Upgrading and Niche Usage of PC Operating Systems.

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Abstract

Microsoft has been dominating the market for PC operating systems (OS) for the last two decades. This paper analyzes the decision of firms to standardize on the mainstream OS family and assesses whether upgrading to the latest version within the MS family is a substitute for using niche OS. We address the following questions: 1) How likely is a firm to standardize on the Microsoft family? 2) How quickly will a firm upgrade to a new version of the mainstream system? 3) Which niche operating system is a firm likely to use, if any? We find that upgrading and niche usage seem to be substitutes to some extent, but that larger and more IT-intensive firms will rather use niche systems than upgrade to the latest Windows version.

JEL: L15, L86. Keywords: Operating Systems, Standardization, Upgrading, Niche Products.

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1 Introduction

Microsoft's operating systems have long dominated the market for Personal Computer Operating Systems (PC OS). Since the introduction of Microsoft DOS (**D**isk **O**perating **S**ystem) in 1983, Microsoft has commanded a market share of around 90% for newly purchased PCs. This dominance has extended over several generations of Microsoft systems (in particular DOS, Windows 3, Windows 95, Windows NT, and Windows 2000) and countless version upgrades (such as Windows 3.1, 3.11 etc.). Despite Microsoft's dominance, however, not every firm uses exclusively their operating systems, and this is the focus of this paper. In particular, we ask whether using the latest version of the mainstream Microsoft family in our dataset (Windows 95) and usage of a niche operating system are substitutes, complements, or if usage and upgrading decisions are taken independently of each other. Using detailed cross-section data, we attempt to capture these interdependencies and find determinants of upgrading and niche usage of PC operating systems. We find that upgrading and niche usage seem to be substitutes, and that firms with more diverse needs, and external links will tend to standardize less, while firms that improve the performance of their basic OS will be more standardized.

Related literature

The empirical literature on markets with network effects has increased in the past years.[1] With the availability of new data and the development of econometric techniques, network externalities have been shown to exist in PC spreadsheets (Gandal 1995, Brynjolfsson and Kemerer 1996), VCRs (Ohashi 2003), CD players and disks (Gandal, Kende and Rob 2000), DVD players (Dranove and Gandal 2003), and ATM machines (Saloner and Shepard 1995). The computer industry has received particular attention in the literature. The impact of advertising on the competition between the IBM-Microsoft-Intel standard and Apple/Macintosh has been analyzed in Greenstein and Salant (1999). The effect of the intensity of competition between the two formats on diffusion speed has been documented by Koski (1999). The common message of these studies is that a larger installed base has a positive effect on the value of the technology. Taking this argument one step

[1] For a recent survey of the empirical literature on network industries, see Koski and Kretschmer (2004).

further, a standardized market seems possible and likely, which confirms the theoretical results of Arthur (1989) and Arthur et al. (1987), namely that a market exhibiting significant unbounded increasing returns will eventually settle on one industry standard.[2]

This result has been refined in a number of ways in the literature. Farrell and Saloner (1986b) show that if the preference for variety (i.e. heterogeneity) in the consumer population is large, standardization might not occur. Bental and Spiegel (1995) analyze a model of vertical product differentiation and find that with network effects, the largest network commands the highest prices, but still multiple networks can exist in equilibrium. Farrell and Saloner (1986a) show that when a new generation technology emerges, the transition to the new technology might occur prematurely, causing a market split between generations where a standardized solution would be preferable. Common to these theoretical studies is that even though there are some benefits to standardization, a market need not standardize on one technology, and this non-standardization outcome can in fact be an efficient outcome. The stability of a dominant position has also been studied empirically by Breuhan (1998) in the spreadsheet and word processing markets. She finds that following the introduction of a new product generation, switching costs across systems decrease, so that niche products may be able to challenge a leader's dominance following a product upgrade.

Finally, work by Hendel (1999) models the demand for personal computers with a multiple-discrete choice model. Firms simultaneously choose which types of PCs and how many of each type they should purchase. He assumes that computers fulfil certain tasks within an organization, and that firms will select the profit-maximizing option for each task, which then generates a distribution of different types of PCs within an organization. Network effects across tasks however are not considered in his model.

This paper is the first (to my knowledge) to empirically address the trade-off between standardization and variety using intra-firm usage data. By focusing on the usage of niche products and the degree of standardization, it also looks at the stylized fact that, in many network markets there is a dominant standard and a fringe of other products that struggle to survive. This differs from much of the work on standards battles in the early stages of an industry's life cycle, and of many of the empirical studies on more ma-

[2]For a model with network effects but without technological lock-in, see Bassanini and Dosi (1998).

ture markets that are concerned mainly with establishing the existence of network effects. By assessing the impact of network effects on within-firm standardization, this paper aims to offer new insights on the viability of niche products in almost standardized markets.

2 The Operating Systems Industry[3]

Operating systems provide the basic instructions and functionality for PCs. While early operating systems were little more than converters of an instruction set encoded on punch cards into orders for the processor, more recent operating systems fulfill much more extensive tasks. Even before the advent of personal computers, increased memory and more diverse tasks performed by the computer required operating systems to allocate computing resources to multiple tasks (multitasking or time sharing). The latest operating systems designed for personal computers now come with networking capabilities, file management systems, virus checkers and hardware diagnosis tools as built-in basic functions.

Bill Gates is quoted as saying that

> '[Microsoft] look[s] for opportunities with network externalities — where there are advantages to the vast majority of consumers to share a common standard.'[4]

The source of network effects is mainly through indirect channels: An OS is not a standalone product, but can only be used in conjunction with complementary products, the most important of which are a processor[5] and

[3]Detailed accounts of the rise of Microsoft, which has been the dominant firm in the market since its inception, are given in Yoffie et al. (1996), Rukstadt et al. (2000), Burgelman et al. (1997) and Burgelman (1997). A history of the Microcomputer market from an economist's angle is given in Bresnahan and Greenstein (1999). The dynamics of the OS industry in the late 1980s and the effect of advertising on the success of the MS/IBM and the Apple/MAC standard, respectively, are analyzed in Greenstein and Salant (1999). On the level of PC applications software, Breuhan (1998) provides a history of word processing, spreadsheet, and communications software. The data in this section mainly draws on these sources and on information from the main players' websites (http://www.microsoft.com, http://www.ibm.com, http://www.apple.com).

[4]Yoffie et al. (1996), p.1.

[5]Some operating systems are "portable OS". They are designed to work equally well with several processors. Historically, however, they had to trade off increased flexibility with a loss in performance.

end-user applications. An operating system which does not have a sufficient number and range of compatible applications will not be attractive to consumers, which in turn decreases the incentives for applications programmers to develop applications, thus initiating a vicious cycle.[6]

The industry's history shows that there are indeed advantages for a large share of the market to using the same system, as would be expected in industries with significant network effects.

The evolution of the PC OS market

When the MITS Altair 8800 was introduced in 1975 as the first personal computer, Bill Gates and Paul Allen adapted the **B**eginner's **A**ll-purpose **S**ymbolic **I**nstruction **C**ode (BASIC) programming language that had been developed a decade ago for the Altair's needs. Within a few years, Microsoft (the trade name was registered in late 1976) had started selling BASIC to other clients such as DTC, General Electric, NCR and Citibank as well and launched another programming language, FORTRAN-80, an improved version of FORTRAN. By 1981, they were part of the dominant PC family. IBM, which had previously relied on exclusive in-house development of their products' components, had outsourced the development of the processing unit to INTEL and the operating system to Microsoft for their personal computer. Microsoft purchased an operating system from Seattle Computer Products for $50,000, refined and adapted it to the IBM PC, and named it Microsoft Disk Operating System, MS-DOS. Prices for the first PCs started at $1,565, and PCs were distributed via mass consumer outlets such as Sears, Roebuck & Co. and ComputerLand. Two years later, Microsoft's first operating system upgrade was released, MS-DOS 2.0. The market for PCs took off, and within 18 months, IBM had sold 136,000 PCs, alongside a large number of IBM-compatible PCs that used INTEL's 8088 processor and Microsoft's DOS. In the mid-1980's, MS-DOS' market share was reported to be 85%, resulting in an initial public offering raising $61 million.

In late 1985, Microsoft had developed an early version of their graphical user interface (GUI) called Windows. It was programmed to mimic the look and feel of the Macintosh by Apple introduced in 1985, making computer use more intuitive than it had been with their own OS, MS-DOS. Initially,

[6]Indirect network effects for operating systems are further strengthened by learning effects for end-users and systems administrators and data exchange requirements among PCs.

Windows was a user interface to be run on top of MS-DOS, providing Microsoft with two revenue streams for all PCs sold with DOS and Windows. Windows took off with the release of the powerful INTEL 80286 and 80386, which allowed users to make full use of Windows' multitasking capabilities.

Following Windows, Microsoft had started developing OS/2 jointly with IBM as a long-term successor to MS-DOS. OS/2 was eventually released in 1988 by IBM alone after Microsoft withdrew from the project. In Spring 1990, Windows 3.0 was released. Microsoft continued developing MS-DOS, however, releasing upgrades up until 1994, at which point Windows 95, a full standalone OS, had been preannounced for release in Summer 1995.

Windows NT was launched in May 1993 (but preannounced as early as 1990) and was targeted at the network server market dominated by Novell Netware. Windows NT simultaneously offered strong network management capabilities and a 'general purpose OS that could also run general applications.' Compatibility with other Microsoft OS was limited and the emulators Microsoft offered to ensure compatibility with MS-DOS or Windows 3 were extremely slow, so initial takeup was disappointing. With the coordinated releases of a new, more stable version of NT and Windows 95 however, NT finally took off. Increased stability meant that it now was a viable alternative to Novell Netware. Microsoft's strategy of 'certifying' applications to run both on Windows 95 and Windows NT[7] prompted a huge increase in available applications software for Windows NT. Within the first month of NT's release, there were 130 software packages available for Windows NT.

Two other operating systems also held minor market shares in the PC OS market. The Macintosh/Apple standard ran on incompatible hardware and was especially competitive in the graphics design market. It is often argued that the Apple/Mac standard was in fact superior to the "Wintel" standard, but market forces early in the industry's history confined Apple to a niche role. Unix, initially developed by AT&T, was a so-called open standard, meaning that the basic source code was freely available. Over time however, several (mostly proprietary) variants of it were developed,[8] the most successful being Santa Cruz Operation's Xenix and SCO Unix,[9] Sun's

[7] In order to be certified as a Windows application, software needed to be able to run on both Windows 95 and Windows NT without losses in performance.

[8] http://www.computerhope.com/unix/unix.htm

[9] In fact, Xenix was initially developed by Microsoft who licensed the source code to software OEMs (Original Equipment Manufacturers), including Santa Cruz Operations. Their variant of Xenix then finally became known as SCO Xenix

Solaris and Univel, a joint effort by Novell and Unix System Labs.[10] Even proprietary versions, however, were still considered difficult to operate and mainly suited for high-end users. Recently, Linux emerged as the leading operating system of the Unix family, but similar to previous versions, its strengths lay mainly in operating servers rather than providing a platform for end users.

3 Standardization in the PC operating systems market

This section highlights a number of qualitative features of the PC operating systems industry. The dataset we use is a 1998 cross-section of 4729 UK sites gathered by ZD Market Intelligence, now Harte-Hanks Market Intelligence. It contains a vast amount of information on the information and communications technologies used on a particular site.[11] It is described in more detail in Appendix B. Our variable definitions and descriptive statistics are also in Appendix B. The aggregate figures on industry trends in OS usage have also been provided by Harte-Hanks Market Intelligence, but do not form part of our later firm-level analysis.

Network effects suggest that large groups of users will want to use the same operating system. An operating system with a large installed base should be attractive for applications developers, generating indirect network effects. For homogeneous firms, this would imply unanimous choice of the dominant operating system. Even if firms are heterogenous in their needs, a number of factors make it costly to run multiple operating systems within a single firm. Firstly, since most OS have a distinctive user interface, end-users will learn how to work on particular operating systems. Similarly, system administrators will learn how to deal with problems arising from particular operating systems. Therefore, end-users and IT personnel create an individual and firmwide body of expertise for a particular operating system, which will result in a cost that affects switching to (or concurrent use of) another OS.[12] Secondly, computers – and especially the applications that run

(http://www.computerhope.com/unix/xenix.htm).

[10] http://www.att.com/news/1291/911212.ula.html

[11] We use the terms "firm" and "site" interchangeably.

[12] According to Rukstad et al. (2000), this switching cost can run up to four times the purchase price of the operating system.

on them – will occasionally exchange data and, more generally, be required to operate jointly within and across firms. This could be via direct communication of employees using email, workers changing jobs, resource sharing within a firm, or providing external access to a task that is being performed by a PC in this firm. Since an operating system provides a basic set of instructions that ensures the portability across computers (running the same OS), more use of an operating system within the firm implies more potential for communication and consequently higher benefits from using this specific system.

The existence of substantial switching cost therefore also makes it attractive to vendors to get firms to standardize on a particular OS, which creates an incentive for suppliers to lock-in consumers to their standard.[13] This appears to play a significant role in the operating systems market. In the (for now) final judgement on the Microsoft US antitrust case in November 2002, Microsoft was explicitly prohibited from retaliating against OEM manufacturers that were "shipping a Personal Computer that (a) includes both a Windows Operating System Product and a non-Microsoft Operating System, or (b) will boot with more than one Operating System"[14]. This suggests that Microsoft has been trying to get OEMs to standardize and lock-in to Microsoft Operating Systems. The peculiar pricing policy employed by Microsoft (Microsoft charged a royalty per PC sold, irrespective of Microsoft OS being installed or not) also gives OEM manufacturers incentives to install Microsoft OS on their computers (at zero marginal cost), which again discourages the emergence of niche Operating Systems.

To see if the forces favouring standardization from the supply- and the demand side are indeed overwhelmingly strong, we first investigate aggregate market share of Microsoft operating systems in the PC industry. Then, we use detailed firm-level data to see if firms do indeed standardize on a single operating system.

Industry trends in OS usage

Figure 1 graphs the development of UK market shares of the mainstream Microsoft PC OS between 1994 and 1998.

[13] Klemperer (1995) discusses the impact of switching cost on market prices and dynamics.

[14] http://www.usdoj.gov/atr/cases/f200400/200457.htm

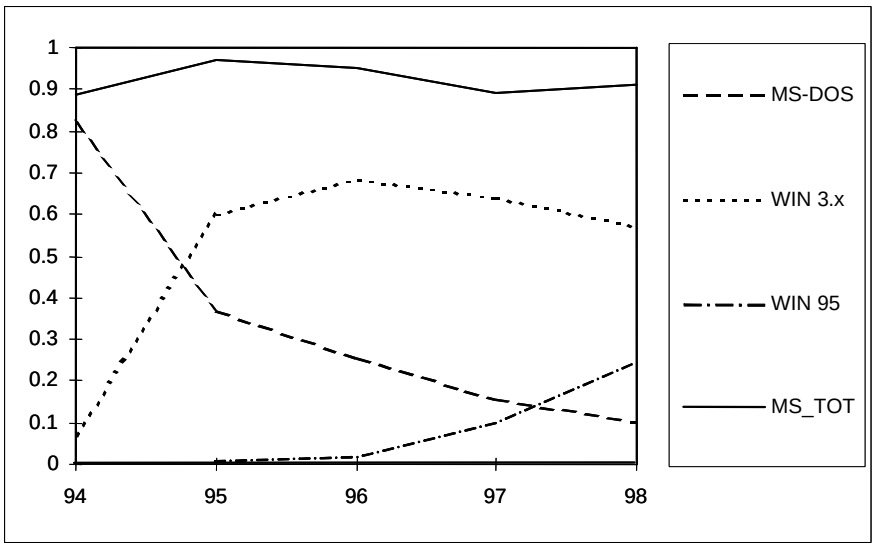

Figure 1: UK Market share fluctuations of main Microsoft PC OS (Source: Harte-Hanks Market Intelligence).

Microsoft's aggregate market share has remained almost constant over the years, while market shares of the individual OS have varied dramatically in the same time period. Overall, the variation of mainstream Microsoft market share was less than ten percentage points during this time period, suggesting that Microsoft succeeded in marketing successive generations of mainstream operating systems.

Firm level statistics

About 10% of PCs run on other OS. Two extreme cases could generate this result: First, one firm out of ten uses a single, competing OS. Second, all firms run one-tenth of their PCs on another OS. The two cases have different implications. The first indicates strong intra-firm network effects, while the second implies network effects through availability of complementary programs for specific tasks. Table 1 gives the distribution of the number of OS used within firms in 1998, split by using mainly (i.e. $> 50\%$) Microsoft products or not. We treat all mainstream Microsoft operating systems as a single operating system since MS-DOS, Windows 3.x and Windows 95 were

specifically designed to share a large portion of the source code and thus to ensure high compatibility.[15]

Table 1: Number of OS used by dominance of MS products.

	Dominance of Microsoft products		
#OS	no	yes	Total
1	117	3273	3390
2	241	996	1237
3	24	70	94
4	2	5	7
5	1	0	1
Total	385	4344	4729

Note: Dominance is defined as more than half of PCs within the firm using Microsoft DOS, WIN3, or WIN95. The number of OS used consists of all OS with usage >0% (MS DOS, WIN3 and WIN95 are treated as a single OS).

We can see from the Table that 1071 of the 4344 firms (or 24.65 % of MS-users resp. 22.65% of all firms) using predominantly mainstream Microsoft OS (i.e. the right column) are using a mix of Microsoft products (namely, MS-DOS, Windows 3, and Windows 95) *and* another product concurrently. The Table also shows that firms not using mainly Microsoft products (i.e. the left column) often use two operating system families (in 241 cases of 385 in total). This suggests that mainstream Windows products indeed fulfill most tasks within an average firm, while other operating systems seem less extensive in scope or appeal to firms with more diverse needs. It is also evident that there are much less than the maximum of 90% of firms using exclusively Microsoft products, which is an indicator that firms may require functions absent in mainstream products in other (niche) systems, and run these OS on a subset of their PCs. Figure 2 orders all firms by their share

[15] In our analysis, we will focus on the firms using predominantly mainstream Microsoft OS. It is therefore important to ask whether these firms differ significantly from the firms that do not. In Table 9 in the Appendix, we compare the values of the independent variables in the columns (Microsoft dominance? Yes/No) and find that the descriptive statistics are largely comparable apart from the use of a server, which is higher for minority users of mainstream Microsoft OS.

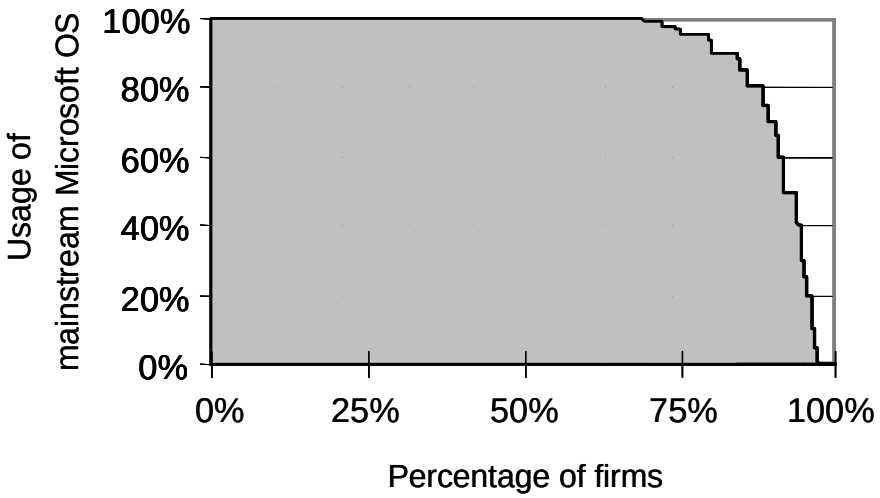

Figure 2: Cumulative market share of mainstream MS OS.

of mainstream MS PCs (shaded area) on the horizontal axis and plots the share of mainstream Microsoft OS on the vertical axis. Note that the shaded area corresponds to Microsoft's overall market share.

Apart from using niche OS in addition to the mainstream MS option, firms can also utilize additional functions if they upgrade to the most current version of Microsoft's mainstream family in 1998, Windows 95. Table 2 illustrates that even in 1998, only about half of all firms have made use of that possibility, and that MS-DOS is still used in one quarter of all firms.[16]

To summarize, upgrading and using niche OS both provide the firm with added functionality over the status quo. Both options have their respective advantages and disadvantages. Since a new generation OS uses a significant portion of the existing code, the potential for differentiation from the current version is limited. On the other hand, the common heritage ensures intergenerational compatibility at least to some extent. Niche OS are not bound by existing code of the dominant OS which permits them to concentrate in-

[16]It should be noted, however, that our data generates a lag of almost one year, since Windows 95 was introduced in August 95 and the interviews were conducted in July of each year. Likewise, Windows 98 was only introduced in June 1998 (http://www.theeldergeek.com/windows_timeline.htm), which was too late to register for the July 1998 data.

Table 2: Number of OS used by dominance of MS products.

	Dominance of Microsoft products		
	no	yes	All
% using Win95	47.17%	52.51%	50.94%
% using DOS	31.21%	25.90%	24.68%
Total	385	4344	4729

Note: Dominance is defined as more than half of PCs within the firm using Microsoft DOS, WIN3, or WIN95.

stead on the "holes", i.e. missing tasks, left by the mainstream system and therefore specifically target a minority of adopters dissatisfied with the currently dominating OS. Users of niche OS, however, will experience a loss of intra-firm network effects, since compatibility is conceivably lower between PCs running on operating systems by different vendors. A compromise strategy would be adoption of a niche system by Microsoft (Windows NT), which adds to the tasks fulfilled by mainstream MS OS, but achieves greater compatibility, in particular with the then-current version of Windows, Windows 95.

There is considerable heterogeneity in the upgrading and niche usage behaviour across firms, which raises the question if firms are likely to substitute one for the other, or if both niche usage and upgrading occur jointly in firms. To analyze this and related topics, we address three separate questions before synthesizing our conclusions.

1. First, we look at determinants of intra-firm standardization on the Microsoft OS family. We regard MS-DOS, Windows 3 and Windows 95 as a single (mainstream) OS family and identify explanatory variables that influence the degree of standardization (or the expected share of PCs that run on Microsoft).

2. We then study firms' speed of upgrading to new versions of Microsoft OS. We examine the proportion of PCs within the MS family that are running on Windows 95 (as proxy for the speed of upgrading) and the proportion of PCs running on MS-DOS (as indicator for inertia in abandoning an old product).

3. Finally, we examine usage of operating systems outside the mainstream family. In particular, we will examine whether firms use Windows NT or not, i.e. how "far" their niche system is from the mainstream standard. This identifies firms that sacrifice compatibility for increased variety.

The coefficients we obtain from these regressions give an indication of the degree of substitutability between upgrading and niche usage. For example, if firm size has a positive effect on upgrading and a negative effect on niche usage, large firms prefer to upgrade rather than use niche OS, implying that the two are substitutes with respect to firm size.

4 Assumptions and Hypotheses

4.1 Benefits from OS Usage

Similarly to Hendel (1999), we assume that within a firm, an operating system has to fulfill different tasks. A single OS will not perform all tasks equally well, i.e. it is specialized on a subset of them. If an OS performs additional functions, this will come with a certain performance loss. A firm requiring two subsets of tasks with different "optimal" OS will therefore trade off additional costs[17] of running multiple systems with the performance loss from having an OS perform certain tasks suboptimally. Consider the following net benefit function of OS i:

$$U^i = U^i\left(S^i, B^i, C^i\right) = \sum_{t=1}^{V} s^i(t) + B^i(N) - C^i(N),$$

where $S^i = \sum_{t=1}^{V} s^i(t)$ is the sum of the standalone values of the V different tasks t fulfilled by the OS, $B^i(N)$ are the network benefits from N users, and $C^i(N)$ are the costs of installing and maintaining an OS for N users. We make the following assumptions about this benefit function:

A1: $s_t^{i\prime} < 0$,
A2: $B_N^{i\prime} > 0, B_N^{i\prime\prime} < 0$,
A3: $C_N^{i\prime} > 0, C_N^{i\prime\prime} < 0$.

[17] Mainly learning cost, loss of network benefits across applications and tasks and maintenance cost.

A1 states that an OS is better at doing some tasks than others and that an OS will be purchased to fulfil tasks in decreasing order of OS/task match. For example, an OS may be purchased mainly for its user friendliness but may also be used for data sharing and transferring. It seems reasonable to assume that different OS have different strengths (Appendix A contains a table with the characteristics of the OS used in our study) and that average performance per task decreases with increasing task heterogeneity. **A2** imposes decreasing marginal network benefits. Assuming that there are network benefits across users and tasks, the marginal benefits from having, say, users from unrelated departments running the same OS are smaller than the benefits from within-department compatibility. **A3** assumes economies of scale in OS setup and maintenance cost: On the one hand, per-unit prices of OS typically decrease with the number of units purchased, and on the other hand it is cheaper to provide maintenance for n users using a single OS than for n different OS with one user each.

This allows for niche products and mainstream products to coexist: An OS that delivers utility mainly through high network benefits and low per-unit costs may be used jointly with a high-performance, few-tasks OS. For our estimations now, we have to make some assumptions about the degree of differentiation between the different OS in our sample: Suppose a firm has three options to fulfill non-standard needs that arise. It can either upgrade within the mainstream OS family to a higher performance OS, it can use a non-Microsoft niche OS, or it can purchase Windows NT as an intermediate solution.

We make the following assumptions about the different groups of OS in our sample:

- *Mainstream Microsoft OS.* MS-DOS, Windows 3, and Windows 95, are assumed to fulfill the basic functions required in a firm. While later versions are better (i.e. $s^{W95} > s^{W3} > s^{DOS} \quad \forall t$), the focus is still on general rather than specialist use. We assume that compatibility among these three systems is higher than with any of the other OS.

- *Niche OS.* We assume that non-MS OS are perfectly (maximally) horizontally differentiated relative to the mainstream OS. While this is clearly a simplification, experiments with an ordering of niche OS in terms of their "differentness" to MS OS yield essentially the same regression results, however at the expense of explanatory power and

degrees of freedom. Since our main concern is the tradeoff between compatibility and specialization, grouping non-Microsoft OS into one "niche" category seems a sensible compromise.

- *Windows NT.* Windows NT was marketed as a compatible, but advanced version of the mainstream Microsoft OS. Thus, it is reasonable to assume that NT will only be differentiated within the limits of the Microsoft standard, while it will still be compatible with the mainstream. Firms that place a high value on compatibility will therefore prefer a solution involving Windows NT.

Figure 3 illustrates our assumptions about OS differentiation.

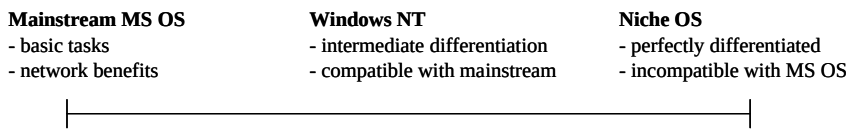

Figure 3: Location of three OS groups on a horizontally differentiated line.

The variables contained in our dataset can all be thought of as influencing the OS benefit function, either by decreasing the cost of running multiple systems, or by changing the benefits from running specialized systems.

4.2 Data Issues and Hypotheses

4.2.1 Endogeneity Issues

As mentioned previously, the data used in our analysis is a single 1998 cross-section. Modelling a dynamic decision using a cross-section entails several shortcomings. For example, it is not possible to put a date on the adoption decisions of a niche OS or the new-generation OS. We also are not able to estimate the effect of introducing a new-generation mainstream OS on the overall degree of dominance of Microsoft. Furthermore, variables might be jointly determined and problems of endogeneity cannot be fully eliminated without using lagged variables or other suitable instruments. Additionally, by only distinguishing between Microsoft and non-Microsoft niche systems, we sacrifice some of the distinguishing features of the specific operating systems. Despite these limitations however the question of substitutability or

complementarity between upgrading and niche usage can still be addressed satisfactorily with our data, and it allows us to draw inferences about the tradeoff between firmwide compatibility and variety. Further, our dataset is very rich in information on the individual firms, enabling us to assess the effect of several relevant variables on the niche or upgrading decision. In our estimations, we select instruments that are highly correlated with our factors of interest while posing the least possible problems of endogeneity.

4.2.2 Hypotheses

Several factors can influence the benefits of using one or several OS. We will focus on three factors: Task diversity within the firm, external links requiring additional tasks, and firms' efforts to improve OS performance via more suitable (we will shortly define our interpretation of this) end-user applications.

Internal Diversity

The effect of task diversity is essentially a decrease in the marginal benefits s'_t of a mainstream OS, since the tasks taken on are increasingly different from the bread-and-butter operations that mainstream OS have been designed to perform. A niche OS on the other hand essentially experiences an increasing network benefit (**A2**) and may achieve a more efficient scale of units (**A3**).

Hence, if tasks within an organisation are diverse, a single operating system may not be sufficient to achieve satisfactory performance in all of them. On the other hand, a niche OS may reach a sufficient scale within the firm, which makes the compatibility advantage of Windows NT over other niche OS relatively less important. Consequently, we expect more diverse firms to be less standardized and to be using more "distant" niche OS. The effect of internal diversity on upgrading within the mainstream is less clear. On the one hand, upgrading to a recent version may improve performance for a large number of tasks, creating a tendency towards quicker upgrading. On the other hand, niche OS may be serving more of the "critical" tasks, so that performance for the mainstream OS is less important, thus decreasing the need for upgrading. Our regressions will show which effect dominates. We measure internal diversity through firm size and IT intensity:

Log of Firm size (SIZE). Larger firms will typically have more varied needs that are increasingly distant from the standard tasks a mainstream

OS fulfills. For example, larger firms typically require security systems or file sharing facilities.

IT staff/Total staff (IT_STAFF). An IT-intensive firm will typically have more sophisticated needs. IT-workers are better informed about possible functions of operating systems, leading them to demand more of an OS.[18]

Links (internal and external)

Intra- and interfirm links are likely to place additional demands on an operating system. In that sense, its effect is similar to task diversity. However, the additional demand refers to a subset of tasks, namely communications tasks (subscript c). Therefore, the weight placed on the standalone value of communications tasks will be higher, i.e. s_c' is higher for firms with high communications requirements. Further, we expect that network effects across all PCs will play an important role, i.e. firms place a premium on compatibility (high $B(N)$).

While Microsoft's mainstream OS all had some facilities for connecting PCs within the same firm, connecting computers across sites or making communication between servers and PCs possible was not one of their strengths. We therefore expect standardization to decrease with stronger internal or external links. On the other hand, Windows NT was designed to enhance communications capabilities while at the same time avoiding the loss in network effects from departing from the MS mainstream. We therefore expect use of Windows NT at the expense of more distant niche OS for both internal and external links. External links and the associated need for compatibility also imply that connected computers will want to use the same generation of mainstream OS since backward compatibility was not always perfect. We expect therefore that upgrading will take place at slower pace since the slowest upgrader will be setting the pace for upgrading. On the other hand, using a server often characterizes a technologically sophisticated firm, thus implying quicker upgrading speed. This tendency would be reinforced by the fact that Windows 95 was designed to be complementary to Windows NT, the OS we expect to benefit most from server usage. We proxy internal links with a dummy variable for server usage and external links with a dummy for multisite operations.

[18] Endogeneity is a potential problem here since OS usage may affect the hiring of new IT staff. Since IT staff typically has more diverse tasks than simply maintaining the firm's OS and therefore many other factors will influence the level of IT staff, we expect the reverse causality to be dwarfed by the direct effect.

Server usage (SERVER). Running a server is similar to being part of a multisite firm in the sense that additional requirements arise in terms of communication. Contrary to multisite operations however, communication between computers in the same organization has to be ensured.

Multisite operation (MULTISITE). Operating as part of a multisite environment requires tasks that go beyond the standard mainstream OS. What is different from the more general task variety measures, however, is that the extension of tasks is in a specific direction, namely ensuring communication across firm boundaries.

Enhancing OS Performance

So far, we have implicitly divided tasks within a firm into *standard* and *specialized* tasks and assumed that mainstream Microsoft OS fare best in fulfilling standard tasks. For standard tasks in particular, OS utility derives mostly from of ease-of-use and performance of the associated applications. Microsoft office applications are designed to take full advantage of Microsoft's mainstream OS and consequently command a similarly dominant market share in the office applications market as in the OS market. A number of firms, however, choose to purchase office applications by other vendors. Sometimes, these choices are by historical accident and the cost of switching to a Microsoft application are too high.[19] For some firms however choosing a non-Microsoft application simply maximizes the utility derived from standard tasks on a particular OS, i.e. s'_s is high for these firms. That is, we can interpret usage of a non-Microsoft office application as a "fine tuning" of the standalone value of mainstream OS. We therefore expect such firms to be more standardized. On the other hand, the extent of network benefits through data exchangeability across applications for example will be lower across different Microsoft operating systems because applications and OS are now less harmonized. Therefore, the tendency to use Microsoft NT over other niche systems should decrease. Similarly, we expect upgrading to occur at a slower pace, since again applications software and the latest version of the Windows family are not synchronized as closely as an all-Microsoft combination would be. Using office applications that are not by Microsoft

[19] Breuhan (1998) however has found that switching costs decrease as new versions of applications are introduced, so that the effect of firms that are still using non-MS products by default should be rather low.

could be an indicator that a firm adjusts their mainstream OS to their specific needs.

Non-MS Spreadsheet Applications (NON_MS_SS). Customizing the mainstream family by using non-Microsoft applications captures the intuition of enhancing basic tasks in order to be less reliant on non-standard OS. We choose spreadsheets since the degree of standardization has traditionally been lower than for word processing applications (Breuhan 1998), and since competing spreadsheet programs have not yet adopted most of the leading program's characteristics (Groehn 2000).[20]

In summary, we expect the firm characteristics discussed above to have the following effects on our questions:

Table 3: Expected effects of independent variables.

	Non-stand.	Upgrading	Distance
Task Variety	+	?	+
Links (ext./int.)	+	-/+	-
Enhanced OS	-	-	+

It should be noted at this point that our variables are not perfect proxies for the concepts we seek to explore. For example, size may proxy for firm age and/or the size of the installed base of PCs running on a particular OS. Whenever appropriate therefore, we will discuss alternative interpretations.

[20]It should be noted that this variable is arguably most susceptible to endogeneity issues: Since OS and applications are used in conjunction, adoption decisions on either level may be made simultaneously – Microsoft applications and OS are often even preinstalled on PCs. However, the usage of non-Microsoft applications is likely to be determined by explicit consideration of the joint benefits of OS and application. Since firms typically switch application families less often than individual OS versions, we believe that this does not pose a major problem. We did however run our regressions without NON_MS_SS as regressor and found results to be unchanged.

5 Empirical Specifications

5.1 Intra-firm standardization on Microsoft OS

We consider two different specifications of intra-firm standardization. The first looks at the log of the "numbers equivalent", i.e. LOG(N_EQ).[21,22] The numbers equivalent is a convenient measure of standardization since it treats standardization as a continuous variable rather than a dichotomous decision. It is the inverse of the "OS Herfindahl Index" and therefore places higher weight on asymmetric structures with one dominant OS and some niche OS, which is what we observe in many firms in our sample. On the other hand, it is more refined than just the share of the mainstream Microsoft family, which does not take the structure of the niche OS into account. The degree of non-standardization is then characterized by

$$LOG\left(N\_EQ_i\right) = \beta_i' \mathbf{X}_i + \epsilon_i,$$

where β_i' are the parameters to be estimated, $\mathbf{X}_i$ is a vector of the firm observables discussed in the previous section and ϵ_i is a random error term. We also report results from a model in which the decision to use anything else but mainstream Microsoft products is modelled as a dichtotomous variable. This would be more realistic if the fixed costs of setting up an additional OS are high. We assume the existence of a latent variable p^* which guides the standardization decision such that

$$p^* = \beta_i' \mathbf{X}_i + \epsilon_i$$

and the following decision rule:

$$if \begin{cases} p^* < \widetilde{p}, & \text{then } NOT\_EXCL = 0 \\ \widetilde{p} < p^*, & \text{then } NOT\_EXCL = 1 \end{cases}$$

Where $NOT\_EXCL = 0$ is standardization and 1 is usage of any niche OS on at least one percent of PCs. We also experimented with other specifications, such as the total number of OS used in an ordered logit model,

[21] Definitions of our dependent variables are given in Table 7 in the Appendix.

[22] Note that we treat the mainstream Windows family, i.e. DOS, Windows 3.x and Windows 95, as a single Operating System. This is because our hypothesis on intra-firm standardization is essentially a static one, so that we are not asking which generation of the mainstream operating systems family is being used in the firm. This issue is then addressed in the second set of regressions, which deal with the issue of upgrading.

or creating a trichotomous variable indicating some, little, or intense use of niche OS and found qualitatively similar results.

5.2 Upgrading within the Microsoft family

Since we do not have information on the time of first use of Windows 95, we use the proportion of PCs running Windows 95 of all PCs running any mainstream Microsoft OS in 1998, i.e. $W95\_SHARE = \frac{WIN95}{DOS+WIN3+WIN95}$, as proxy for the extent and speed of upgrading.[23] Specifically, we use the following equation.

$$LOG\,(W95\_SHARE) = \beta_i' \mathbf{X}_i + \epsilon_i$$

By defining the dependent variable as the share of Windows 95 of all Microsoft-run PCs, we isolate the process of within-system upgrading. In addition, we run regressions on $LOG\,(1 - DOS\_SHARE)$. Since DOS is made obsolete by Windows technology, firms will replace it over time. Analogous to our first set of regressions, we also use a dichotomous dependent variable on Windows 95 usage:

$$u' = \beta_i' \mathbf{X}_i + \epsilon_i$$

This leads to the following decision rule:

$$if \begin{cases} u' < \widehat{u}, & \text{then } W95\_USE = 0 \\ \widehat{u} < u', & \text{then } W95\_USE = 1 \end{cases}$$

5.3 Determinants of niche OS usage

We use an ordered probit specification for the part of the analysis. The need for variety in niche OS is captured again by a latent variable.

$$d^* = \beta_i' \mathbf{X}_i + \epsilon_i.$$

Following Figure 3, we can say that if the need for variety is comparably low, additional tasks can be fulfilled adequately by Windows NT. If it is very high, a (combination of) non-Microsoft OS is required. In intermediate

[23] This seems a reasonable approximation since usage has been increasing since the introduction of Windows 95 (see Figure 1) and displacement by Windows 98 had not yet taken place (see footnote 11).

cases, a combination of Windows NT and other OS is optimal. This gives the following rule:

$$if \begin{cases} 0 \leq d^* < \widehat{d}, & \text{then } OS\_NICHE = 1 \\ \widehat{d} \leq d^* < \widehat{\widehat{d}} & \text{then } OS\_NICHE = 2 \\ \widehat{\widehat{d}} < d^* & \text{then } OS\_NICHE = 3, \end{cases}$$

where $OS\_NICHE = 1$ means using only Windows NT as niche OS, $OS\_NICHE = 2$ using NT and at least one other niche OS, and $OS\_NICHE = 3$ using exclusively non-Microsoft niche OS. We estimate the equation using an ordered probit specification. We obtain similar results if we use the share of WinNT of all PCs running on niche systems as dependent variable.

6 Results

6.1 Intra-Firm Standardization

Our results on firms' standardization decisions are reported in Table 4. We run the regression on the log of the numbers equivalent (LOG(N_EQ)) with three-digit industry dummies (1), the average industry share of LOG(N_EQ), AVE(LOG(N_EQ)), (1'), and the extent of upgrading (W95_SHARE) in the firm (1") to capture interaction effects between upgrading and standardization. We also restrict our sample to the non-standardized firms and include niche usage (OS_NICHE) and W95_SHARE (1"'). As a robustness test, we run a probit regression with industry dummies with non-standardization (NOT_EXCL) on the LHS (2).

Table 4: Determinants of the Standardization Decision.

Dependent Variable	LOG(N_EQ)				NOT_EXCL
Covariates	(1)	(1')	(1")	(1"')	(2)
SIZE	.001**	.010**	.010**	.000	.319**
IT_STAFF	.054**	.060**	.056**	.027	1.380**
SERVER	.029**	.031**	.027**	-.011	.902**
MULTISITE	.016**	.014**	.015**	-.013	.511**
NON_MS_SS	-.023**	-.023**	-.021**	-.043**	-.398**
AVE(LOG(N_EQ))		.109**			
W95_SHARE			.012**	.031*	.164
OS_NICHE				.001	
CONST	-.009	-.032**	-.015**	.288**	-3.685**
R^2	.103	.047	.104	.206	.131
Obs	4344	4323	4344	1071	4164

Notes: * denotes significance at the 5% level, ** denotes significance at the 1% level.
(1): Linear regression with Log of OS numbers equivalent as dependent variable, set of independent variables and industry dummies.
(1'): As (1), with average share of dependent variable instead of industry dummies.
(1"): As (1), with log of Windows 95 share of mainstream OS share as covariate.
(1"'): As (1), sample restricted to firms using any niche OS, with log of Windows 95 and OS niche as covariates.
(2): Probit regression with dichotomous variable indicating any niche usage as dependent variable, covariates as in (1).

Both proxies for task variety, SIZE and IT_STAFF, have positive and significant signs in regressions (1) - (1") and the probit regression in (2). They are not significant in the regression only for non-standardized firms. It seems therefore that task variety does have an impact on a firm's decision to standardize: Larger firms and firms with a large fraction of IT personnel on their payroll will be more likely to run additional OS on top of the mainstream Microsoft OS. Similarly, the coefficients on internal and external links are positive and significant in all but the restricted sample regressions, indicating that networking tasks are best fulfilled using a non-mainstream OS. Usage of non-Microsoft spreadsheet programs carries a negative and significant sign in all specifications, suggesting that firms improving on the performance of standard tasks will be more likely to remain within the mainstream Microsoft family. The industry average of standardization is positive and significant in (1"), suggesting that either there are industrywide network effects or that firms in the same industries have similar task structures. The speed of upgrading is positive and significant (at the 1% level in (2") and at the 5% level in (2"')) in the numbers equivalent regressions but not in the probit regression (2). This may be because the effect of upgrading to Windows 95 is stronger when firms are not standardized rather than affect the decision to fully standardize in the first place. This intuition would also be supported by the increase in magnitude of the coefficient between (1") and (1"'). Finally, we find that the type of niche products used and the corresponding "distance" from the mainstream Windows standard does not affect the degree of standardization (2"').

6.2 Upgrading Speed

We report the regression results on the speed of upgrading in Table 5. As our baseline regression, we take the log of the share of Windows 95 of all mainstream Microsoft PCs LOG(W95_SHARE) and again use three-digit industry dummies (3), the average industry share of LOG(W95_SHARE), AVE_W95, (3'), and the OS numbers equivalent of the firm (3") and again a restricted sample with LOG(N_EQ) and OS_NICHE on the RHS (3"'). As a further test of the robustness of our results concerning specification, we use a dummy indicating any Windows 95 usage (4) and the log of the share of Windows (version 3 and 95) of mainstream Microsoft PCs (5).

Table 5: Determinants of the Upgrading Decision.

Dep. Var.	LOG(W95_SHARE)				USE_W95	LOG(1-DOS)
Covariates	(3)	(3')	(3")	(3"')	(4)	(5)
SIZE	-.260**	-.194**	-.277**	-.076	-.091**	-.056*
IT_STAFF	-1.312**	-1.53**	-1.41**	-.493	-.446**	.036
SERVER	1.14**	1.07**	1.09**	.563**	.456**	.278**
MULTISITE	-.566**	.598**	.538**	.004	.290**	.192**
NON_MS_SS	-.954**	-.951**	-.914**	-.338**	-.350**	-.140*
AVE(W95_SHARE)		2.62**				
LOG(N_EQ)			1.76**	.156	.887**	-.080
OS_NICHE				-.806**		
CONST	-2.569**	-4.16**	-2.55**	.270	.542*	-.687**
R^2	.131	.070	.137	.270	.092	.102
Obs	4344	4344	4344	1071	4285	4344

Notes: * denotes significance at the 5% level, ** denotes significance at the 1% level.
(3): OLS regression with share of Windows 95 of all mainstream OS as dependent variable, set of independent variables and industry dummies.
(3'): As (3), with average share of dependent variable instead of industry dummies.
(3"): As (3), with log of OS numbers equivalent as covariate.
(3"'): As (3), sample restricted to firms using any niche OS, with log of numbers equivalent and OS niche usage as covariates.
(4): Probit regression with dichotomous variable indicating any use of Windows 95 as dependent variable, covariates as in (4).
(5): OLS regression with log of all mainstream Windows (Windows 3 + 95) as dependent variable, as (3) otherwise.

SIZE has a negative sign in all specifications and is significant in all but (3"'). IT_STAFF is negative whenever it is significant and is only positive in (5). This (weakly) supports the notion that firms with more varied tasks will upgrade less rapidly than "single-task" firms. SERVER is consistently positive and significant in all the specifications, indicating that internally linked firms are likely to upgrade quicker. The sign and significance of MULTISITE is not consistent however: It is negative and significant in regression (3), but positive in all others and significant in all but (3"'). It should also be noted that the magnitude of coefficients is consistently bigger for SERVER than for MULTISITE. It appears then that the effect of internal links is strong and robust, while we obtain mixed results for the effect of external links on upgrading speed. NON_MS_SS is negative in all specifications providing strong evidence that usage of non-Microsoft office applications has a negative effect on upgrading. The coefficient on industry average (AVE_W95) is positive and significant (3'), and the degree of standardization has a positive effect when significant (regressions (3") and (5)) as expected. OS_NICHE carries a negative and significant sign, implying that firms using more distant OS will upgrade less quickly.

6.3 Niche Usage

Our niche usage regressions are found in Table 6. As in our other regressions, we run several robustness checks: In addition to our set of independent variables, we include industry dummies (6), the percentage of firms using exclusively or some niche OS, AVE(ALL_NICHE) and AVE(SOME_NICHE) respectively, in regressions (6') and (6"), as well as the values of the other dependent variables, LOG(N_EQ) and LOG(W95_SHARE) in (6"').

Table 6: Niche usage Regressions.

Dependent Variable	OS_NICHE			
Covariates	(6)	(6')	(6")	(6"')
SIZE	.158*	.079	.069	.076
IT_STAFF	1.13*	.511*	.495*	.584*
SERVER	-.673**	-.328**	-.325**	-.317**
MULTISITE	-.537**	-.271**	-.275**	-.288**
NON_MS_SS	1.08**	.654**	.663**	.592**
AVE(ALL_NICHE)		3.70**		
AVE(SOME_NICHE)			2.58**	
LOG(N_EQ)				.147
LOG(W95_SHARE)				-.131**
R^2	.198	.060	.058	.231
Obs	1071	1071	1071	1071

Notes: * denotes significance at the 5% level, ** denotes significance at the 1% level.
(6): Ordered logit regression with niche OS usage as dependent variable, set of independent variables and industry dummies.
(6'): As (6), with industry share of firms using only non-Microsoft niche OS instead of industry dummies.
(6"): As (6'), with industry share of firms using some non-Microsoft niche OS instead of industry dummies.
(6"'): As (6), with log of numbers equivalent and log of Windows 95 share as covariates.

The coefficients on SIZE are consistently positive, but only significant at the 5% level in the baseline ordered logit regression (6). On the other hand, IT_STAFF, our alternative proxy for task variety, has a positive and significant coefficient in all specifications. Jointly, this lends support to the hypothesis that greater task variety will trigger the use of OS that are less compatible with the mainstream but that this effect is more likely to originate from increased IT intensity than from sheer size. Both SERVER and MULTISITE have highly significant negative coefficients. This supports the hypothesis that compatibility requirements and Windows NT's specialized capabilities dominate in such firms. NON_MS_SS carries a strongly significant positive sign: Firms using non-Microsoft applications are likely to use more distant niche OS. There are strong and significant industry effects (6') and (6"), and the cross-effect of upgrading on niche usage is significant and negative (6"'). That is, firms that are using more of Windows 95 are less likely to use niche OS. OS_N_EQ on the other hand is not significant in (6"').

7 Discussion

Our regressions show that task variety, internal and external linkages and their efforts to improve standard tasks have a significant impact on OS choice. We consistently find strong industry effects, which seems intuitive for a product with strong network effects and task similarity within the same industry. There are also strong interaction effects among the decisions to standardize on mainstream products, to upgrade within the mainstream family, and to use more or less compatible niche OS. Our results seem rather robust with respect to included and excluded variables and functional form.

Task variety

A firm with more varied tasks will be **less standardized**, **upgrade less quickly**, and (conditional on niche usage) use **more distant niche OS**. Firms therefore will fulfill their more heterogeneous needs by running non-Microsoft OS on part of their PCs. That is, firms will distance themselves from the mainstream simply because their needs require additional functions to be handled by the OS. Upgrading to the latest version of Windows presents no profitable alternative to these firms, so that they resort to non-Microsoft products. Firm size, however, could also be a proxy for firm age rather than

task variety, in which case we would expect slower upgrading and possibly a strong legacy effect of older OS. Assuming that non-Microsoft OS have experienced a decrease in their market share,[24] we would therefore expect older (and therefore larger) firms to be less standardized on Microsoft OS. Table 9 compares the main independent variables split by dominance of Microsoft. From the mean values on L_SIZE we can see that this does not seem to be the case.

Links (ext./int.)

Internal linkages (SERVER) leads to **less standardization**, but **faster upgrading** and use of **Windows NT** as niche OS. That is, firms running a server will place a high premium on running compatible OS on most of their PCs, which favours simultaneous use Windows 95 and its close relative, Windows NT. Firms that are part of a network of firms will be **less standardized** as well and use **Windows NT** as a niche OS, while the results on upgrading speed are inconclusive. In summary, it appears firm that linkages will lead to additional task requirements that can be met mostly by using Windows NT.

Enhanced OS Performance

Firms using non-MS office applications will **standardize more**, **upgrade more slowly**, and use **more distant** niche OS (if any). Our conjecture that such firms derive more utility from the basic OS family is confirmed, as is the expected effect that firms would rather use distant niche OS because there is less need to maintain compatibility with the mainstream OS within the firm. Further, when using non-Microsoft applications, firms have less incentive to use the latest version of the mainstream OS since upward compatibility is likely to be lower compared to Microsoft's own office applications. Could the use of non-Microsoft applications also be an indicator of general dissatisfaction with Microsoft products? Possibly, the use of non-Microsoft products suggests a desire for standardization, just not necessarily on Microsoft. Following this interpretation, we would expect that non-Microsoft application users use less Microsoft OS as well. Table 9 however shows that firms using predominantly non-Microsoft applications are not more likely to standardize on another OS. In fact, the table suggests the opposite since the use of non-Microsoft spreadsheets is higher for heavy Microsoft users.

[24] This is certainly true for Apple/Mac and OS/2, both of which have lost market share in the years prior to 1998.

Interactive Effects

All variables (except MULTISITE in regression (3)) have opposite coefficients for upgrading speed and distance of niche usage. This strongly supports the hypothesis that upgrading and non-Microsoft usage are substitutes, since a variable that implies quicker upgrading will at the same time imply less distant niche OS. This is also confirmed by the cross-effect of LOG(W95_SHARE) and OS_NICHE: Both are significant and negative, even though they refer to separate decisions, namely to upgrade within the currently dominating OS and which niche OS to choose.

What can be learned from this study? First of all, many firms choose to use a non-Microsoft OS to fulfil at least some of the tasks in their firm. It seems then that intra-firm network effects are not overwhelmingly strong or that at least some tasks are not affected as strongly by them as "standard" tasks. Thus, if operating systems are an experience good, it is likely that a better product may be successful after all: There appears to be no huge threshold for niche OS to be used on at least some PCs or for some tasks within the firm.[25] Second, our study provides some evidence that Microsoft has cemented their dominant position in the market by introducing Windows 95 and Windows NT jointly, with a strong emphasis on compatibility between the two. Internally and externally linked firms are likely to use both jointly, making it more difficult for niche OS to break in. It is remarkable however that large firms and IT-intensive firms are less likely to standardize on the Microsoft family: These are precisely the firms that seem attractive to OS vendors. In the more recent past, this trend of niche OS gaining ground in large organizations seems to have been confirmed by the emergence of Linux, which has won several high-profile accounts from Microsoft (including the Air Force, the US Postal Service and various government offices in Germany, France and China, to name a few). Interestingly, and perhaps counterintuitively, the use of non-Microsoft applications seems to strengthen Microsoft's dominance in the mainstream OS market. This may be the result of a "mix-and-match" process in which users pick complementary products according to their preferences and utility from the baseline product is higher as a consequence (Matutes and Regibeau, 1988). Whether this effect is stable

[25] This is similar to the intuition in Christensen (1997), who illustrates how firms may fail to maintain their lead in the market as technological progress forces them to upgrade their current technology, which in turn may cause current users to switch to another, disruptive (and initially even lower-quality) technology.

in the long run however has to be questioned given my results on upgrading speed and the distance of niche usage, where firm usage of non-Microsoft applications works to Microsoft's detriment.

Clearly, this study has some limitations. First, the PC OS market is a very particular one with unique charcteristics such as a stable near-monopoly market structure and close links with complementary products. The applicability of our results to other industries and industries may therefore be limited. Second, our assumptions about the benefit function and the horizontal locations of the three groups of OS is a crude approximation of what is clearly a multidimensional product and will often be purchased in conjunction with new hardware, a decision we do not take into account due to data limitations. A more refined modelling of the OS choice process à la Hendel (1999) may yield more information about the precise nature of firm's preferences for variety and compatibility, but to arrive at robust conclusions with just a single cross-section may be a difficult task. Finally, we may have omitted variables that significantly shape firm decisions, such as financial data, or the use of other related technologies. Financial data however was not available for a large proportion of our firms. Information on the use of other related technologies is present in the data, but in a cross-section, questions of endogeneity have to be taken seriously, which is why we chose not to use variables that would suffer from this problem.

Despite the limitations given above, this study has implications both in terms of the PC operating systems industry in particular and niche products in network markets in general. We find that even though aggregate market share has been almost constant for the last few years, firms are quite heterogeneous in their choice of operating systems. We can also see that in order to fulfill certain tasks that go beyond the standard OS, compatibility with the dominant system seems to play an important role in the choice of system. A more general dispersion of tasks however, gives incompatible (or less compatible) systems an opportunity to gather a critical mass of users (and tasks) within a firm to present a profitable solution. There seems to be a polarization of solutions for firms that customize their mainstream system: On the one hand, they are more likely to standardize, but if they do not, they are more likely to choose an incompatible OS as their niche OS. On a more general level, our results suggest that network effects can lead to persistence of a dominant standard, but that demand heterogeneity allows for "islands" of a competing technology. This result resonates with the literature on localized network effects, where similar agents standardize on a

single technology, but different populations may well choose different technologies best suited to their particular needs.[26] Our finding that upgrading and niche usage are substitutes has important implications for prospective challengers of an industry standard. As a new generation of the dominant standard is introduced, the standard seems most susceptible to losing existing users to a competing technology - a result confirmed by Breuhan (1998) for the word-processing and spreadsheet markets. As there will almost always be a (temporary) loss in compatibility across generations, the network effect favouring the dominant standard will be weakened and competitors stand a better chance of making inroads into the market. On a static level therefore we confirm Farrell and Saloner's (1986b) result that if consumers are sufficiently heterogeneous, niche products can be sustained in the market, while on a dynamic level, generational upgrades cause a temporary loss in the stronghold of the dominant standard on the industry. While this work clearly calls for additional studies in other network industries and over a longer time horizon, as a first look at the question of standardization and upgrading we hope that this study presents a number of interesting results and opens avenues for future research on almost (but not quite) standardized markets.

[26] E.g., see Cowan and Miller (1998) and Jonard and Yildizoglu (1998).

A OS Characteristics

	DOS	Win3	Win95	WinNT	OS/2	MAC	UNIX
# bit	16	16	32	32	16/32	8-32	16/32
Flexibility/ Portability	no	no	no	yes	yes	no	yes
User friendliness	mid	high	high	high	low	high	low
Network Capabilities	no	no	some	yes	some	some	yes
End-user Applications	high	high	high	some	low	some	low
Perceived Strengths	low sys. require-ments	GUI, soft-ware	GUI, soft-ware	Network OS w/ GUI	Expert OS	intuitive	Expert OS

Figure 4: OS characteristics.

B Data

Our dataset is a 1998 cross-section of 4729 UK sites (i.e. organizationally distinct entities, e.g. production facilities) gathered by ZD Market Intelligence, now Harte-Hanks Market Intelligence. The data was generously provided by Luke Spikes and Matthew Shannon. The information is gathered by the firm through telephone interviews. The full dataset consists of a collection of over 10.000 UK-based sites that gave information about their internal IT landscape and a number of firm descriptives such as size, SIC group, and others. Among the data provided on the IT landscape were PC and server Operating Systems used, end-user software, IT personnel, in-house programming practices etc.. Sites were eliminated from the sample if they did not report 100% of the operating systems used on site, i.e., if the sum of individual shares reported for all OS did not add up to 100%. They were also eliminated if they were the only site operating within their three-digit industry. We confine our

analysis to sites using (a combination of) DOS, Windows 3, and Windows 95 on more than half of their PCs, which leaves 4602 observations.

To judge whether the surveyed sites are representative of the general population of UK sites, we have to look at the method by which they are selected: Firstly, Harte-Hanks Market Intelligence approach firms independently and interview their senior IT managers, and secondly, they are provided with a list of firms by their clients that they would like interviewed. Focusing on senior IT staff ensures that whoever makes the decision to purchase an OS is interviewed. According to Luke Spikes, former CEO of the company, the surveyed firms from the clients' list have in the past done business with their clients, which generates a bias towards firms that have previously shown a propensity to purchase IT-related products. Also, the sample contains a disproportionately high number of public sector organizations (e.g. local councils or government agencies). Omitting these entities from our analysis does not change our qualitative results. We also have to ask whether our subsample generates a bias vis-à-vis our full sample. We find that sites not reporting 100% of their OS usage are not significantly different in terms of size and their approximate number of PCs, but they report significantly less use of information technologies. This may either represent a lower willingness to answer detailed IT-related questions or a lower dispersion of information technologies in the firm. Given that the number of PCs reported is approximately similar, we expect the first factor (lower willingness to report) to play a more important role than the second (lower usage).

For the firms in our final sample, Table 7 defines and describes the variables used in our estimations. The descriptive statistics for the variables are in Table 8 and a correlation matrix in Table 9.

Table 7: Variables used.

Variable Name	Definition
Dependent Variable	
OS_N_EQ	$\frac{1}{HHI}$, where $HHI = \sum s_i^2$, the square of shares of all active OS.
LOG(N_EQ)	log of OS_N_EQ.
NOT_EXCL	1 if firm not using a combination of DOS, Win 3 and Win 95.
W95_SHARE	$\frac{WIN95}{DOS+WIN3+WIN95}$, i.e. share of Win95 PCs of mainstream PCs.
L_W95SHR	log of W95_SHARE
USE_W95	1 if firm runs Windows 95 at all.
1-DOS_SHARE	$1 - \frac{DOS}{DOS+WIN3+WIN95}$
L_1_DSHR	log of 1-DOS_SHARE
OS_NICHE	1 if all non-mainstream PCs run on Windows NT, 2 if some but not all of them do, 3 if none of them do.
Task Diversity	
FT_SIZE	Number of full-time employees in the firm.
L_SIZE	log of FT_SIZE.
IT_INT	Share of full-time IT personnel of all full-time employees.
Links (ext./int.)	
MULTISITE	One if firm is connected to other offices or sites.
SERVER	One if firm runs a server.
Enhanced OS Performance	
NONMS_SS	One if firm uses only non-Microsoft spreadsheet applications.
Industry Effects	
N_AVE_LNEQ	Net average log(N_EQ) in the firm's 3-digit industry.[d]
N_AVE_W95	Net average percentage of upgraded mainstream PCs.
N_AVE_ALN	Net average percentage of firms using only non-MS niche OS. (OS_NICHE=3)
N_AVE_SMN	Net average percentage of firms using some non-MS niche OS. (OS_NICHE=2 or 3)

Table 8: Descriptive statistics.

Variable Name	Mean	SD	Min	Max	Obs
Dependent Variable					
OS_N_EQ	1.103	.251	1	4.587	4729
LOG(N_EQ)	.791	.178	0	1.523	4729
NOT_EXCL	.308	.462	0	1	4729
W95_SHARE	.265	.374	0	1	4602
L_W95SHR	-3.927	2.990	-6.908	0	4602
USE_W95	.509	.500	0	1	4729
1-DOS_SHARE	.889	.251	0	1	4602
L_1_DSHR	-.397	1.544	-9.210	0	4602
OS_NICHE	1.444	.792	1	3	1071
Task Diversity					
FT_SIZE	353.43	579.44	2	13000	4729
L_SIZE	5.21	1.19	.693	9.472	4729
IT_INT	.075	.145	0	1	4729
Links (ext./int.)					
MULTISITE	.426	.495	0	1	4729
SERVER	.629	.483	0	1	4729
Enhanced OS Performance					
NONMS_SS	.228	.420	0	1	4729
Industry Effects					
N_AVE_LNEQ	.096	.052	0	.810	4705
N_AVE_W95	.247	.084	0	.708	4602
N_AVE_ALN	.065	.058	0	.5	1071
N_AVE_SMN	.093	.078	0	.5	1071

	LOG(N_EQ)	NOT_EXCL	L_W95SHR	USE_W95	L_1_DSHR	OS_NICHE	L_SIZE	IT_INT	MULTISITE	SERVER	NONMS_SS
LOG(N_EQ)	1										
NOT_EXCL	.667	1									
L_W95SHR	.088	.118	1								
USE_W95	.077	.090	.951	1							
L_1_DSHR	.017	.032	.217	.218	1						
OS_NICHE	.056	.835	.031	.005	-.024	1					
L_SIZE	.101	.163	-.020	.009	.099	.149	1				
IT_INT	.061	.105	-.037	-.015	.012	.101	-.185	1			
MULTISITE	.093	.164	.109	.123	.105	.114	.177	.140	1		
SERVER	.162	.233	.166	.145	.116	.163	.214	.103	.164	1	
NONMS_SS	-.071	-.080	-.152	-.127	-.064	.008	.046	-.033	-.054	-.037	1

Figure 5: Correlation Matrix.

Table 9: Descriptive statistics by Microsoft dominance.

	Dominance of Microsoft products	
	no	yes
L_SIZE	5.304	5.197
IT_INT	.081	.074
MULTI	.494	.420
SERVER	.790	.615
NONMS_SS	.195	.231

Note: Dominance is defined as more than half of PCs within the firm using Microsoft DOS, WIN3, or WIN95. The number of OS used consists of all OS with usage >0% (MS DOS, WIN3 and WIN95 are treated as a single OS).

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