a limited field of areas where state intervention and regulation is required and justified is a false and misleading one, due to inevitable normative policy questions beneath the market.²⁰¹ Any legal and regulatory framework is based on normative considerations. Market forces act in frameworks established by rights systems, created by the state and enforced by virtue of its coercive power.²⁰² The present intellectual property rights system that gives rise to Microsoft's monopoly is neither fixed and irrevocable, nor is it founded on natural rights for the creators. If anything, it is *a gift of social law*, to put it with Jefferson, and its *raison d'être* is the promotion of social welfare rather than private benefit. Policymakers, in their capacity as representatives of the public at large, have a duty to consider welfare enhancing measures, even if they entail lower profits for Microsoft and its shareholders, and a reconsideration of the rationales behind the ongoing global information enclosure movement. When Microsoft's vice president wonders whether they have done enough to educate policymakers to understand the threat from open source, I shall retort and ask whether enough has been done to educate policymakers about the threat from Microsoft's perpetual monopoly.

Today's economy is dominated by intangibles rather than tangibles, and fixed costs rather than variable costs. Neoclassical price theory has been largely invalidated by some pioneering work in the field of information economics, yet we are merely at the beginning of what may revolutionize mainstream economics and replace frameworks that have become inappropriate in view of their restrictive assumptions. What is needed is genuine and unbiased research, free from preconceived opinions revolving around false assumptions, and rhetorical exer-

²⁰¹See also Brown (1992), and James Boyle, *Missing the point on Microsoft*, salon.com, April 7, 2000 (available from <<http://www.salon.com/tech/feature/2000/04/07/greenspan>>) who comments: "Neo-liberals should try applying the same skepticism to the process of granting and defining state-conferred monopolies called intellectual property rights that they do to the state-conferred regulatory monopolies that affect certain kinds of banking business or the electromagnetic spectrum".

²⁰²"[E]fficiency is a function of rights, and not the other way around" (Medema et al. 2000, p. 440).

cises which trivialise and obscure what is at issue. Statements like: “Our claim is that good products win. . . There is a world of evidence to support our view” (Liebowitz and Margolis 1999, p. 243) become somewhat dubious when there is, in fact, not a ‘world of evidence’, and the authors show a somewhat disturbing propensity for rhetorical questions rather than sound arguments.

The answers to questions posed by the changing characteristics of a world that is rapidly evolving and progressing are not likely to lie just around the corner. Yet the quest for patterns and rules is not a mistake, and we shall not be afraid of throwing outdated principles overboard, for advancing opinions which differ from common prejudices, and promoting actions that break with accepted wisdom have always been the principal drivers of human evolution and progress.

A Glossary

application programming interface an operating system's or application program's interface for applications to make requests to the operating system or the application.

bug commonly used name for programming errors, a legacy from an early era in computing when bugs frequently caused computer failures by interfering with mechanical elements. Bugs occur at all levels in the process of software engineering, from incomplete and inconsistent specifications to accidental programming errors on the implementation level. Complexity, stemming from the sheer size of software, is understood to be the chief cause of bugs, making comprehensive testing of large software impossible.

client a computer program that requests a service in a client/server relationship.

compiler a computer program that translates source code written in a higher level programming language into machine executable object or binary code. A compiler may also produce bytecode that is interpreted or recompiled by a virtual machine, as is the case with Java.

internet a worldwide system of computer networks which is defined by a set of protocols called TCP/IP (Transmission Control Protocol/Internet Protocol). It was conceived by the Advanced Research Projects Agency (ARPA) of the US government in 1969. Electronic mail (email) and the World Wide Web (WWW) are the most widely used applications on the internet.

Java a strictly object-oriented programming language designed for use in the distributed environment of the internet. It is considered a relatively robust and secure language. Java applications are platform independent, they run on a Java virtual machine (JVM) rather than a specific computer platform. JVMs are available for all major platforms.

kernel the core of an operating system, which provides vital interfaces for system calls to application programs, including those that add auxiliary functionality to the operating system.

operating system a set of system programs which controls the overall operation of a computer system and provides hardware-specific routines like memory allocation, job scheduling and input/output control to higher level

application programs, making it effectively a virtual machine whose characteristics are more tractable than the underlying hardware. It generally includes a number of programs, commonly referred to as commands, for manipulating files, and a command-line and/or graphical user interface (GUI) through which the user can access and execute those programs.

server a computer program that provides services to other programs. The computer that the server program runs on is also frequently referred to as a server.

B Software as a Complex Good

What we do not understand we do not possess.

— *Johann Wolfgang Goethe*

It is rarely appreciated that large software is beyond full human comprehension and comand, an unfortunate fact that inevitably entails programming errors.²⁰³ Says Brooks Jr. (1995, p. 182): “Software entities are more complex for their size than perhaps any other human construct”. In fact, the notion that a man-made thing eludes his own comprehension is beyond most people.²⁰⁴ Weizenbaum (1993) reflects nicely:

The reasons for this appear to be almost impossible for the layman to understand or accept. His misconception of what computers are, of what they do, and how they do what they do is attributable in part to the pervasiveness of the mechanistic metaphor and the depth to which it has penetrated the unconscious of our entire culture. (p. 233)

The process of software engineering differs profoundly from other fields of engineering in that it is vastly more complex. Brooks Jr. (1995) captures the problem neatly:

The complexity of software is an *essential property*, not an accidental one.... Many of the classical problems of developing software products derive from this essential complexity and its nonlinear increase with size. From the complexity comes the difficulty of communication among team members, which leads to product flaws, cost overruns, schedule delays. From the complexity comes the difficulty of enumerating, much less understanding, all the possible states of the program, and from that comes the unreliability. From the complexity of the functions comes the difficulty of invoking those functions,

²⁰³This is reflected in the disclaimer of warranty clauses of all software licences the author is aware of. For two exemplary excerpts see Appendix D.

²⁰⁴Says Thimbleby (1990, p. 418): “I believe that the entire industry is set up to exploit users... I believe the industry’s dismissive attitude to bugs is the most serious problem facing computing today”.

which makes programs hard to use. From complexity of structure comes the difficulty of extending programs to new functions without *creating side effects*. From complexity of structure comes the unvisualized states that constitute security trapdoors. Not only technical problems but management problems come from the complexity. This complexity makes overview hard, thus impeding conceptual integrity. It makes it hard to find and control all the loose ends. It creates the tremendous learning and understanding burden that makes personnel turnover a disaster. (pp. 183–4, emphasis added)

The organisational implications are possibly immense as programmers, or rather, teams of programmers are an unprecedentedly specific asset to firms.²⁰⁵ Performance levels can differ dramatically, but as performance is virtually impossible to be measured perfectly, controlling and monitoring employees is vastly more complicated than in other professions.²⁰⁶ Delivering projects in accordance with initial specifications is almost impossible. Brown, Malveau, McCormick III, and Mowbray (1998) state:

[T]he likelihood of success for practicing managers and developers is grim... [F]ive out of six software projects are considered unsuccessful, and approximately a third of software projects are cancelled. The remaining projects delivered software at almost double the expected budget and time to develop as originally planned... More than half of all software cost is due to changes in requirements or the need for system extensions. Some 30 percent of the development cost is due to changes in requirements during system construction. (pp. 3–4, references omitted)

According to the Business Week²⁰⁷, “complex and buggy software costs Corporate America up to \$85 billion a year”. However, the precise costs of bugs are hard to estimate. Moreover, quantification is largely rendered futile since bugs

²⁰⁵As opposed to general treatments of the notion of firm-specific human capital, only little research has been conducted in the context of the software industry. However, programmers earn far higher wages than any other engineering profession and find themselves in strong team situations. For an interesting phenomenological investigation into Microsoft’s corporate culture regarding the treatment of programmers see Fallows (2000).

²⁰⁶Sackman et al. (1968) found average performance differences between best and worst performers of ten to one. They conclude: “When a programmer is good, [h]e is very, very good, [b]ut when he is bad, [h]e is horrid” (p. 6).

²⁰⁷Anonymous, *Software that doesn’t work*, Business Week, December 6, 1999.

are an *inherent* feature of software and here to stay.²⁰⁸

From the complexity of software stems a second and possibly even more considerable problem, that of usability and user-friendliness. Carroll and Rosson (1987, p. 80) put it: “For most people, computers have more possibility than they have real practical utility”. Landauer (1996) laments that:

[T]he systems are not simple enough. They are too complex, have far too many features, give the user far too many options. Almost all users use their computers for only a few operations. Nevertheless, their machines and minds are loaded up with a vast junk pile of options, commands, facilities, doodads, and buttons, most of them superfluous to the user and there just because somebody knew how to program it. (p. 127)

Carroll and Rosson (1987) point at two crucially important phenomena of computer use, which are to be viewed as ‘true paradoxes that necessitate programmatic tradeoff solutions’:

[P]eople have considerable trouble learning to use computers and their skills tend to asymptote at relative mediocrity... A motivational paradox arises in the ‘production bias’ people bring to the task of learning and using computer equipment. Their paramount goal is throughput. This is a desirable state of affairs in that it gives users a focus for their activity with a system, and it increases their likelihood of receiving concrete reinforcement from their work. But on the other hand, it reduces their motivation to spend any time just learning about the system, so that when situations appear that could be more effectively handled by new procedures, they are likely to stick with the procedures they already know, regardless of their efficacy. A second, cognitive paradox develops from the ‘assimilation bias’: People apply what they already know to interpret new situations. This bias can be helpful... [b]ut irrelevant and misleading similarities [can lead] them to draw erroneous comparisons and conclusions, or preventing them from recognizing possibilities for new functions. (pp. 80–1, references omitted)

²⁰⁸See Gribble (2001), and Candea and Fox (2001) for the notion that as nondeterministic and unpredictable bugs are impossible to eliminate, complex systems have to be fault-tolerant and “*expect failure and plan for it accordingly*” (Gribble 2001, emphasis in original).

This holds for experts as well novices.²⁰⁹ The reality is that “[a]dults resist explicitly addressing themselves to new learning” (p. 101, emphasis in original). Designing user interfaces is inevitably a tradeoff between, rather than a logical and comprehensive treatment of conflicting issues. ‘Ease of use’ may compromise efficiency, graphical metaphors consistency, and ‘intelligent’ help systems are almost impossible to design as they have to strike a difficult balance between intrusiveness and reservation.²¹⁰

²⁰⁹In fact, the common classification of users into novices, intermediate, and expert users is overly simple in that it reduces expertise to a one-dimensional variable. See also Draper (1984) for an interesting empirical study.

²¹⁰See also Faulkner (2000) for an introductory account of interface design issues.

C Windows and Linux Market Shares

Tables 6 and 7 on page 81 are compiled from several articles and internet sources,²¹¹ which principally refer to research reports from International Data Corporation (IDC).²¹²

Market shares in software markets, however, are notoriously difficult to determine. A recent CNET report,²¹³ for example, points at markedly different research figures for 2000, released by IDC and Gartner in June: “Gartner [in a study partly sponsored by Microsoft] found that Linux accounted for just 8.6 percent of U.S. server shipments for the third quarter of last year, while IDC insisted that Linux accounted for nearly one-third of the total server market”. There are a number of methodological problems in estimating the market shares as they can not easily be inferred from sales figures. This is especially true for Linux, where the passalong rates decisively impact on the usage figures. The tables below are derived from sales figures, and for Linux some passing along has been taken into account.

²¹¹Anonymous, *Microsoft strengthens its grip, narrowing the window of opportunity for other operating environments*, IDC, February 28, 2001 (available from <<http://www.idc.com/software/press/PR/SW022801pr.stm>>), Stephen Shankland, *Linux shipments up 212 percent*, CNET News.com, December 16, 1998 (available from <<http://news.cnet.com/news/0-1003-202-336510.html>>), Stephen Shankland, *Linux sales surge past competitors*, CNET News.com, February 9, 2000 (available from <<http://news.cnet.com/news/0-1003-200-1546430.html>>), Stephen Shankland, *Linux growth underscores threat to Microsoft*, CNET News.com, February 28, 2001 (available from <<http://news.cnet.com/news/0-1003-200-4979275.html>>), Anonymous, *Linux Not Ready for Desktop Move*, The Associated Press, June 3, 2001 (available from <<http://www.nytimes.com>>), Stephanie Miles, *Linux closing in on Microsoft market share*, CNET News.com, July 24, 2001 (available from <<http://news.cnet.com/news/0-1003-200-2332817.html>>).

²¹²The IDC research papers “Server Operating Environments: 2000 Year in Review” and “Client Operating Environments: 2000 Year in Review” are available from IDC for \$1,500 each (for contact see <<http://www.idc.com/software/press/PR/SW022801pr.stm>>).

²¹³Matthew Broersma, *Linux making corporate inroads*, CNET News.com, August 16, 2001 (available from <<http://news.cnet.com/news/0-1003-200-6886089.html>>).

OS	1997	1998	1999	2000
Windows NT	36	38	38	41
Linux	7	16	25	27
Netware	26	23	19	17
UNIX	17	19	15	14

Table 6: Market shares in the server operating systems market

OS	1999	2000
Windows	89	92
Linux	1	2
Mac OS	5	4

Table 7: Market shares in the client operating systems market

D Excerpts from Software Licence Agreements

D.1 Excerpt from a Supplemental End User License Agreement For Microsoft Software

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E Quantative Data from Study 2

Table 8 shows the data collected in the questionnaire survey.²¹⁴

The following conventions for the coding have been assumed. In the second column, 1 stands for Windows, 2 for Linux, and 3 for MacOS. In columns 7, 8, and 12, 1 stands for yes, 0 stands for no. In column 14, 1 stands for male, and 2 for female. Missing values are indicated by a zero, except for column 12, where 2 indicates a missing value. The missing values originate from the respondents' inability to give answers that fit into the given categories.

Table 8: Raw data collected in the questionnaire survey

	Questionnaire number	Used operating system	Overall satisfaction	Stability	User-friendliness	Technical quality	Installed on acquisition	Awareness of Linux (Windows)	Linux' (Windows') stability	Linux' (Windows') user-friendliness	Linux' (Windows') technical quality	Consideration of switching	Age	Sex
1	2	4	4	3	4	0	1	2	3	2	0	25	1	
2	1	3	2	3	3	0	1	4	3	4	1	26	1	
3	1	4	5	3	5	1	1	4	3	3	0	23	2	
4	1	1	1	3	3	1	1	0	0	0	1	22	1	
5	1	1	2	4	3	0	1	0	0	0	1	23	2	
6	1	3	2	4	3	1	1	5	2	4	0	22	2	
7	1	2	3	2	3	1	1	4	3	4	0	24	1	
8	1	2	1	2	3	1	1	3	3	3	2	29	1	
9	1	5	3	5	4	0	1	0	0	0	0	21	2	
10	1	4	4	3	4	1	1	0	0	0	2	25	2	
11	1	3	3	3	3	1	1	5	4	4	1	22	1	
12	1	3	3	4	4	1	1	5	4	5	1	21	1	
13	1	4	5	3	4	1	1	0	0	0	0	20	2	
14	1	4	1	4	3	1	1	3	0	4	0	20	2	
15	1	4	3	4	4	1	1	5	5	5	0	20	1	
16	1	4	2	2	2	0	1	0	0	0	0	23	1	

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²¹⁴The raw data in plain text and SPSS format, as well as frequency tables, cross tabulations, chi square (χ^2) tests, and correlation computations for selected combinations in HTML are available from <<http://www.phobos-lab.com/mb/dissertation2001/>>.

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	Questionnaire number	Used operating system	Overall satisfaction	Stability	User-friendliness	Technical quality	Installed on acquisition	Awareness of Linux	Linux' (Windows') stability	Linux' (Windows') user-friendliness	Linux' (Windows') technical quality	Consideration of switching	Age	Sex
17	1	3	2	4	3	0	1	4	3	4	1	21	1	
18	1	4	3	3	3	0	0	0	0	0	0	19	2	
19	1	3	3	3	2	0	1	4	3	4	0	30	1	
20	1	4	4	3	4	1	1	0	0	0	0	21	1	
21	1	4	3	3	2	1	1	0	0	0	0	26	1	
22	1	4	3	4	3	1	1	0	0	0	0	20	2	
23	1	3	3	4	3	1	1	0	0	0	0	22	1	
24	1	1	5	2	3	1	1	0	0	0	2	26	1	
25	1	4	4	4	4	0	0	0	0	0	0	21	2	
26	1	3	3	3	3	0	1	4	2	0	1	24	1	
27	1	3	5	4	2	1	0	0	0	0	1	22	2	
28	1	4	4	4	3	1	0	0	0	0	0	27	2	
29	1	3	4	4	5	1	0	0	0	0	0	27	2	
30	1	3	2	4	3	1	1	4	3	4	1	25	1	
31	1	3	3	5	3	1	1	0	0	0	0	22	1	
32	1	3	2	3	3	1	1	0	0	0	1	23	2	
33	1	3	2	4	3	1	1	4	2	3	0	21	1	
34	1	4	3	5	3	1	1	0	0	0	0	21	1	
35	1	3	2	5	4	1	1	0	0	0	1	24	2	
36	1	3	4	4	3	1	1	0	0	0	1	25	1	
37	1	2	2	4	3	0	1	4	2	3	1	30	1	
38	1	3	4	3	3	1	1	0	0	0	0	27	1	
39	3	3	3	5	5	1	1	0	0	0	0	22	1	
40	1	4	3	3	4	1	0	0	0	0	0	20	2	
41	1	4	2	3	3	1	1	0	0	0	0	23	2	
42	1	3	4	4	3	1	0	0	0	0	0	20	2	
43	1	1	1	3	3	0	1	0	0	0	1	21	1	
44	1	4	4	4	3	1	1	0	0	0	0	23	1	
45	1	5	5	5	5	1	1	0	0	0	1	22	2	

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Questionnaire number	Used operating system	Overall satisfaction	Stability	User-friendliness	Technical quality	Installed on acquisition	Awareness of Linux (Windows)	Linux' (Windows') stability	Linux' (Windows') user-friendliness	Linux' (Windows') technical quality	Consideration of switching	Age	Sex
46	1	3	1	3	3	1	1	4	3	4	0	25	2
47	1	3	4	4	3	1	1	0	0	0	0	28	1
48	1	4	4	4	4	1	1	0	0	0	0	31	1
49	1	4	3	4	4	1	1	0	0	0	0	20	2
50	1	2	4	5	3	0	1	3	2	5	0	22	1
51	1	3	3	3	2	0	0	0	0	0	1	25	2
52	1	2	1	4	4	0	1	0	0	0	1	21	1
53	1	1	1	4	3	1	0	0	0	0	1	25	1
54	1	3	2	2	2	1	1	0	0	0	1	26	1
55	3	5	5	5	4	1	1	0	0	0	0	26	2
56	1	3	5	5	5	1	1	0	0	0	1	28	2
57	1	3	1	4	3	0	1	0	0	0	0	27	1
58	1	4	4	3	3	0	1	0	0	0	1	27	1
59	1	3	3	4	3	0	1	5	4	4	1	26	1
60	1	4	4	4	4	1	1	0	0	0	0	24	2
61	1	4	4	4	4	0	1	0	0	0	0	21	1
62	1	3	2	3	3	0	0	0	0	0	0	20	2
63	1	3	3	3	3	0	0	0	0	0	0	20	2
64	1	3	3	4	4	0	1	0	0	0	0	19	1
65	1	4	2	4	4	0	1	4	3	4	0	21	1
66	1	3	3	4	0	0	0	0	0	0	0	26	2
67	1	4	3	4	4	0	1	5	3	5	0	25	1
68	1	3	3	5	3	0	0	0	0	0	0	22	2
69	1	1	1	1	1	0	1	3	2	5	1	27	1
70	1	3	3	4	4	0	1	0	0	0	0	22	1
71	1	2	3	3	2	1	1	4	0	4	1	25	1
72	1	2	5	3	2	1	0	0	0	0	0	29	2
73	1	3	4	3	3	1	0	0	0	0	0	24	2
74	1	4	4	3	2	1	1	5	4	4	0	20	1

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	Questionnaire number	Used operating system	Overall satisfaction	Stability	User-friendliness	Technical quality	Installed on acquisition	Awareness of Linux (Windows)	Linux' (Windows') stability	Linux' (Windows') user-friendliness	Linux' (Windows') technical quality	Consideration of switching	Age	Sex
75	1	4	3	4	4	0	1	0	0	0	0	24	2	
76	1	3	3	4	3	1	0	0	0	0	1	23	1	
77	1	5	4	5	5	1	1	5	5	5	0	26	1	
78	1	3	3	4	4	1	1	0	0	0	0	24	2	
79	1	4	4	4	4	1	0	0	0	0	0	26	2	
80	3	4	3	5	4	1	1	0	0	0	0	34	1	
81	1	3	2	4	3	0	1	0	0	0	1	24	1	
82	1	2	3	2	0	1	1	0	0	0	0	28	2	
83	1	4	4	4	0	1	1	0	0	0	0	25	2	
84	1	4	4	3	2	0	1	0	0	0	1	26	2	
85	1	4	3	4	4	1	1	0	0	0	0	29	1	
86	1	3	4	3	3	1	1	4	2	4	0	22	1	
87	1	2	3	4	2	1	1	0	0	0	0	28	1	
88	1	3	4	3	4	1	1	0	0	0	1	27	1	
89	1	3	4	3	0	0	1	3	2	4	1	21	2	
90	1	3	4	3	0	1	1	0	0	0	0	20	2	
91	1	3	4	3	2	1	1	0	0	0	1	25	2	
92	1	4	3	4	0	0	0	0	0	0	0	24	2	
93	1	1	1	4	3	1	1	0	0	0	1	26	1	
94	1	4	2	4	3	1	1	0	0	0	0	23	1	
95	1	4	4	4	3	1	0	0	0	0	0	21	2	
96	3	4	5	5	5	1	0	0	0	0	0	24	2	
97	1	4	5	5	5	0	1	5	2	3	1	23	1	
98	1	3	3	4	4	1	1	5	4	5	1	29	2	
99	1	4	4	3	0	0	1	0	0	0	0	24	2	
100	2	5	4	3	5	0	1	2	4	1	0	32	1	

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