Ain't it "Suite"? Bundling in the PC Office Software Market

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Abstract

Our paper examines the importance of office suites for the evolution of the PC office software market in the 1990s. We develop a discrete choice model of product differentiation that enables us to estimate correlation in consumer preferences across spreadsheets and word processors. Estimation confirms strong positive correlation of consumer values for spreadsheets and word processor products, a bonus value for suites, and an advantage for Microsoft products. We use the estimated demand model to simulate various 'hypothetical' market structures in order to shed light on the welfare and competitive effects of bundling in the office productivity software market.

We examine the competitive effects of bundling in a simulated market setting of partial competition, in which Lotus sells only a spreadsheet and WordPerfect sells only a word processor, while Microsoft sells both components as well as a suite. Assuming the rivals remain active in the market, when the correlation is positive, the introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance. This is mainly because the suite bonus 'value' is much larger than the difference between the suite price and the sum of Microsoft's component prices when Microsoft does not offer a suite. When there is strong positive correlation (as we find), there are many such consumers who purchase both components separately when suites are not available. All of these consumers 'switch' to the suite when it is introduced, and reap significant benefits. The simulations show that the introduction of Microsoft's Office suite also expands the distribution of spreadsheets and word processors, and this is beneficial to consumers as well.

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1. Introduction

When is it profitable to bundle different products in a package rather than just sell them separately? When does product bundling discourage or accommodate competition from rival firms? Does product bundling raise or lower consumer welfare? These and related questions gained much attention in the theoretical industrial organization literature on product bundling, and to a lesser extent in the subsequent empirical literature. We reconsider such questions with an empirical model of the evolution of the office productivity software market in the 1990s.

The most important office productivity software products in the 1990s were spreadsheets, word processors, and office suites—which combined a spreadsheet and a word processor with other value-added features and programs. The office productivity software market experienced dramatic structural change during the 1990's. The market grew tremendously from 1991-1998, the period for which we have consistent data. In addition, the market saw a shift from DOS based software programs to WINDOWS based software programs, and a shift in market leadership from Lotus (in the spreadsheet market) and Wordperfect (in the word processor market) to Microsoft. Finally, there was a shift in strategy led by Microsoft from selling separate products to selling office suites.

We study the importance of office suites for the evolution of market structure and the performance of the PC office software market, focusing on how the correlation of consumer preferences for spreadsheets and word processors mattered for the profitability and the competitive effects of suites. To examine these issues, we estimate a parsimonious model of consumer demand for spreadsheets, word processors, and suites. The model allows correlated common components of consumer tastes for spreadsheets and for word processors, plus an independent idiosyncratic component for each product in each category. The model assumes consumer tastes for suites incorporate the common taste components of spreadsheets and word processors, and a separate independent idiosyncratic component. Perfect positive correlation of the common components indicates a general taste component for office productivity products, while the idiosyncratic component limits the overall degree of correlation between products. The model also allows suites to add a bonus value to mean consumer utility

(reflecting value-added features and/or better integration of the components of the suite), and for Microsoft products to have an advantage over the other vendors (possibly reflecting smoother operation with Windows.)

Estimation of our demand model reveals a strong positive correlation in consumer preferences over word processors and spreadsheets,[2] a moderate bonus value for suites on top of the value of the constituent spreadsheet and word processor products, and significant advantages for Microsoft products. We use the estimated demand model to simulate various 'hypothetical' market structures in order to shed light on the welfare and competitive effects of bundling in the office productivity software market.

We first examine the competitive effects of bundling in a simulated market setting of partial competition, in which Lotus sells only a spreadsheet and WordPerfect sells only a word processor, while Microsoft sells both components as well as a suite. Simulations show that Microsoft's mixed bundling strategy had significant competitive effects. The introduction of Microsoft Office shifts market share away from Lotus and WordPerfect and intensifies price competition.

Assuming the rivals remain active in the market, when the correlation is positive, the introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance. This is because, in large part, the suite bonus 'value' is much larger than the difference between the suite price and the sum of Microsoft's component prices when Microsoft does not offer a suite. When there is strong positive correlation (as we find), there are many such consumers who purchase both components separately when suites are not available. All of these consumers 'switch' to the suite when it is introduced, and reap significant added value. Further, there is an increase in unit sales of spreadsheets and word processors (via the suite) when the suite is introduced, and this also increases consumer surplus. This result is robust to variations in the estimated model.

[2] Nalebuff (2004) argues that positive correlation is natural due to an income effect, i.e. higher income consumers that greater value for both spreadsheets and word-processors. Additionally, positive correlation might be due to an education effect.

Simulations also show that competing firms may be better off when a dominant firm sells components and a bundle rather than just selling a bundle. The intuition is the following: suppose a consumer likes Microsoft Word, but also likes the Lotus spreadsheet. If Microsoft sells components, then the consumer can mix and match, but if Microsoft sells only suites, the consumer cannot purchase the mix and match combination. Hence, when Microsoft sells only bundles, this reduces the demand and profitability of those firms only selling components.[3] Of course, there is the (well known) opposing effect: the Lotus spreadsheet faces less head-to-head competition when Microsoft sells only bundles, and consumers who would prefer Microsoft Excel purchase from Lotus instead. The first effect dominates when the correlation in consumer preferences is positive and large.

We then examine the effect of correlation in consumers' preferences on profitability in the case of suite competition. We first compare the simulated setting in which Microsoft is a monopoly in the market for suites with the alternative setting in which Microsoft faces competition from other suites. Our simulations show that the other suites do not provide any more competition to the Microsoft suite than that provided by individual components. This is because the other suites (the WordPerfect/Corel suite and the Lotus/IBM suites) each had one component with high quality and one component with relatively low quality.[4]

Our simulations also suggest that a merger between WordPerfect and Lotus, the dominant firms in the word processing and spreadsheet markets in the DOS era, might have been welfare enhancing. To examine this issue, we use the estimated parameters to predict oligopoly conduct for a hypothetical merger between WordPerfect and Lotus. When we compare the setting in which the Microsoft suite competes with merged (Lotus/WordPerfect) suite with the setting in which all three suites compete, we find that sales weighted prices are slightly lower in the 'three suite' world, but total sales are about 50% higher in the 'two suite' world. Additionally, the sales weighted quality of the products sold in market is much higher. Welfare calculations indeed show that consumer surplus is higher in the case in which WordPerfect and Lotus merge, even though the number of firms is reduced from three to two.

[3] Nalebuff (2004) makes a similar point.
[4] In the case of WordPerfect/Corel, the word processor was the high-quality component while in the case of Lotus/IBM, the spreadsheet was the high-quality component.

In these simulations, we also empirically examine the importance of two Microsoft advantages: (I) a higher observed quality of components;[5] and (II) higher unobserved quality. The second category includes potentially all of the following: a better reputation, better service, better additional components in the suite, better integration with Windows, better integration of components, and higher unobserved quality of components. We find that the first effect (higher observed quality of components) played only a very small role in determining Microsoft's advantage.[6] This result is also robust to variations in the estimated model.

Our simulations also examine how less correlation in consumer tastes for spreadsheets and word processors would affect the profitability of selling suites. Holding constant the other estimated model coefficients, less correlation has a negative effect on the profitability of a Microsoft's bundling strategy. This property holds regardless of whether Microsoft is assumed to be a monopolist or competing with rival firms in the spreadsheet and word processor markets.

Our conclusion that greater correlation enhances the profitability of bundling might seem counterintuitive, especially in the monopoly case, because it is well understood from the literature that bundling may be a particularly effective price discrimination strategy under negative correlation, and that bundling does not improve on separate selling under perfect positive correlation. However, since the industry serves only a fairly small portion of the *potential* market,[7] the increased variance of preferences for the suites that results from greater correlation increases the demand for suites, illustrating what Johnson and Myatt (2006) call an "expanding niche market."[8] In the case of pure bundling, the niche-market effect alone is sufficient to overturn the standard intuition and insure that profits increase in correlation. In

[5] By 1995, Microsoft's component products were rated higher than the high-quality components of the competing products.

[6] Liebowitz and Margolis (1999) previously studied the evolution of word processor and spreadsheet markets. They argue based on product reviews that Microsoft's dominance of the word processor and spreadsheet markets is due to the superior quality of Microsoft's component products. Our simulations suggest that the superior observed quality of Microsoft's component products was not that important for Microsoft's success in the suite market.

[7] We define the potential market to be the number of operating systems sold or distributed via OEMs.

[8] In the monopoly pure bundling case, Microsoft serves 20% of the potential market. Although we use the term 'expanding niche market' to be consistent with JM (2006), simulations in Appendix E show that this effect holds even when pure bundling serves 40 percent of potential consumers.

the case of mixed bundling, the suite bonus value contributes directly to the profitability of suites even with perfect positive correlation. The market expansion effect of greater correlation magnifies this contribution.[9] Thus, the standard intuition is overturned in the case of mixed bundling because of the interaction of the suite bonus with the market expansion effect.

The paper proceeds as follows. In section 2, we review the literature on bundling in oligopolies and discuss the difficulty of theoretically modeling oligopoly competition when firms sell both bundles and component products (mixed bundling). In this section, we also discuss the few empirical papers that estimate models of bundling in oligopoly settings. Section 3 discusses the evolution of the PC office software market. Section 4 discusses the data we employ in our empirical analysis. In section 5, we develop the parametric model we use to estimate the demand side of the market and we discuss the estimation algorithm and our identification strategy. Section 6 presents the empirical results, while section 7 uses the estimated parameters to predict oligopoly conduct for counterfactuals. Section 8 briefly concludes.

2. Bundling in Oligopoly Settings

2.1 Incentives to Bundle – Theoretical Literature

The profitability of bundling by a multiproduct monopolist has received a lot of attention in the theoretical industrial organization literature. Stigler (1963) used a simple example to show that pure bundling could be profitable even without demand complementarity or scope economies. In a setting in which consumer values for two goods have a symmetric bivariate normal distribution, Schmalensee (1984) found conditions in which pure bundling dominates separate selling for any degree of correlation short of perfect positive correlation. Fang and Norman (2006) provide more general conditions for the independence case such that pure bundling is more profitable than separate selling. The intuition is that bundling reduces the dispersion of the reservation values (i.e., makes consumers homogenous) and hence enables greater extraction of surplus.

[9] The market expansion effect of greater correlation has not been emphasized in the bundling literature although it is implicit in Schmalensee (1984); in particular, see Case III in Figure 2.

Turning to mixed bundling, Adams and Yellen (1976) showed mostly with examples that mixed bundling could also be a profitable way to price discriminate, i.e., segment markets, and dominated pure bundling except in special cases. Working with an arbitrary bivariate distribution having a continuous density function, Long (1984) extended Schmalensee (1984)'s result for the bivariate normal case that mixed bundling is strictly more profitable than separate selling when consumer values are negatively dependent or independent. McAfee, McMillan, and Whinston (1989) relaxed the assumption of a continuous density function and provided a general sufficient condition for the profitability of mixed bundling that applied to a broader range of cases than just independence. Using a general copula approach to modeling joint distributions,[10] which allows varying dependence of random variables while holding their marginal distributions constant, Riordan and Chen (forthcoming, 2012) reformulated the McAfee, McMillan and Whinston (1989) sufficient condition with weaker technical conditions to show that mixed bundling is more profitable than separate selling if values for the two products are negatively dependent, independent, and positively dependent to a bounded degree.

The theoretical literature does not say very much about whether more or less correlation of consumer preferences increases or decreases the profitability of bundling. The intuition that bundling reduces consumer heterogeneity, and examples in Stigler (1964) and Adams and Yellen (1976) illustrating this starkly for perfect negative dependence, suggests that the profitability of bundling decreases with correlation. Using a copula that mixes independence and perfect negative dependence, Chen and Riordan (forthcoming, 2012) provide a counterexample in which the profitability of bundling decreases with correlation in the neighborhood of perfect negative correlation. The counterexample seems extreme because it requires at the limiting case of perfect negative correlation that no consumer is willing to pay the cost of the bundle. Furthermore, Chen and Riordan (forthcoming, 2012) provide a different example using the FGM copula and uniform marginal distributions in which profits from bundling decrease with correlation over the limited range of dependence allowed by the FGM copula. These examples suggest the intuition that greater negative correlation increases profits by decreasing heterogeneity may hold except in extreme cases.

[10] For an introduction to copulas, see Trivedi and Zimmer (2005.)

The theoretical industrial organization literature also has studied bundling in partial oligopoly settings in which a monopolist in one market faces a competitor (or potential competitor) in a second market. The results on the competitive effects of bundling are mixed depending on details on market structure. On the one hand, by tying the sale of the monopoly good to the purchase of the competitive good, the monopolist sometimes can exclude the competitor either by creating more intense price competition (Whinston 1990) or by reducing the competitor's market share (Nalebuff 2004). On the other hand, bundling can accommodate the competitor by vertically differentiating products and thereby relaxing price competition (Carbajo, deMeza and Seidman 1990; Chen 1997) due to vertical differentiation.[11] Thus the competitive effects of bundling seem to be an empirical question.

It is a challenge to model correlation of preferences in oligopoly settings, because in general the number of correlation coefficients to keep track of rises quickly with the number of different products. Some kind of simplifying assumption seems necessary to draw meaningful conclusions.[12] Nalebuff (2004), for example, modeled correlation of product categories as a mixture between perfect dependence and independence, while assuming that preferences for products in the same category are perfect substitutes (i.e. perfectly correlated). Our approach is to model correlation across product categories with a bivariate normal distribution, similar to Schmalensee (1984) for the monopoly case, and to add an independent taste component for each individual product, similar to multinomial logit models. Therefore, we only need to keep track of one correlation coefficient for the two product categories in order to interpret our results.

The theoretical industrial organization literature includes some discussion of product complementarity in bundling models. Lewbel (1985) extended the Adams and Yellen (1979) model and showed with a crude example that separate selling could be profit maximizing even

[11] Choi (2004) and Choi and Stefanidis (2001) examine the effects of tying on investment incentives. Anderson and Leruth (1993) show that firms might commit not to offer bundles in order to avoid unprofitably competing on many fronts. There is also a related literature on oligopoly bundling of system components (Matutes and Regibeau 1988; DeNicolo 2000), focusing on whether firms will sell compatible bundles so consumers can "mix-and-match" or whether they will choose incompatibility so that consumers will need to buy all components from a single firm. Armstrong (2010) allows products in the bundle to be substitutes.

[12] Chen and Riordan (2012) however are able to prove the profitability of bundling over separate selling in a fairly general setting.

with product complementarity. Nalebuff (2004) argues that product complementary is a greater barrier to a single product entrant. Our model accommodates product complementarity by allowing for a bonus value for suites that could arise either from product complementarity or from value added features of the suite, and is consistent with the idea that complementarity requires some kind of integration of the component products.

2.2 Empirical Literature on Bundling in Oligopoly Settings

The empirical literature on bundling is much smaller than the theoretical literature. Bundling is quite prevalent in information technology and media markets, i.e., video to the home services. Crawford (2008) empirically examines the importance of bundling in the cable television industry. He shows that the demand for network bundles is more elastic when there are more networks in the bundle. Our approach differs from his in the sense that we allow for, model, and estimate the correlation in unobserved consumer preferences over products, as well as the standard deviations over these preferences.

In an additional paper on cable television, Crawford & Yurukoglu (2012) examine how bundling affects welfare. They estimate a model of viewership, demand, pricing, and input market bargaining. Channels are virtually always sold in large bundles; hence they do not have enough data to estimate individual channel demand. But by combining bundle data (prices and quantities) and individual channel viewing data (without prices), they are able to simulate the market with la carte pricing (i.e., no bundles) – and compute consumer benefits from individual sales. Their simulations also take account of the fact that input costs rise when channels are sold individually. Our model is quite different and we do have data both on individual sales, as well sales of bundles. Further, we focus on other issues.[13]

Gentzkow (2007) examines the online newspaper industry. Like us, he also examines both correlations over preferences and complementarity among products. However, he addresses very different issues and uses a very different identification strategy than the one we employ.

[13] Using numerical analysis, Chu, Leslie, and Sorensen (2011), show that when firms sell many products, simple pricing strategies (i.e., setting prices that depend only on the size of bundle purchased) are close to the profits obtained under mixed bundling.

His identification strategy is based on the exclusion of variables from the utility of some of the products and on employing panel data.

3. Evolution of PC Office Software Market, 1991-1998

At the start of the 1990's, the PC office software market was already well established with a clearly delineated structure. Wordperfect led in the word processor category (Figure 1), Lotus in the spreadsheet category (Figure 2) and presentation graphics, and Borland in database management. These software applications were distinct and sold separately, and overwhelmingly were based on the DOS operating system. The total market for PC office software was approximately $2.6 billion in 1991: Office software revenue in the DOS market was $1.6 Billion, while revenue for Windows office software was $1 Billion.

The release of WINDOWS 3.0 in 1990, and subsequent improvements, changed all of this. By 1998, Microsoft dominated the PC office software market. The previously distinct applications were bundled in office suites, and overwhelmingly based on the WINDOWS platform. The size of the market had grown to more than $6 billion in 1998. See Figure 3.

1990-1992 was a period of new product introduction and improvement, as competitors adapted to the new WINDOWS platform. Microsoft was first out of the gate with WINDOWS based applications. Microsoft Excel was the first spreadsheet for WINDOWS and Microsoft Office (1990) was the first office suite for WINDOWS.[14] Competitors followed, but generally experienced more difficulty ironing out the bugs. Reviews generally agreed that the Microsoft products were superior. Nevertheless, the data clearly show that the switch in platforms from DOS to WINDOWS did not eliminate rivals in the spreadsheet and word processing markets.

Lotus' acquisition of AmiPro in 1991 enabled it to field a WINDOWS based suite in late 1992. Suites contributed little to industry revenue during this period. The early office suites contained non-integrated word-processors, spreadsheets, database, and graphics programs. Competitors introduced WINDOWS based products later, and generally experienced more difficulties ironing out the bugs.

[14] Samna's Ami (later renamed Ami Pro) was the first word processor for WINDOWS.

Office suites gathered importance in 1993-94. This was a period of continuous product improvement as office software vendors adapted to an improved version of WINDOWS released in 1992. The new generation of suites were better, but still lacked significant integration. Microsoft was best positioned in the office suite category because it already had highly-rated versions of key underlying components.

Microsoft's new office suite, released in early 1994, was extremely well received by computer software trade journals.[15] Microsoft Office 4.2 (including Word 6.0, Excel 5.0 and Powerpoint 4.0) was better integrated than the previous generations of suites and went beyond the standard embedding at the time. Word 6.0 offered a feature where a user could insert an Excel toolbar icon into a document, and then graphically size and place an Excel 5.0 spreadsheet object.[16] PowerPoint 4.0 included a "ReportIt" feature that took a Presentation and converted it to a Word outline. Microsoft Office 4.2 also included an updated version of Microsoft Office Manager (MOM), a tool that integrated Office applications more tightly.[17]

A major reorganization of industry assets followed, as Novell acquired WordPerfect and Borland's QuattroPro in order to field a competitive suite in late 1994.[18] By the end of 1994, WINDOWS dwarfed DOS as a platform for office applications (Figure 4), suites had emerged as the most important product category (Figure 5), and Microsoft had the dominant product in this category (Figure 6).

[15] MS Office was awarded the highest overall score by PC/Computing magazine in its February 1994 issue comparing office suites. In the head-to-head comparison, Office outscored all other office suites in each of the five categories, including integration, usability, individual applications, customization and "the basics." Office also swept all the categories in CIO magazine's Readers Choice Awards for Office suites.

[16] Andrews, Dave "It's a Family Affair," BYTE Magazine, 01 November 1993: Vol. 8, No. 12.

[17] Nevertheless, Office 4.2 did not offer full integration. Only Excel 5.0 could both control and be controlled by other applications through Visual Basics Applications Edition. Word 6.0 could control another application through VBA—but it could only expose its own WordBasic objects so that Excel could use it. PowerPoint 4.0 was not able to control or be controlled by other applications through VBA.

[18] The reviewers still weren't persuaded, and Novell eventually exited the industry, selling its office software assets to Corel in 1996.

In the summer of 1995 Microsoft released WINDOWS95 and Office 95 simultaneously.[19] Competitors didn't immediately manage to come out with new versions of their own products that took advantage of WINDOWS95. The market for DOS applications all but vanished, and Microsoft's revenue share of the fast growing WINDOWS based office software market surged upward.

In 1996, the competition struck back. Corel's Wordperfect Suite and Lotus' SmartSuite were well-received and achieved modest market shares (Figure 6). This success led to increased price competition (see Figure 7), as Microsoft significantly reduced the price of its suite. This caused revenue growth to slow for the first time. Microsoft Office remained the most highly rated office suite among the three, and by the end of 1998 was dominant in the market.

Word Processors and Spreadsheets are by far the most important two components of the PC office software packages — Figure 5 shows that these categories were much larger than the Presentation and Database Management Categories in the 1990s. Indeed, during the 1991-1998 period, word processors, spreadsheets and suites accounted for more than 90% of PC Office software revenue. Hence, we focus on these three products in the empirical analysis.

There were essentially three firms in the office software market: Microsoft, IBM/Lotus (or Lotus)[20] and Borland/Corel/Novell/WordPerfect (hereafter Corel/Word Perfect or Word Perfect). These three firms accounted for at least at least 90% of the WINDOWS office software market from 1993-1998 and 94% of all revenues in every year in the spreadsheet, word processors and suite markets combined during the 1991-1998 period. No other firm had more than a negligible market share in any of these markets during the 1991-1998 period (See Figure 3.) Hence we limit our econometric analysis to products offered by these three firms.

4. Data

[19] Microsoft announced in July (1995) that it would ship its new version of its popular suite of application programs on August 24th, the same day that it intended to release Windows 95. See "Microsoft's office suite to be shipped in August," Wall Street Journal, 11 July 1995: Section B5.
[20] IBM acquired Lotus in 1995.

Our dataset includes the key office software products: spreadsheets, word processors, and suites. Computer hardware (operating systems) and software are complementary products and the benefit from software consumption can only be realized if consumers have an operating system capable of running the particular software package. In order to focus exclusively on software effects, the sample was restricted to spreadsheets, word processors, and office suites that were compatible with the WINDOWS operating system.[21] Packages that were compatible only with the Apple/Macintosh operating system, for example, were not included.

Data on prices and quantities (denoted PRICE and QUANTITY) come from two Dataquest/Gartner Reports on Personal Computing Software, one for the 1992-1995 period and one for the 1996-1998 period.[22] Dataquest/Gartner reports (worldwide) shipments and total revenues for each product; hence price is the average transaction price.[23] The variable QUANTITY is the number of units sold (in thousands), and the variable PRICE is the average price.[24] The price of a "mix and match" combination is the sum of the prices of the components. Importantly, according to Liebovitz and Margolis (1999) (hereafter LM), for the period we analyze, office software products were typically sold directly to consumers rather than via the OEM market.

Data on quality of spreadsheets and word processors come from LM; they employed reviews that gave numerical ratings, and they normalized the top score to 10 in each year. Given the normalization, these scores are not comparable across years. This, however, is not important for our analysis since the choice set consumers see is the software available in a particular

[21] For ease of presentation we refer to WINDOWS for all versions of the WINDOWS operating system made for PCs, including WINDOWS 3.x, WINDOWS95, and WINDOWS98. For the years in which WINDOWS was a graphical user interface that worked with the DOS operating system, we only include products that were made for WINDOWS.

[22] The first report was purchased from Dataquest/Gartner; we are grateful to Dataquest/Gartner for supplying us the relevant data from the second report.

[23] The data on unit sales (or shipments) is comprehensive and includes new licenses, upgrades, and units distributed through original equipment manufacturer (OEM) channels.

[24] In some cases, we need to average over several versions of the product. For example, in some years, the Microsoft office suite comes in separate versions for WINDOWS and WINDOWS95. There was little difference in price between the versions available for various generations of the WINDOWS operating system.

year.[25] We calculate quality relative to the quality of the leading product in the beginning of our dataset: Lotus and WordPerfect. Hence for spreadsheets,

RELQUAL_SS= (rating of the relevant product – rating of Lotus SS)/(rating of Lotus SS.) Similarly, for Word Processors,

RELQUAL_WP= (rating of the relevant product – rating of Word Perfect Word processor/(rating of Word Perfect Word processor.)

K_SS is a dummy variable equal to one if the product purchased is either a spreadsheet or a suite, and zero otherwise.

K_WP is a dummy variable equal to one if the product purchased is either a word processor or a suite, and zero otherwise.

K_SUITE is a dummy variable that takes on the value one if the consumer purchases a suite. It takes on the value zero otherwise, including the case where a consumer mixes-and-matches from different vendors.

YEARXX is a yearly dummy variable for year 19XX; for example, YEAR93 is a yearly dummy for 1993.

YEAR96-98 is a dummy variable that takes on the value 1 for the 1996-1998 period, and zero otherwise.

The variable MICROSOFT (or MS) takes on the value one for Microsoft word processors and spreadsheets, and two for Microsoft suites, since a suite includes both a word processor and a spreadsheet.

[25] In the case of the LM ratings for Spreadsheets, there are no ratings for 1993 and 1995; fortunately, there are two ratings for 1994 and 1996. We use the first rating in 1994 (which takes place very early in the year) as the rating for 1993; similarly, we use the first rating in 1996 as the rating for 1995. In the case of LM ratings for word processors, there are no ratings for 1996 and 1998. Since there is only a single rating for 1995 and 1997, we average the 1995 and 1997 ratings to obtain ratings for 1996 and use the 1997 ratings for 1998 as well.

Note that the variable SUITE controls for the possibility of 'superadditive' utility from the suite. Superadditivity likely exists for suites for two reasons: (I) suites contained additional packages, such as presentation software and (II) there are likely synergies (complementarities) among the components in computer software office suites because of the links between (and integration of) the components, and because of commands that are common across components. We wanted to include a quality variable that measures how well the components of the suite are integrated. Unfortunately, this variable is available for just two years, 1994 and 1998.

Since the three products of the three key firms in the market were essentially compatible for the period of our data -- for example, word processing documents written in Word Perfect could be read into Microsoft Word and edited -- there would not seem to be a network effect advantage. Indeed, under full compatibility, each product would have essentially the same network size. In such a case, multicollinearity would prevent us from estimating any (common) network effect. Hence, we do not include network effects in our empirical analysis.

We have 63 model observations. Sales data are available for all products that had a 'non-trivial' number of sales. Products with a very tiny market share were not recorded by Gartner. All three Microsoft products (word processor, spreadsheet, suite) had significant sales in all years. In the case of Lotus and Word Perfect, not surprisingly, Lotus had a very small market share in word processors for 1996-1998, and Word Perfect had a non-trivial number of sales only in the suite category for 1996-1998. For the products with virtually no sales, we assumed that these products had a market share equal to the smallest market share for products for which we have complete data. Our results are robust to making these ‘small’ market shares even smaller, or eliminating these products from the data.

For these products (with a very tiny market share,) we calculated prices by taking our prices from the Gartner data and comparing them with prices reported by LM. LM use prices to OEM vendors; they have price data through 1997. We adjusted the LM series so the last price observation we have from the Gartner data equals that LM price. We then used the LM

percentage declines in prices in order to compute the prices for the remaining years.[26] Prices for suites appear in figure 8, prices for word processors appear in Figure 9, while prices for spreadsheets appear in Figure 10. Descriptive Statistics are shown in Table A1 in Appendix A.

The potential market for office software is defined to be the number of operating systems sold or distributed via OEMs during the relevant year. Our data on operating systems for 1992 comes from Woroch et al (1995), while our data on operating systems for 1993-1998 comes from a Dataquest report on Operating System Shipments.[27] The data in Table 1 show that, on average, approximately 80 percent of all consumers with a computer (operating system) purchased an office software product in 1992 and 1993. By 1998, only approximately 50 percent of all consumers purchased an office product. One possible explanation for this decline is that the household market had increased relative to the size of the business market. Indeed, National Telecommunications and Information Administration (NTIA) data show that the percent of households with a personal computer increased in the U.S. from 24.1 percent in 1994 to 36.6 percent in 1997.[28]

Year	A: WINDOWS Sales of Operating Systems	B: Sales of Word Processors	C: Sales of Spreadsheets	D: Sales of Suites	Share of inside goods (B+C+D)/A
1992	11.056	4.650	3.442	0.578	0.784
1993	18.228	6.852	4.640	3.194	0.806
1994	32.107	5.987	5.233	7.689	0.589
1995	54.352	4.693	3.876	12.982	0.397
1996	68.083	2.908	2.979	26.810	0.480
1997	78.406	4.186	2.972	32.977	0.512
1998	89.489	2.091	1.867	38.801	0.478

Table 1: Units of Operating Systems and Office Software Products (millions), 1992-98

5. Discrete Choice Model and Estimation

[26] As noted, LM data are through 1997. Hence for the three 1998 products for which we do not have price data, we use the 1997 value. Prices for these goods were already very low in 1997. Our main results are robust to assuming that prices fell from 1997 to 1998 at the same rate they fell from 1996 to 1997.

[27] The Dataquest reports and the Woroch et al (1995) data delineate between "DOS without WINDOWS" and "DOS with WINDOWS," so it is straightforward to simply include the latter.

[28] See http://www.ntia.doc.gov/ntiahome/net2/presentation/slide14.html. Since we have a yearly dummy variable, changes in the share of the inside goods primarily affect the coefficient associated with the relevant yearly dummy.

In this section, we formally specify our discrete choice model. We define a product to be a combination of a software category and a vendor. Each consumer compares products across four software categories: Consumers can either purchase a spreadsheet only, a word processor only, an office suite, or a "mix and match" wordprocessor-spreadsheet combination from two different vendors. Hence when all three firms offer word processors, spreadsheets, and office suites, there are 15 possible "products": 3 spreadsheets, 3 wordprocessors, 3 office suites, and 6 "mix and match" wordprocessor and spreadsheet combinations from different vendors.[29] Consumers evaluate the products and purchase the one with the highest utility, or make no purchase if that is the best option.

The utility from a particular choice is

$$(1) \qquad U_{jk} = \delta_j + \theta_{jk}$$

where j indexes the product and k indexes the consumer. The time subscript is suppressed throughout for ease of notation. Consumer k's utility for choice j has a mean component and a random component that we discuss in turn. The utility from making no purchase at all is normalized to zero. Optimal consumer choice given these preferences leads to characterization of expected market shares of the products of each vendor.

Mean Utility

The variable δ_j measures the mean utility for product j. We assume that:[30]

$$(2) \qquad \delta j = \beta_0 * PRICE_j + \beta_1 * K\_SS_j + \beta_2 * K\_WP_j + \beta_3 * K\_SUITE_j + \beta_4 * YEAR94_j + \beta_5 * YEAR95_j + \beta_6 * YEAR96\text{-}98_j + \beta_7 * K\_SS_j * RELQUAL\_SS_j + \beta_8 * K\_WP_j * RELQUAL\_WP_j + \beta_7 * MICROSOFT_j + \beta_8 * MICROSOFT_j * K\_SUITE_j * YEAR96\text{-}98_j + \xi_j$$

[29] Given the pricing of the suite and the components and the extra software contained within the suite, no consumer would purchase a spreadsheet or a word processor from the same firm, since the utility from the choice is lower than that of the suite.

[30] We could have put in a constant by leaving the K_SUITE variable out of the mean utility.

where the error variable ξ_j measures the mean value of any unobserved characteristics of product, and the $\beta's$ are parameters to be estimated.

Note that the coefficient vector is restricted to be the same for all products, and does not vary by product category, and the number of year dummies is restricted by combining 1992-93 and 1996-98. [31] We do this because, with only a limited amount of data, we are unable sensibly to estimate too many parameters with sufficient precision. The variable ξ_j measures the mean value of any unobserved characteristics of product *j*.

Random Utility

The variable θ_{jk} represents consumer *k*'s deviation from the mean utility of product *j*. We assume this variable includes a common component depending for the product category and an independent and identically distributed idiosyncratic component for each product:

$$\theta_{jk} = K\_SS_j * \mu_{1k} + K\_WP_j * \mu_{2k} + \varepsilon_{jk} \tag{3}$$

The variable μ_{ik} (i = 1 for a spreadsheet and i = 2 for a word processor) is a consumer-specific random utility for a software category. For example, $\mu_{2k} > 0$ indicates that consumer *k* has a higher than average value for a word processor. These variables introduce consumer heterogeneity for the demand for different categories of software products. It allows for some consumers to place a high value on having a word processor, while others have a great need of a spreadsheet. For suites and "mix and match" combinations, the consumer receives random utility $\mu_{1k} + \mu_{2k}$. Note that an important feature of this specification is that it allows a consumer's demand for a word processor to be correlated with the consumer's demand for a spreadsheet.

[31] This grouping is based on the yearly shares of the 'inside' goods, which are quite similar for 1992-1993 and for 1996-1998. See Table 1.

These utility components are assumed to have a symmetric mean-zero bivariate normal distribution, i.e., $(\mu_{1k},\mu_{2k}) \sim N(0,0,\sigma_1,\sigma_2,\rho)$, where σ_1 and σ_2 are the standard deviations of μ_{1k} and μ_{2k} respectively and ρ is the correlation coefficient. We will estimate the parameters of this distribution, with a particular interest in the correlation coefficient. The variables μ_{1k} and μ_{2k} and their bivariate normal distribution are generated as follows: suppose that Y_1 and Y_2 are independent random variables, with a standard normal distribution, then μ_1 and μ_2 are new random variables defined by $\mu_1 = \sigma_1 Y_1$ and $\mu_2 = \sigma_2 \rho Y_1 + \sigma_2 (1 - \rho^2)^{1/2} Y_2$. [32]

ε_{jk} is consumer k's additional random utility for product j. This term introduces an additional source of consumer heterogeneity; i.e. some consumers may be more attracted to a particular product. Unobserved consumer heterogeneity in preferences over vendors in a particular software category or products involving two software categories enters only through this variable. The ε_{jk} are assumed to be independently and identically distributed according to a Gumbel distribution with mean 0 and variance 1.64.[33] This captures an idiosyncratic preference for individual products, and is the error structure typically employed in discrete choice demand models. It permits a convenient characterization of expected market shares, as described below. It captures an idiosyncratic preference for the individual products, and limits the overall correlation of tastes for different products.

Market shares

Given the logit structure of demand derived from the distributional assumptions on ε_{jk}, the probability that consumer k chooses product j conditional on (μ_{1k}, μ_{2k}) is

$$P_{jk} = \frac{e^{\delta_j + K\_SS_j * \mu_{1k} + K\_WP_j * \mu_{2k}}}{1 + \sum_{l=1}^{15} e^{\delta_l + K\_SS_l * \mu_{1k} + K\_WP_l * \mu_{2k}}}, \quad (4)$$

and the probability that consumer k makes no purchase is

[32] See http://www.ds.unifi.it/VL/VL_EN/special/special7.html for details.
[33] The Gumbel distribution with mean 0 and variance 1.64 is the extreme value distribution that is typically used in this literature.

$$P_{0k} = \frac{1}{1 + \sum_{l=1}^{15} e^{\delta_l + K\_SS_l * \mu_{1k} + K\_WP_l * \mu_{2k}}}.$$

These probabilities can be employed in a straightforward way to simulate market shares for office suites. The calculations for an individual software category are somewhat more complicated. Consider for example a particular vendor's word processor. Let product *j'* refer to the standalone word processor, and let *j''* and *j'''* refer to the two "mix and match" combinations that involve that word processor. Then the probability that consumer *k* purchases this vendor's word processor (separately from the suite) is $P_{j'k} + P_{j''k} + P_{j'''k}$. Making similar calculations for the word processors of other vendor's, it is straightforward to calculate simulated market shares in the word processor category. Obviously, the validity of these calculations requires a large number of (simulated) consumers.

Estimation Algorithm

The estimation algorithm proceeds in several steps.

Step 1: Take random draws of (Y_{1k} ,Y_{2k}) for 100,000 consumers per year. Each consumer makes a single choice.[34]

Step 2: Assume initial values for σ_1 , σ_2, and ρ, and find δ using the contraction mapping

$$\delta_{j,\text{new}} = \delta_{j,\text{old}} + \ln(\textit{actual market shares}) - \ln(\textit{simulated market shares})$$

until convergence ($\hat{\delta}$) is obtained.[35,36]

[34] We abstract from the issue of repurchases and upgrades.

[35] The initial value of δ_j comes from $\delta_j = \ln(s_j) - \ln(s_o)$, where s_o is the share of the outside good. See Berry (1994), Berry, Levinsohn, and Pakes (1995) for details.

[36] Since the data consist of sales of spreadsheets, wordprocessors and suites, the 15 choices are mapped into the 9 products. This is straightforward (as described above) since the total number of Microsoft Word wordprocessor sales (separate from the suite) is the number of consumers who purchased Word as a standalone product plus the number of consumers that "mix and match," i.e., those that purchased Word with The Lotus/IBM spreadsheet and Word with the Corel/WP spreadsheet.

Step 3: Given $\hat{\delta}$, run the GMM regression $\hat{\delta}$=Xβ+ξ, and obtain estimates $\hat{\beta} = \left(X'ZWZ'X \right)^{-1} X'ZWZ'\hat{\delta}$, where *X* is the matrix of right hand side variables, *Z* is the matrix of exogenous right hand side variables and instrumental variables, and the weighting matrix W=(Z'Z)$^{-1}$.[37,38]

Step 4: Compute the implied values of the unobservables, i.e., $\hat{\xi} = \hat{\delta} - X\hat{\beta}$, and evaluate the GMM objective function $\hat{\xi}'ZWZ'\hat{\xi}$

Step 5: Update the values of σ_1, σ_2, and ρ, and return to step 2.[39]

Identification of Linear Parameters

Our data set contains sales and shipments by products and by year. Thus, both variation across products and variation across time are a source of identification of the parameters of the model. The year dummy variables obviously vary over time only. Variation in the share of potential consumers who elect the outside good identify the coefficients on these variables. The vendor variable (MS) varies across products, but not over time. Variations of shares of Microsoft products relative to products of the other vendors identify the coefficient on this variable.

The variable K_SUITE captures added value from suites, relative to components. Hence, the market share of suites (and combinations) identifies the coefficient on this variable for a fixed value of ρ.

The variables K_SS , K_WP , and PRICE vary both by product and by year. Consequently, shifts in market shares of products over time identify the coefficients on these variables.

[37] As Nevo (1998) notes, this weighting matrix yields efficient estimates under the assumption that errors are homoskedastic.
[38] Since price is endogenous, we instrument for it. See the identification section for the discussion of instruments.
[39] The estimates of σ_{WP}, σ_{SS}, and ρ are updated by the software program "*R*" using a grid search. In Appendix D, we discuss a slight modification to the estimation algorithm.

Identification of Non-Linear Parameters:

Identifying the correlation coefficient ρ is not straightforward as both an increase in the correlation in preferences over word processors and spreadsheets and an increase in 'superadditive' utility from suites - in the form of complementarity or integration of the components or additional packages in the suite - lead to the same qualitative effects – an increase in the demand for suites. Consequently, the share of suites for given prices does by itself distinguish the effects of superadditivity from positive correlation in the taste distribution.

We are able to identify the correlation coefficient ρ in our model using the general result from Johnson and Myatt (2006) discussed above, namely that profits of a firm are increasing in dispersion when consumers are heterogeneous. Hence, demand is greater under positive correlation than negative correlation. The superadditive benefit, captured by the variable K_SUITE, on the other hand, does not depends on the magnitude of ρ.

Another way to state this is that when ρ falls, market shares of suites become more sensitive to changes in suite prices. On the other hand, when ρ rises, market shares of suites become less sensitive to changes in price. Since the additional utility from a suite does not depend on ρ, we can separately identify these two effects.

Given the linear parameters and ρ, an increase in σ increases the sales of the relevant class of products (spreadsheets and word processors respectively). Hence, when sigma is high for a particular product type (say word processors) price rises for a particular word processor will lead more consumers to substitute *within* the class, i.e., to another word processor. When σ is low, more consumers will substitute away from that component, rather than purchase another product in the class when price rises. These effects combined with the fact that the ε_{jk} are distributed according to a Gumbel distribution with a known variance enable us to identify the standard deviations of these preferences as well.[40]

[40] As noted above, the assumption of the Gumbel distribution is typical when estimating discrete choice models of product differentiation. If we did not know the variance of ε_{jk}, we would only be able to estimate the ratio of the standard deviations.

Instrumental Variables

Since price is endogenous, we instrument for it. Since we have three non-linear parameters, we need four instrumental variables in order to identify our model. We have the following instrumental variables: (There is a reasonable high correlation between price and the instrumental variables.)

- Relative quality of the best rival product in the same category (where category means spreadsheet, word processor, or suite.)[41]
- Relative quality of best rival suite for spreadsheets or word processors; relative quality of best rival constituent product for suites
- Relative quality of firm's own other constituent product (for spreadsheets or word processors); relative quality of 'best' own constituent product (for suites)
- Dummy Variable for Year 95-98 –Prices declined beginning in 1995 due to the exogenous technological change in OS to Windows95, which made it easier (cheaper) to produce office software

6. Empirical Results

We first estimated the model using Ordinary Least Squares (OLS). In such a case, of course, we do not have any non-linear parameters. Because price is endogenous, we expect the estimated coefficient on the linear variables to be biased upwards. Re-estimating the model using linear instrumental variables (again, no non-linear parameters) results in a more negative and statistically significant estimated coefficient on price compared to the OLS estimation (-.09 versus -.01). This suggests that our instruments are working as expected. (See Table 2)

[41] For this instrumental variable, we define the relative quality of the suite as the sum of relative quality of the relevant spreadsheet and the relative quality of the relevant word processor.

Our estimates for the full random coefficient model are also shown in Table 2. As expected, the estimates for the linear instrumental variables case and the estimates for the full random coefficients model are highly correlated.

The rest of the discussion in this section focuses on the estimates from the full random coefficients model. We begin with the non-linear parameters, focusing in particular on ρ, which is the main parameter of interest in our analysis.

The estimate of ρ is 1.00 and is statistically significant. This suggests that there is strong positive correlation in preferences for word processors and spreadsheets, the two key components of the office software market. The positive correlation in preferences makes sense, given that preferences for components of office software suites are likely positively correlated through an income effect.[42] Note that although our estimate is ρ = 1, the correlation over preferences is a function of the random error term (ε_{jk}), as well as μ_1, μ_2. Using our estimates of ρ and the two estimated variances, as well as the variance of the random error term, it is straightforward to show that when ρ=1 the correlation in preferences is 0.68.[43] Hence, varying when ρ between -1 and 1 allows us in our simulations to examine correlations between -0.68 and 0.68. While this means that we cannot fully explore the entire range of correlation in preferences, this does not have a qualitative effect on the results as the range we are able to study is still quite large. Furthermore, the general JM (2006) result means that profits are monotonic in the correlation coefficient when firms sell suites and serve a niche-market, so our results can be generalized for the parameter regions we are not able to directly study.

The estimated coefficient for the standard deviation over preferences for word processors (5.66) is larger than the estimated standard deviation for spreadsheets (1.23). Recall that when the standard deviation is relatively large, consumers will likely substitute within the class when price rises. This makes sense since spreadsheet use during the 1990s was primarily for simple

[42] In Appendix C, we use supplementary data from 'Current Population Survey' to provide supporting evidence for positive correlation in consumer preferences over word processors and spreadsheets through income levels.

[43] $Cov(\mu_1 + \varepsilon_{jk}, \mu_2 + \varepsilon_{mk}) = Cov(\mu_1, \mu_2) = \sigma_1 * \sigma_2 * \rho$. Further, $Var(\mu_i + \varepsilon_{jk}) = (\sigma_i^2 + 1.64)$ since the $var(\varepsilon_{jk}) = 1.64$ for the Gumbel distribution. Hence, the correlation between $\mu_1 + \varepsilon_{jk}$ and $\mu_2 + \varepsilon_{mk}$ is $\rho * \sigma_1 * \sigma_2 / [(\sigma_1^2 + 1.64)(\sigma_2^2 + 1.64)]^{.5}$. Plugging in ρ=1 and estimated values for $\sigma_{\_WP}$ and $\sigma_{\_SS}$ yields 0.68.

calculations. Word processors were either used by professionals for writing manuscripts, or simply used to write letters. It is, therefore, likely that there was less variance in the value of spreadsheets compared to the variance of the value placed on word processors.

We now discuss the linear parameter estimates. Key coefficients have the expected sign. In particular the PRICE coefficient is negative and significant at the 95 percent level. The inverse of the coefficient, which arises from normalizing the variance of ε_{jk}, indicates consumer taste heterogeneity for individual products. The coefficients on the relative quality variables (K_i*RELQUAL_i), which measure the value associated with observed quality of components, are positive for both product categories, but not significant. This suggests that the ratings on which the relative quality measures are based on product attributes consumers indeed value.

The yearly dummy variables capture shifts in the difference between the value of office software products and the outside option. The coefficients associated with the yearly dummies are declining in value. This is in large part due to the fact that the consumer purchases of spreadsheets, word processors and suites divided by the number of operating systems was declining as well. (See Table 1.) That is more consumers who purchased a computer elected not to purchase an office software product in later years. This could reflect the notion that as the price of personal computers (i.e., operating systems) declined significantly, more consumers who were less sophisticated in their software use entered the market. These consumers could likely manage well without a word processor or a spreadsheet. They could use a utility that came with the operating system like 'notepad' as a substitute for word processor and could use a calculator (another free utility) as a substitute for a spreadsheet. Alternatively, it could mean that as computer usage grew significantly in countries without strong intellectual property protection during the 1990s, and thus piracy of applications software increased. Since we use these dummy variables as a control, we are neutral regarding this or other explanations for the reduction in the percentage of consumers that purchased a spreadsheet, a word processor, or suite over time.

Recall that the variable MS takes on the value one for Microsoft component products (word processors and spreadsheets) and two for Suites and is thus intended to capture the unobserved

quality of Microsoft component products. The estimated coefficient associated with the variable is positive and statistically significant. This suggests Microsoft benefited from some or all of the following: a better reputation, better service, better additional components in the suite, better integration of components, and higher unobserved quality of components.

Suites included additional components like presentation software. This is picked up by the dummy variable K_SUITE. The coefficient on the variable K_SUITE is positive, although not statistically significant. The positive estimate suggests that consumers value the other software components in the suite in addition to the main components and/or the complementarity or integration of the components. The dollar value of the "suite bonus" is obtained by dividing the K_SUITE coefficient by the absolute value of the PRICE coefficient, i.e. approximately $36. [44]

The coefficient associated with the Microsoft suite for the 1996-1998 period is positive and nearly statistically significant. Given that we control for K_SUITE, the coefficient of the Microsoft suite for 96-98 is likely picking up a complementarity/compatibility effect and may reflect the fact that Microsoft's components were much better integrated in the Microsoft suite than in other suites. This is consistent with the trade press (see Appendix B) which shows that, even in 2001, there is a large difference in cross-application compatibility between the Microsoft suite and other suites.[45]

Overall, with the exception of price, ρ, MICROSOFT, and the Microsoft suite for 1996-1998, the parameter estimates are not statistically significant. This is likely the result of the limited number of observations in combination with the non-linear model we employ. As we discussed earlier, our main goal is to examine the effect of the correlation coefficient on incentives to

[44] The estimated standard deviation of the coefficient associated with K_SUITE is quite high, but the point estimate (2.49) is not that different from the point estimate when we estimate a linear model with instrumental variables (3.05.) In that case, the estimated coefficient is significant. Furthermore, under the linear model with instrumental variables, the estimated suite bonus is very similar: $34 (3.05/.09)

[45] Stan Miastkowski, writes about the 1997 Corel/WP as follows: "Prior versions of WordPerfect Suite showed the results of cobbling together a bunch of disparate applications…"See "Corel's Nearly Perfect Suite Spot," *Byte.com*, July 1997, available at http://www.byte.com/art/9707/sec11/art4.htm#077ev2t1 (accessed September 29, 2004). LM note, "When they [Microsoft's competitors] did assemble competing suites, they tended to cobble together products that had little in common."

bundle and strategic interaction in the market. Hence, the fact that several of the estimated coefficients are not statistically significant is not important for our main analysis which we present in the next section – the variables associated with these estimates are primarily included for controls.

Table 2: OLS, Linear IV and Non-Linear Instrumental Variable Estimates

OLS	Coef.	Std. Error	t
price	-0.01	0.01	-1.57
y94	-0.72	0.49	-1.46
y95	-1.30	0.50	-2.58
y96_98	-1.81	0.68	-2.66
MS	1.31	0.37	3.52
k_SS	-1.27	2.12	-0.60
k_WP	0.12	4.28	0.03
suite	3.19	0.53	6.01
k_SS*rel quality	-0.12	2.31	-0.05
k_WP*rel quality	-1.64	4.12	-0.40
MS*suite*y96_98	1.66	1.09	1.52
63 observations	Adj. R^2=.31		

Non-Linear IV	Coef.	Std. Error	t
sigma SS	1.23	16.12	0.08
sigma WP	5.66	17.51	0.32
rho	1.00	0.54	1.86
GMM	15.75		

Linear IV	Coef.	Std. Error	t	Coef.	Std. Error	t
price	-0.09	0.05	-1.92	-0.07	0.04	-1.87
y94	-2.92	1.66	-1.76	-2.60	4.77	-0.54
y95	-5.55	2.63	-2.12	-5.58	1.64	-3.39
y96_98	-9.86	4.73	-2.08	-7.89	3.16	-2.49
MS	3.02	1.27	2.37	2.59	0.92	2.81
k_SS	-4.20	5.11	-0.82	-4.14	8.36	-0.50
k_WP	-2.55	9.91	-0.26	1.32	39.88	0.03
suite	3.05	1.22	2.51	2.49	13.85	0.18
k_SS*rel quality	13.13	9.06	1.45	10.96	8.76	1.25
k_WP*rel quality	11.17	11.80	0.95	4.90	32.23	0.15
MS*suite*y96_98	2.60	2.54	1.02	2.31	1.43	1.61

7. Counterfactuals/Simulations

We conducted simulations for both 1995 and 1998. There is little qualitative difference in the simulations' results between these years. Hence, we present and discuss the results for 1995 in the body of the paper and, in Appendix E, we present the results for 1998.

Marginal costs are 'backed' out of the first order conditions under the assumption that the firms are competing in prices and are at a Nash equilibrium. The marginal cost primarily includes the marginal cost of marketing and the marginal cost of providing consumer support (i.e., phone support, etc.) In the case of Microsoft products in 1995, the estimated marginal costs are as follows: MS Word - $74; MS Excel - $101; MS Suite - $205. Recall that the Suite includes other software packages and that there are complementarity/integration features as well; hence, there may be additional marketing or technical support expenses required. Hence, it is not surprising that the marginal cost of the MS Suite exceeds the sum of the marginal costs for Word and Excel by $30.

Given the estimated suite bonus of $36, the additional $30 in costs implies that the suite generated $6 in social surplus for the average consumer. Thus the suite presented a profit opportunity to Microsoft, independently of any price discrimination benefits from bundling. This "suite bonus effect" is important for understanding the simulations that follow.

We discuss several sets of simulations for different market structures in Tables 4, 5, and 6. We perform all simulations for three different values of ρ: 1,0,-1. Since our main goal is to examine the effect of changes in the correlation coefficient on profits, prices and market shares, we keep the values of all other parameters constant.

The first set of simulations in Table 4 compares mixed bundling, pure bundling, and separate selling in the case of a monopolistic vendor. The first simulation (case I in Table 4) presents the case where only Microsoft is active in the market and only sells its Office suite (pure bundling.) In this case, monopoly profit increases in ρ. The intuition is as follows: The variance of the random utility for the suite increases in ρ. Since Microsoft serves only a

relatively small portion of the potential market (20% percent in the simulation), the increased variance of preferences increases demand for the suite—illustrating what Johnson and Myatt (2006) call an "expanding niche market." Note that although we use the term 'expanding niche market' to be consistent with JM (2006), simulations in Appendix E show that this effect holds even when pure bundling serves 40 percent of potential consumers.[46] Furthermore, the monopoly price of the suite increases with correlation as well, as higher demand increases the incentive to raise price for a niche market (Chen and Riordan 2011).

In case II of Table 4, Microsoft sells only Excel and Word (separate selling). Consumers can buy both products, but do not receive the suite bonus from the joint purchase. Profits are independent of ρ in this case.[47] Compared with pure bundling, the results demonstrate two contrasting effects discussed in the literature. On the one hand, when correlation is negative, pure bundling is less profitable than separate selling because of the 'penalty' of higher marginal costs (Adams and Yellen 1976). On the other hand, with positive correlation, pure bundling is more profitable than separate selling because of the niche market effect discussed above in addition to incremental profits derived from the suite bonus.

Case III turns to monopoly mixed bundling, where Microsoft sells Excel, Word, and Office. Again, consumers can purchase the components separately, but do not get the suite bonus when doing so. As we know from theory, Microsoft's profits when it is the only firm in the market are always (weakly) higher under mixed-bundling than under pure bundling or separate selling.

In the case of pure bundling, the niche-market effect alone is sufficient for profits to increase in correlation. The third (mixed-bundling) simulation in Table 4 shows that Microsoft's profits increase in the correlation coefficient in this case as well. It is not obvious that profits would increase in correlation in this case, since additional suite sales lead to reduced sales of the individual products. In the case of mixed bundling, the suite bonus and the niche-market

[46] In supplemental simulations in Appendix E, we show that if costs were substantially lower, Microsoft would serve a much larger portion of the market (greater than 50 percent of the potential market,) and the expanding-a-niche-market effect of greater correlation would be reversed.

[47] The reason profits are not identically the same is because of simulation error and the fact that a change in ρ shifts the empirical distribution of μ_2. This is, however, a second order effect – profits from word processors increase by only 0.15% when ρ increases from -1 to 1 in the case of separate selling, while in the case of pure bundling, profits increase by 9.8% when ρ increases from -1 to 1.

effects jointly lead to profits increasing in the correlation coefficient under mixed bundling. The intuition is that the suite bonus creates additional value – and this increases the demand for suites. Further, an increase in correlation also leads to increased demand for suites (via the niche-market effect.) If only the niche-market effect was present, it would not necessarily be the case that profits would increase in correlation in the case of mixed bundling.[48]

From the above discussion, the benefit from mixed bundling relative to separate selling is greatest when the correlation coefficient $\rho=1$. In contrast, the profit advantage of mixed over pure bundling decreases with correlation—the advantage is the greatest with negative correlation. This is due to the ability of mixed bundling to attenuate the cost penalty effect of pure bundling.

Price and consumer welfare comparisons for the different cases are interesting as well.[49] With positive correlation ($\rho=1$), the predicted price of the Microsoft Office Suite under either mixed or pure bundling is about the same, roughly $275, which is approximately $25 higher than the summed prices of Excel and Word under separate selling. Given that the average suite bonus is $36, a $25 price premium over the 'summed prices' makes the suite a good deal for most consumers who would purchase both products. Note that the standalone prices of Excel and Word under mixed bundling are about 5% higher than under separate selling. Thus, many consumers are gently coerced with a 'price penalty' to purchase the bundle. With independence and especially with negative correlation, the suite is priced more attractively and the price penalty is lower.

In view of these price effects, it perhaps seems surprising that consumer welfare (surplus) rises with correlation. In the case of mixed bundling, for example, table 4 shows that consumer surplus (denoted CS in all of the tables) is 63.6 when $\rho=1$ and 42.2 when $\rho=-1$.[50] The reason behind the positive relationship between consumer surplus and correlation is that even though

[48] Indeed in simulations in Appendix E, we show that (i) when there is no suite bonus and (ii) when word processors and spreadsheets enter both the demand and supply side symmetrically, profits decrease in the correlation coefficient (i.e., the standard intuition obtains) when the firm employs a mixed bundling strategy.
[49] It is straightforward to calculate consumer surplus under the different scenarios Using equation (4), which gives the probability a given consumer chooses each product, we calculate the expected utility for each consumer and add over all consumers in order to calculate consumer surplus.
[50] Consumer surplus is in thousands of $.

lower correlation results in more attractive pricing, under negative correlation fewer consumers are attracted by the benefits of the bundle. Further, when $\rho=1$, many consumers buy both components under separate selling. For these consumers, the 'switch' to the suite under mixed bundling leads to a net gain of \$36 – (\$277.4-\$130.5-\$120.2)=\$9.3 per consumer.

It is also perhaps surprising that consumer surplus is lower under mixed bundling than separate selling when $\rho=-1$ (42.2 vs. 46.9.) This is because virtually no consumers (a 0.003 market share) buy both components under separate selling. Hence, very few consumers benefit from the 'switch' from buying both components to buying the suite. Further, most consumers still buy components under mixed bundling when $\rho=-1$ and these consumers face higher prices under mixed bundling relative to the separate selling case. On the other hand, when $\rho=1$, many consumers purchase both components under separate selling (a .063 market share). As noted above, these consumers benefit greatly from the 'switch' to the suite under mixed bundling – and hence consumer surplus is higher under mixed bundling than separate selling when $\rho=1$.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling															
MS Suite	275.6	0.20	13.97	13.97	69.8	264.4	0.19	11.41	11.41	54.5	251.5	0.18	8.43	8.43	36.2
Case II: Separate Selling															
MS word	130.5	0.18	9.84	12.38	45.6	130.0	0.18	9.75	12.29	45.3	130.7	0.17	9.73	12.27	46.9
MS SS	120.2	0.13	2.54			120.2	0.13	2.54			120.2	0.13	2.54		
Case III: Mixed Bundling															
MS word	136.9	0.04	2.57	15.27	63.6	135.4	0.08	4.80	14.47	51.6	133.5	0.12	6.97	13.50	42.2
MS SS	126.8	0.04	1.08			124.4	0.08	1.90			121.3	0.12	2.45		
MS Suite	277.4	0.16	11.62			267.8	0.12	7.76			255.3	0.08	4.08		

Table 4: Monopoly Market Structures and Correlation[51]

Table 5 simulates outcomes for different modes of oligopoly competition. In these simulations, we include the WordPerfect Word processor (marginal cost $73) and the Lotus Spreadsheet (marginal cost $78) as well as Microsoft products. The first result to note is that while in Table 4 the price of Microsoft Word is higher than the price of Microsoft Excel, this relationship flips in Table 5. The intuition behind this is as follows: Profit margins increase with the variance over preferences—this is illuminated in Table 4 where Microsoft is alone in the market and charges a higher price for Word than for Excel, although Excel's marginal cost is lower than Word's. Microsoft finds it profitable to do so as the estimated standard deviation over preferences for word processors (5.66) is much larger than the estimated standard deviation for spreadsheets (1.23). As shown in table 5, once there is competition in the components market, competition from WordPerfect erodes the margins on Microsoft Word significantly to the point where Microsoft prices Excel at a lower price than Word.

A comparison of Cases I and II in table 5 highlights the competitive effects of the introduction of suites. In Case I, Microsoft separately competes against Lotus in the spreadsheet market and against WordPerfect in the word processor market, and there is no 'suite' bonus for consumers

[51] In all simulations, prices are in $, the share is based on the 100,000 potential consumers per year, profits are in hundreds of thousands of $, consumer surplus is in thousands of $, and π-MS is total Microsoft profits from all products.

who purchase both a spreadsheet and a word processor: thus the correlation over preferences is irrelevant. In Case II Microsoft adds Office to its product line at an attractive price: while it increases the price of the components relative to case I, it charges a very small premium (between $9 and $13 depending on ρ) for the suite over the sum of the prices of Excel and Word.

When ρ=1, suites makes up a large percentage of total sales, Microsoft earns most of its profits from the suite (72%), while the shares of Lotus and WordPerfect fall by almost 30% and their profits by almost 35%.

Nevertheless, assuming the rivals remain active in the market, when ρ=1, the introduction of the suite (case II) is pro-competitive (i.e., beneficial for consumers) on balance. This is because, in large part, the suite bonus ($36) is much larger than the difference between the suite price and the sum of Microsoft's component prices in case I. The net benefit per consumer for those who 'switch' from buying both Microsoft components in case I to buying a suite in case II is $9.6 ($36-[250.3-104.9-119.0].) When ρ=1, there are many such consumers in case I – and all of these consumers switch to the suite when it is introduced. Further, there is an increase in unit sales of spreadsheets and word processors (via the suite) when the suite is introduced, and this also increases consumer surplus.

These two positive effects (a significant increase in surplus for the large number of consumers who switch from mix-and-match to a suite and the increase in unit sales of spreadsheets and word processors) when suites are introduced more than offsets the negative effect of an increase in Microsoft's component prices relative to case I when ρ=1. In this case (ρ=1,) the introduction of the suite raises consumer surplus by 30% (from 74.2 to 96.0). This result is robust to variations in the estimated model.

The pro-competitive effects of the suite are attenuated with less correlation, which reduces the demand for suites. In the case, when ρ=0, the introduction of suites increases consumer welfare by 12% (from 74.2 to 82.8), while when ρ=-1, the introduction of suites decreases consumer welfare by 6% (from 78.4 to 74.0.)

Case III examines the effect of competition in the components market by simulating a market where Microsoft only sells its suite, while the other firms sell their component products. Comparing this structure to case II where Microsoft offers both components and the suite, it is interesting to note that the other firms do not necessarily benefit from having the Microsoft component products out of the market. We find that when the correlation is negative or zero, the other firms are indeed better off without competition from the Microsoft components. However, when the correlation is very positive, the opposite effect can obtain; that is, a competing firm may be better off when a dominant firm sells components and a bundle rather than just selling a bundle. The intuition is as follows: Suppose a consumer likes Microsoft Word, but also likes the Lotus spreadsheet. If Microsoft sells components, then the consumer can mix and match, but if Microsoft sells only suites, the consumer cannot purchase the mix and match combination and may thus choose the bundle instead. That is, if Microsoft sells only bundles, demand for Lotus spreadsheets or WordPerfect word processor goes down; reducing the profitability of firms only selling components. Of course, there is (the standard) opposing effect as well: the Lotus spreadsheet faces less competition when Microsoft sells only bundles – and thus it makes higher profits when Microsoft sells only bundles. As before, the interesting result is that which effect dominates depends on the correlation. We find in the simulations that the 'Lotus demand reduction effect' is stronger when the correlation in consumer preferences is positive and large. Otherwise, the (standard) 'reduction in competition' effect dominates. That is, increases in the correlation coefficient make it more likely that competing firms selling components would prefer to compete against a firm selling mixed bundles, rather than a firm selling only the bundle. These simulations indicate that the strategic interaction among the firms is affected significantly by the value of the correlation coefficient.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	π	π-MS	CS
Case I: Component Competition: No 'suite' bonus when purchasing both components															
MS Word	104.9	0.20	5.96	8.15	74.2	104.9	0.20	5.93	8.12	74.2	104.9	0.19	5.89	8.09	78.4
MS SS	119.0	0.12	2.19			119.0	0.12	2.19			119.0	0.12	2.19		
WP Word	92.2	0.09	1.76			92.2	0.09	1.75			92.2	0.09	1.74		
Lotus SS	94.2	0.07	1.16			94.2	0.07	1.16			94.2	0.07	1.16		
Case II: MS sells suites and components, (no suite bonus when purchasing both components)															
MS word	113.9	0.06	2.19	11.29	96.0	109.9	0.10	3.50	10.26	82.8	107.4	0.14	4.62	9.24	74.0
MS SS	125.6	0.04	1.00			121.8	0.08	1.58			119.7	0.11	2.06		
WP word	90.2	0.07	1.16			91.4	0.08	1.40			91.8	0.08	1.56		
Lotus SS	93.1	0.05	0.78			93.9	0.06	0.99			94.2	0.07	1.15		
MS suite	250.3	0.18	8.10			244.7	0.13	5.18			235.8	0.08	2.56		
Case III: MS sells only its suite (no suite bonus when purchasing both components)															
WP word	90.2	0.07	1.13		105.8	94.6	0.09	1.84		87.2	96.7	0.11	2.49		66.7
Lotus SS	93.0	0.05	0.69			95.0	0.06	1.09			95.8	0.08	1.47		
MS suite	248.8	0.23	9.96	9.96		241.9	0.21	7.52	7.52		230.7	0.19	4.69	4.69	

Table 5: Oligopoly competition: Louts and WordPerfect sell components

In the third set of simulations (Table 6) we examine market structures where firms only sell suites. Our 1995 estimated costs for the Lotus and WordPerfect suites are $110 and $125 respectively, both considerably less than the $205 cost for Microsoft Office. These cost differences could be a reflection of Microsoft's quality advantages, or Microsoft's higher marketing and customer support costs.

We first examine the effect of competition in the market for suites. Case I is identical to Case I in table 4 and again presents the case where Microsoft sells its suite monopolistically in the market. Comparing this structure to the case where Microsoft competes against the other two suites (case II), competition decreases Microsoft's price by 8-10% depending on the correlation. Note, however, that competition in the suite market (Case II in Table 6) is not more effective (in terms of affecting the price of the MS Suite) than competition from the component (as shown in Case III in table 5) even when ρ=1. This suggests that the rival suites did not provide significant competition to Microsoft.

Our final two sets of simulations in Table 6 focus on the effect of a potential merger on market outcomes. In particular, we simulate a case where Microsoft's Suite competes against a merged Lotus/Word Perfect Suite. In this setting, we assume that the merged firm's suite includes two high-quality components: the Lotus Spreadsheet and the Word Perfect Word Processor. There are several ways in which to conduct this simulation. Perhaps the most two interesting ways are as follows:

Case III. The merged suite gets the MS dummy effect + same cost as Microsoft

Case IV. The merged suite gets the MS dummy effect + same cost as Microsoft + same quality of components. (Recall that Microsoft's components had the highest ratings in both categories in 1995.)

The results in cases III and IV are quite similar. This means that the observed quality of the components has only a very small effect on the outcome.

When we compare these results with the three suite market (case II), the sales weighted price is slightly lower in the 'three suite' world ($223 vs. $230 when ρ=1), but total sales are much higher (.40 vs. .28 when ρ=1.) Additionally, the sales weighted quality of the products sold in market is much higher. Microsoft's price falls from $246 in the three suites case to $230 when faced with a "stronger" competitor. Moreover, the size of the market increases by more than 30% .The price of the merged suite is higher than the prices of the competing suites in the three suites case; nevertheless the higher quality and larger market offset this negative effect and welfare increase significantly. Hence, the merger is clearly welfare improving. See table 6.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	Share	π	π-MS	CS
Case I: Microsoft is alone in the market – and only sells suites															
MS Suite	275.6	0.20	13.97	13.97	69.8	264.4	0.19	11.41	11.41	54.5	251.5	0.18	8.43	8.43	36.2
Case II: All three firms sell suites															
MS suite	246.1	0.24	9.72	9.72	110.2	244.3	0.22	8.68	8.68	78	241.0	0.20	7.10	7.10	45
WP suite	139.8	0.02	0.33			139.6	0.02	0.27			139.5	0.01	0.19		
Lotus suite	125.9	0.04	0.69			125.7	0.04	0.57			125.2	0.03	0.40		
Case III: MS competes with merged suite – same cost for suites, both firms get MS bonus															
MS suite	229.6	0.19	4.65	4.65	158.2	229.0	0.18	4.32	4.32	118.5	227.9	0.17	3.81	3.8	73.5
Merged suite	230.1	0.20	4.88			229.5	0.19	4.54			228.4	0.17	4.01		
Case IV: MS competes with merged suite – same cost for suites, both firms get MS bonus + MS component quality															
MS suite	229.9	0.2	4.74	4.74	157.2	229.2	0.18	4.41	4.41	117.5	228.1	0.17	3.88	3.88	72.7
Merged suite	229.9	0.2	4.74			229.2	0.18	4.41			228.1	0.17	3.88		

Table 6: Oligopoly Competition – firms only sell suites

Robustness Analyses:

In order to make sure that our main results are robust to different cost structures, we re-did all the simulations in the above three tables under the assumption that the marginal cost of the Microsoft suite is the sum of the marginal costs of the Microsoft components-- $175,[52] while retaining the estimated marginal costs of Microsoft's components and the other components. The intuition discussed in section 7 regarding the effects of correlation on profits and consumer surplus and on the strategic interaction in the market is robust to this alternative cost structure. Further, additional simulations also show that these main results are also robust to conducting the simulations for 1998.[53, 54]

[52] Recall that the estimated marginal costs are MS word - $74; MS Excel - $101; MS Suite - $205.
[53] These simulation results are available in Appendix E.
[54] Some of the results above, of course, depend on the particular cost structure. When the cost-penalty effect is attenuated enough, (i) pure bundling is more profitable than separate selling even when consumer preferences are negatively correlated, and (ii) the profits of mixed bundling are decreasing in correlation. Nalebuff (2004) argues that pure bundling as a better deterrent then mixed bundling.

8. Conclusion

In this paper, we developed a model that allowed us to examine how correlation in preferences over components in the Office productivity software market affects firms' incentives to bundle and the strategic interaction in the market. Our empirical results suggest that consumer preferences over word processors and spreadsheets are positively correlated.

In the case of pure bundling, the niche-market effect alone is sufficient to overturn the standard intuition and insure that profits increase in correlation. In the case of mixed bundling, the standard intuition is overturned (i.e., profits increase in correlation) because of the interaction of the suite bonus with the market expansion effect.

We examined the competitive effects of bundling in a simulated market setting of partial competition, in which Lotus sells only a spreadsheet and WordPerfect sells only a word processor, while Microsoft sells both components as well as a suite. Assuming the rivals remain active in the market, when the correlation is positive, the introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance. This is mainly because the suite bonus 'value' is much larger than the difference between the suite price and the sum of Microsoft's component prices when Microsoft does not offer a suite. This provides large benefits to consumers who 'switch' to the suite when it is introduced. The simulations also show that the introduction of Microsoft's Office suite also expands the distribution of spreadsheets and word processors, and this is beneficial to consumers as well.

Using simulations, we also show that a merger between the second and third largest firms in the industry would have been welfare improving. These simulations also suggest that the superior observed quality of Microsoft's component products was not that important for Microsoft's success in the suite market.

References

Adams, Walter J. and Janet L. Yellen (1976), "Commodity Bundling and the Burden of Monopoly," *Quarterly Journal of Economics*, 90: 475-498.

Anderson, S, and l. Leruth, "Why firms may prefer not to price discriminate via mixed bundling," International Journal of Industrial Organization, 11: 49-61.

Armstrong, M., 2010, "Bundling Revisited: Substitute Products and Inter-Firm Discounts," mimeo, available at
http://www.economics.ox.ac.uk/index.php/papers/details/department_wp_574/

Berry, S, 1994, "Estimating Discrete-Choice Models of Product Differentiation," RAND Journal of Economics 25, 334-347.

Berry, S., J. Levinsohn, and A. Pakes, 1995, "Automobile Prices in Market Equilibrium," Econometrica 63, 841-890.

Bresnahan, T., Stern, S., and M. Trajternberg, 1997, Market Segmentation and the Sources of Rents from Innovation: Personal Computers in the late 1980s, RAND Journal of Economics 28, S17-S44.

Carbajo, Jose, David de Meza, and Daniel J. Seidman (1990), "A Strategic Motivation for Commodity Bundling," *Journal of Industrial Economics*, 38: 283-298.

Chen, Y., (1997), "Equilibrium Product Bundling," *Journal of Business*, 70: 85-103.

Chen, Y. and M. Riordan (2011), "Preferences, Prices, and Performance in Multiproduct Industries," working paper.

Chen Y., and M. Riordan, (2012), Profitability of Product Bundling, forthcoming, *International Economics Review*

Choi, Jay Pil (2004), "Tying and Innovation: A Dynamic Analysis of Tying Arrangements," *Economic Journal*, 114, 83-101.

Choi, Jay Pil and Christodoulos Stefanidis (2001), "Tying, Investment, and Dynamic Leverage Theory," *RAND Journal of Economics*, 32: 52-71.

Chu, C., Leslie, P., and A. Sorensen, 2011, "Bundle-Size Pricing as an Approximation to Mixed Bundling," American Economic Review, 101(1): 263–303

Crawford, G., 2008, "The Discriminatory Incentives to Bundle," *Quantitative Marketing and Economics*, 6:41-78

Crawford, G., and A. Yurukoglu, 2012, "The Welfare Effects of Bundling in Multichannel Television Markets," *American Economic Review*, 102: 643–85.

DeNicolo, Vincenzo (2000), "Compatibility and Bundling with Generalist and Specialist Firms," *Journal of Industrial Economics*, 48: 177-88

Gentzkow, M., 2007, Valuing New Goods in a Model with Complementarity: Online Newspapers, *American Economics Review*, 97:713-744.

Liebowitz, S., and S. Margolis, "Winners, losers and Microsoft: Competition and antitrust in high technology," Second edition, Independent Institute, Oakland, CA 1999.

Matutes, Carmen, and Pierre Regibeau, (1988), "Mix and Match: Product Compatibility Without Network Externalities," *Rand Journal of Economics*, 19: 219-234.

McAfee, Preston R., John McMillan, and Michael D. Whinston, 1989 "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values," *Quarterly Journal of Economics*, 104: 371-384

Nevo, Aviv, 1998, "A Practitioner's Guide to Estimation of Random Coefficients Logit Models of Demand," Journal of Economics & Management Strategy, 9(4), 513-548.

Nalebuff, Barry (2004), "Bundling as an Entry Barrier," *Quarterly Journal of Economics*, CXIX, 159-188.

Salinger, Michael (1995), "A Graphical Analysis of Bundling," *Journal of Business*, 68: 85-98

Schmalensee, Richard (1982), "Commodity Bundling by Single-product Monopolies," *Journal of Law and Economics*, 25: 67-71

Schmalensee, Richard (1984), "Gaussian Demand and Commodity Bundling," *Journal of Business*, 57: 58-73.

Trivedi, P., and D. Zimmer (2005), "Copula Modeling: an Introduction for Practitioners, *Foundations and Trends in Econometrics*, 1:1-111.

Whinston, Michael D. (1990), "Tying, Foreclosure, and Exclusion," *American Economic Review*, 80: 837-59.

Appendix A: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
sales000	2870.59	5549.39	33.17	32682.70
price	117.25	83.41	8	350
y94	0.14	0.35	0	1
y95	0.14	0.35	0	1
y96_98	0.14	0.35	0	1
MS	0.44	0.69	0	2
k_SS	0.67	0.48	0	1
k_WP	0.67	0.48	0	1
suite	0.33	0.48	0	1
k_SS*rel quality	0.70	0.51	0	1.35
k_WP*rel quality	0.69	0.49	0	1.22
MS*suite*y96_98	0.05	0.21	0	1

Table A1: Descriptive Statistics

Appendix B: Supplementary Product Reviews

Product	Integration	Applications	Customization	Basics	Usability
Microsoft Office 4.0	86	90	78	85	89
Lotus Smartsuite 2.1	77	83	62	73	84

Table B1: Reviews from PC World, February 1994

Product	Integration	Applications	Performance
WordPerfect Suite 8	6.7	7.1	5.9
Lotus Smartsuite 97	7.6	7.6	9.6
Office 97 (Professional)	7.6	8.4	9.4

Table B2: Reviews from PC World, February 1998

	Microsoft Office	Lotus Smart Suites	WordPerfect Suite
Value	8	9	8
Productivity	7	8	8
Features	8	6	7
Ease of Use	8	8	7
Component Compatibility (CC)	8	5	6
Overall Rating	7.8	7.2	7.2
Overall Rating without CC	7.75	7.75	7.5

Table B3: Reviews from ZDNet 2001

ZDNet overall ratings are compiled by averaging across all five of the components listed in the above table.[55] The main difference between the Microsoft suites and the other suites is the difference in cross-application compatibility. Here Microsoft continues to receive significantly higher rankings that the other firms.

[55] The ZDNet Microsoft review is from April 20, 2001, and is available at http://www.zdnet.com/supercenter/stories/overview/0,12069,477325,00.html; the WordPerfect review is from May 2, 2001, and is available at http://www.zdnet.com/supercenter/stories/review/0,12070,475950,00.html ; the Lotus Smart Suite October 24, 2001, and is available at http://www.zdnet.com/supercenter/stories/review/0,12070,476275,00.html.

Appendix C: Supplementary Regressions: from Current Population Survey (CPS) Supplement on Computer and Internet Use (2001)

In order to further assess whether our estimates of positive correlation and positive complementarity are reasonable, we obtained survey data from the Current Population Survey (CPS) Supplement on Computer and Internet use from September 2001.[56] The supplemental data on computer and Internet use were first collected in 1998. However, questions about spreadsheet and word processor usage were only asked beginning in 2001. There were approximately 160,000 individuals in the 2001 CPS Supplement. The CPS uses weights to produce basic demographic and labor force estimates.

In 2001 the following questions were asked about spreadsheet and word processors for both home and office use:[57]

- Do you use the computer at home (at the office) for word processing or desktop publishing?
- Do you use the computer at home (at the office) for spreadsheets or databases?

The weighted results are shown in the following table.

Home Use	Use Spreadsheets?	
Use WPs?	Yes	No
Yes	0.27	0.32
No	0.05	0.36

Office Use	Use Spreadsheets?	
Use WPs?	Yes	No
Yes	0.50	0.17
No	0.12	0.21

Table C1: CPS Supplement on Computer and Internet

[56] The CPS is a joint project of the Bureau of Labor Statistics and the Bureau of the Census. See http://www.bls.census.gov/cps/ for more details.
[57] The possible answers are either yes or no.

As table 3 shows, in the case of home (office) use, 63% (71%) of the individuals answered either yes to both of the questions or no to both of the questions. This provides some support for positive correlation and/or superadditive utility.

Here we use the individual data from the CPS Supplement on Computer and Internet Use (2001) to examine whether income was a factor influencing use of spreadsheets and word processors. We show that the coefficient on income is positive and statistically significant in a regression where the left hand side variable is USE (2 if the answer to both questions is yes, 1 if the answer to one of the questions is yes and 0 if the answer to both questions is no is). This reinforces the notion that there is strong positive correlation in computer preferences over word processors and spreadsheets through income levels.

In the regressions below, we use the individual data from the CPS Supplement on Computer and Internet Use (2001). In the table below, the dependent variable is USE, where USE is equal to 2 if the answer to both questions is yes, 1 if the answer to one of the questions is yes and 0 if the answer to both questions is no. The independent variables are

INCOME - a variable that takes on whole numbers between 1-14 that correspond to ranges of yearly family income. For example, 1=less than $5000, 7=$20,000-$24,999, and 14=$75,000 or more.

EDUCATION - a variable that represents the total years of schooling. It takes on the range 31-46, where 31=less than first grade, 39=a school high degree, and 46=Ph.D. degree.

COMPUTERS – a variable that represents the number of computers in the household, where 0=no computers, 1=one computer, 2=two computers, and 3=three or more computers.

SCHOOL – is a dummy variable that takes on the value one if the individual is in school and zero otherwise.

INTERNET – is a dummy variable that takes on the value one if the household has Internet service and zero otherwise.

Independent Variables	**Home Use**		**Office Use**	
	Coefficient	**T-Statistic**	**Coefficient**	**T-Statistic**
Constant	0.08	25.33	-0.12	-33.15
INCOME	0.0043	16.84	0.013	43.67
EDUCATION	0.013	160.42	0.014	147.54
COMPUTERS	0.18	148.98	0.078	56.07
SCHOOL	0.037	22.69	-0.09	-49.32
INTERNET	-0.16	-89.16	-0.11	-55.58
Number of Obs.	158,865		158,865	
Adj. R-squared	0.33		0.20	

Table C2: Regressions of Use on Income & Other Factors

The positive and statistically significant coefficients on INCOME reinforce the notion that there is positive correlation in computer preferences over word processors and spreadsheets through income levels.

Appendix D: Slight modification of estimation algorithm

Despite the fact that all of our parameters are identified and despite the fact that we have the requisite number (and quality of) instrumental variables to consistently estimate the coefficient on price and the non-linear parameters, we have very few observations, relative to the number of non-linear parameters that need to be estimated. Hence, despite our best efforts, we were not able to 'simultaneously' estimate the non-linear parameters of the model using the algorithm described above.

Hence, we slightly modified by the algorithm by changing step 5, so we estimate the non-linear parameters by an iterative grid search. In this grid search, we first fixed the standard deviations. For each value of ρ between -1 and 1 (in intervals of .01), we then used steps 2-4 in order to calculate the value of the GMM function. Once we found a 'preliminary' estimate for ρ, we then obtained preliminary estimates of the standard deviations via grid search. Once we found these preliminary estimates, we repeated the iterative grid searches for ρ and for the two standard deviations until we obtained convergence.

From this iterative process, it is clear that the estimate ρ is very close to (if not equal to) one. If we restrict ρ to be greater than 0.7, we can estimate all three non-linear parameters simultaneously (jointly.)

Appendix E: Supplementary Simulations

In this appendix, we report the additional simulations we refer to in the text. The first two sets of simulations (Tables E1-E3 and Tables E4-E6) show that our main results in Tables 4-6 in the body of the paper are robust to different cost structures.

In tables E1-E3, we assume that the marginal cost of the Microsoft suite is the sum of the marginal costs of the Microsoft components-- $175.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling															
MS Suite	255.1	0.26	20.8	20.8	101.8	244.0	0.27	18.2	18.2	85.7	230.5	0.28	15.2	15.2	66.3
Case II: Mixed Bundling															
MS word	143.9	0.01	0.7	21.36	98.5	142.0	0.03	1.73	19.8	80.3	139.8	0.04	2.67	18.04	61.0
MS SS	129.2	0.03	0.83			125.8	0.07	1.67			122.1	0.11	2.38		
MS Suite	255.9	0.25	19.83			245.5	0.24	16.40			231.9	0.23	12.99		

Table E1: Monopoly Market Structures and Correlation

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	Welfare	Price	share	Π	π-MS	Welfare	Price	share	π	π-MS	Welfare
Case I: Component Competition: No 'suite' bonus when purchasing both components															
MS Word	104.9	0.20	5.96	8.15	74.2	104.9	0.20	5.93	8.12	74.2	104.9	0.19	5.89	8.09	78.4
MS SS	119.0	0.12	2.19			119.0	0.12	2.19			119.0	0.12	2.19		
WP Word	92.2	0.09	1.76			92.2	0.09	1.75			92.2	0.09	1.74		
Lotus SS	94.2	0.07	1.16			94.2	0.07	1.16			94.2	0.07	1.16		
Case II: MS sells suites and components, (no suite bonus when purchasing both components)															
MS word	126.9	0.01	0.68	18.1	132.4	119.0	0.03	1.56	15.9	113.4	115.7	0.05	2.22	14	91.8
MS SS	130.9	0.02	0.69			124.3	0.06	1.35			121.1	0.10	1.97		
WP word	88.8	0.04	0.66			90.5	0.05	0.94			90.8	0.06	1.10		
Lotus SS	92.8	0.04	0.55			94.0	0.05	0.84			94.4	0.07	1.10		
MS suite	235.2	0.28	16.7			226.3	0.26	13.0			214.6	0.25	9.80		
Case III: MS sells only its suite (no suite bonus when purchasing both components)															
WP word	88.7	0.04	0.62		136.6	91.5	0.06	1.00		120	91.9	0.07	1.24		98.7 50.9
Lotus SS	92.8	0.04	0.54			94.9	0.06	0.95			95.9	0.08	1.41		
MS suite	235.0	0.30	17.6	17.6		225.3	0.30	14.6	14.6		213.1	0.31	11.5	11.5	

Table E2: Oligopoly competition: Louts and WordPerfect sell components

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	π	π-MS	Welfare	Price	Share	Π	π-MS	Welfare	Price	Share	π	π-MS	Welfare
Case I: Microsoft is alone in the market – and only sells suites															
MS Suite	255.1	0.26	20.79	20.79	101.8	244.0	0.27	18.2	18.2	85.7	230.5	0.28	15.17	15.17	66.3
Case II: All three firms sell suites															
MS suite	233.6	0.31	17.74	17.74	139.4	230.5	0.30	16.36	16.36	107.3	224.7	0.29	14.34	14.34	74.3
WP suite	139.3	0.01	0.17			139.2	0.01	0.13			139.1	0.01	0.09		
Lotus suite	124.9	0.02	0.36			124.7	0.02	0.28			124.5	0.01	0.18		
Case III: MS competes with merged suite – same cost for suites, both firms get MS bonus															
MS suite	200.6	0.25	6.18	6.18	242.5	200.1	0.25	6.08	6.08	198.4	199.4	0.25	5.96	5.96	146.1
Merged suite	201.1	0.26	6.47			200.6	0.26	6.38			199.9	0.26	6.26		

Table E3: Oligopoly Competition – firms only sell suites

The second set of simulations (Tables E4-E6) present the simulations in Table 4-6 for 1998. The estimated marginal costs are MS Word: $7.7; MS Excel: $122.8, MS Suite: $109.5; Lotus Spreadsheet: $50.5; WordPerfect Word Processor: $17.5. It seems implausible that the marginal cost of the suite is lower than the sum of the marginal costs of the components. For this reason, the costs for 1995 make more sense intuitively, which is why we decided to focus on the 1995 simulations. Nevertheless, Tables E4-E6 show that all of our main results are robust to the 1998 costs as well.

1998	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling															
MS Suite	198.1	0.31	27.88	27.88	133.5	186.9	0.33	25.75	25.75	119.1	174.0	0.36	23.53	23.53	101.1
Case II: Separate Selling															
MS word	72.8	0.25	16.10	17	71.4	72.7	0.25	16.11	17	73.7	72.6	0.25	16.26	17.16	76.4
MS SS	139.1	0.06	0.90			139.1	0.06	0.90			139.1	0.06	0.90		
Case III: Mixed Bundling															
MS word	84.9	0.02	1.68	28.3	129.1	84.2	0.04	3.32	26.75	113.0	83.0	0.06	4.40	25.2	93.6
MS SS	153.1	0.01	0.17			147.2	0.02	0.48			141.6	0.04	0.82		
MS Suite	198.6	0.30	26.42			188.0	0.29	22.96			174.9	0.31	20.00		

Table E4: Monopoly Market Structures and Correlation

1998	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	π	π-MS	CS
Case I: Component Competition: No 'suite' bonus when purchasing both components															
MS Word	56.7	0.28	13.8	14.6	92.2	56.7	0.28	13.83	14.6	95.8	56.7	0.28	13.96	14.7	100.8
MS SS	138.2	0.05	0.74			138.2	0.05	0.74			138.2	0.05	0.74		
WP Word	32.9	0.04	0.59			32.9	0.04	0.59			32.9	0.04	0.59		
Lotus SS	67.0	0.08	1.28			67.0	0.08	1.28			67.0	0.08	1.28		
Case II: MS sells suites and components, (no suite bonus when purchasing both components)															
MS word	79.1	0.02	1.73	27.0	145.2	71.7	0.05	3.47	24.8	133.2	69.6	0.07	4.45	23.1	113.8
MS SS	154.3	0.005	0.15			145.9	0.02	0.38			141.0	0.04	0.64		
WP word	32.0	0.02	0.26			32.6	0.02	0.34			32.6	0.03	0.38		
Lotus SS	65.0	0.03	0.48			66.6	0.05	0.81			67.3	0.07	1.17		
MS suite	190.4	0.31	25.11			178.1	0.31	20.93			165.6	0.32	18		
Case III: MS sells only its suite (no suite bonus when purchasing both components)															
WP word	31.9	0.02	0.23		155.0	33.4	0.02	0.38		143.4	33.4	0.03	0.45		124.5
Lotus SS	65.0	0.03	0.41			67.0	0.05	0.81			68.1	0.07	1.27		
MS suite	187.3	0.34	26.25	26.25		175.6	0.36	23.6	23.6		163.6	0.40	21.4	21.4	

Table E5: Oligopoly competition: Louts and WordPerfect sell components

1998	ρ=1					ρ=0					ρ=-1				
	Price	Share	π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	Share	π	π-MS	CS
Case I: Microsoft is alone in the market – and only sells suites															
MS Suite	198.1	0.31	27.88	27.88	133.5	186.9	0.33	25.75	25.75	119.1	174.0	0.36	23.53	23.53	101.1
Case II: All three firms sell suites															
MS suite	162.4	0.39	20.42	20.42	216	161.1	0.39	20.17	20.17	177.8	158.5	0.41	19.91	19.91	135
WP suite	41.6	0.03	0.40			41.5	0.03	0.37			41.4	0.02	0.32		
Lotus suite	57.4	0.05	0.72			57.3	0.04	0.66			57.0	0.04	0.57		
Case III: MS competes with merged suite – same cost for suites, both firms get MS bonus															
MS suite	138.3	0.38	11.06	11.06	304.6	135.4	0.42	10.77	10.77	271.5	128.7	0.50	9.57	9.57	247.1
Merged suite	128.0	0.18	3.42			126.8	0.18	3.06			124.7	0.15	2.32		
Case IV: MS competes with merged suite – same cost for suites, both firms get MS bonus + MS component quality															
MS suite	132.2	0.30	6.93	6.93	341.6	130.7	0.32	6.75	6.75	305.1	125.7	0.35	5.66	5.66	278.4
Merged suite	132.2	0.30	6.93			130.7	0.32	6.75			125.7	0.35	5.66		

Table E6: Oligopoly Competition – firms only sell suites

In Table (E7) below, we show that the niche-market effect obtains under pure bundling even when the market share served is close to 40%. In order to generate this simulation, we lowered the marginal cost of the suite by $80. We also show a simulation with the suite cost reduced by $150 in order to show that when the market share served is quite large, the niche-market effect disappears – and profits decrease in correlation under pure bundling.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling – MS Suite															
Base case	275.6	0.20	13.97	13.97	69.8	264.4	0.19	11.4	11.4	54.5	251.4	0.18	8.4	8.4	36.2
Cost less $80	223.6	0.34	36.8	36.8	171.3	212.8	0.4	35.0	35.0	157	200.3	0.45	33.4	33.4	140.1
Cost less $150	185.9	0.52	68.3	68.3	291.8	177.2	0.57	69.0	69.0	279.5	168.0	0.64	71.7	71.7	265.2

Table E7: Change in niche-market effect under pure bundling when firm serves a larger market

In Table E8 below, we show that (i) when there is no suite bonus and (ii) when word processors and spreadsheets enter both the demand and supply side symmetrically, profits decrease in the correlation coefficient (i.e., the standard intuition obtains) when the firm employs a mixed bundling strategy.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Mixed Bundling, symmetry across components - Without Suite Bonus															
MS Word	113.9	0.12	3.2	8.5	4.9	113.2	0.15	3.8	8.9	4.6	112.3	0.18	4.3	9.4	0.6
MS SS	113.9	0.12	3.2			113.2	0.15	3.8			112.3	0.18	4.4		
MS Suite	208.5	0.06	2.1			204.4	0.05	1.3			198.4	0.03	0.7		

Table E8: Symmetry on demand and costs and no suite bonus

Figure 1: Word Processor Market:1991
Total Market $952 Million:
DOS $567 Million, WINDOWS (W) $385 Million

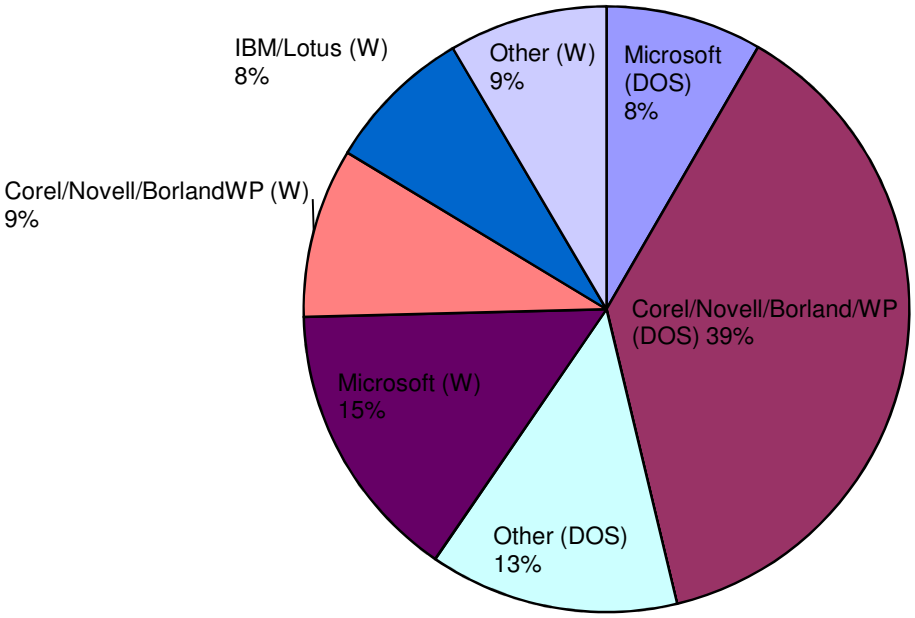


Figure 2: Spreadsheet Market:1991
Total Market $809 Million:
DOS $239 Million, WINDOWS $569 Million

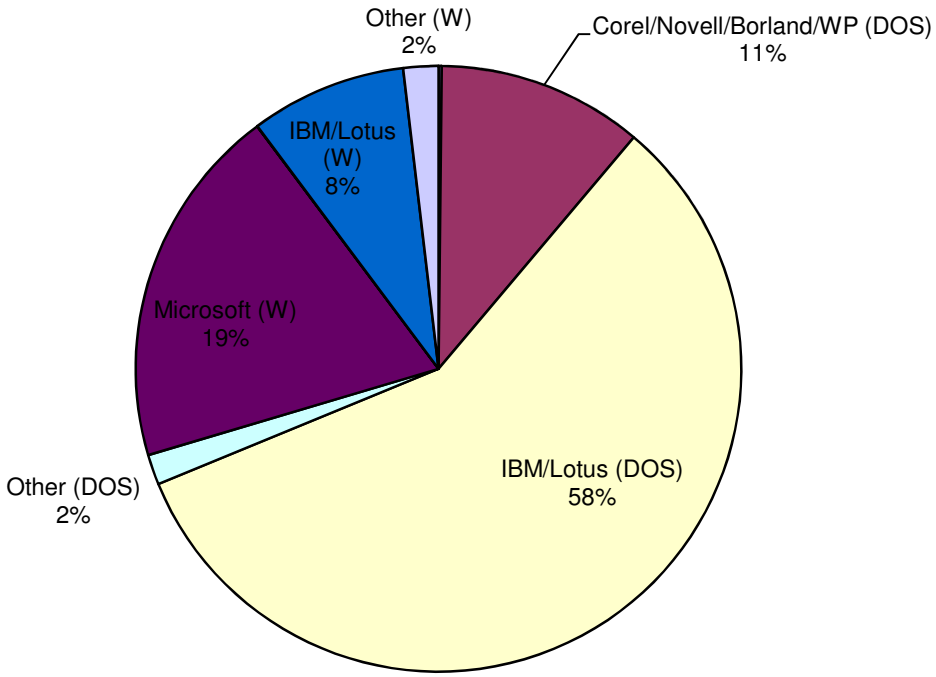


Figure 3: Office Software Revenue for WINDOWS Platform by Firm 1991-1998

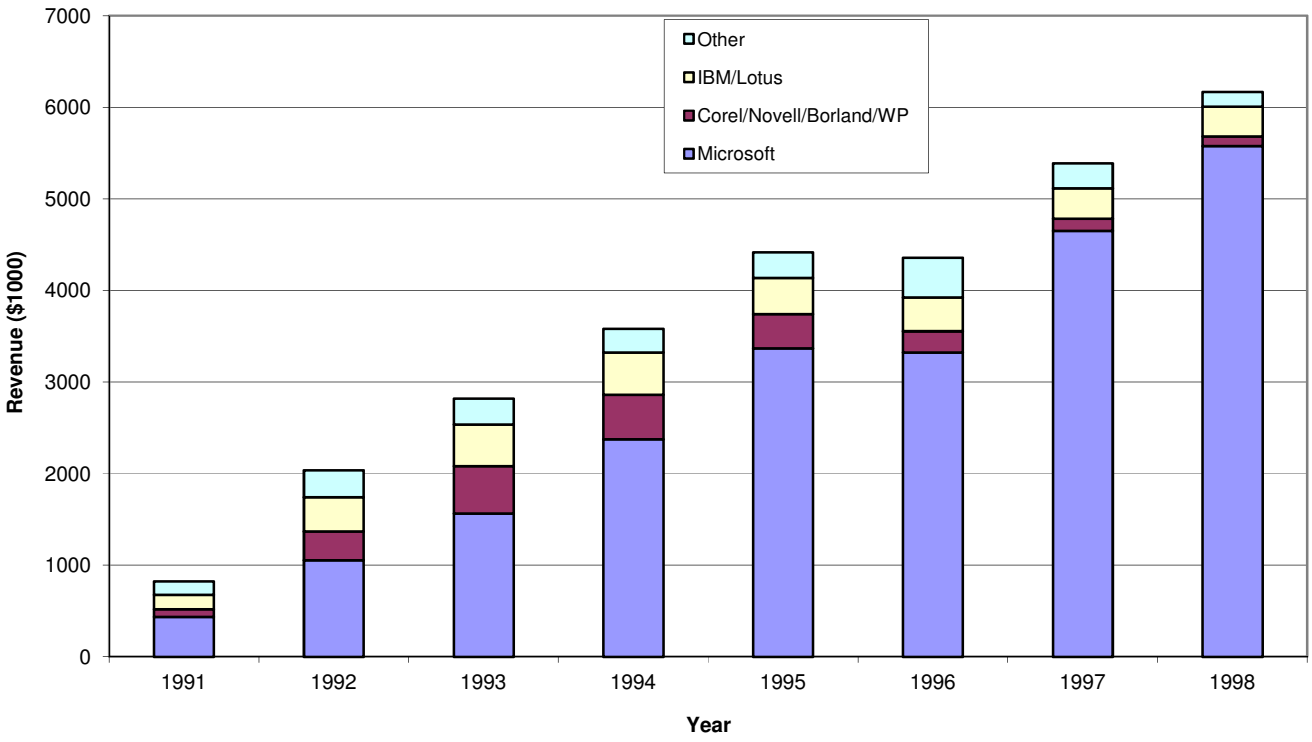


Figure 4: Office Software Revenue by Platform, 1991-1998

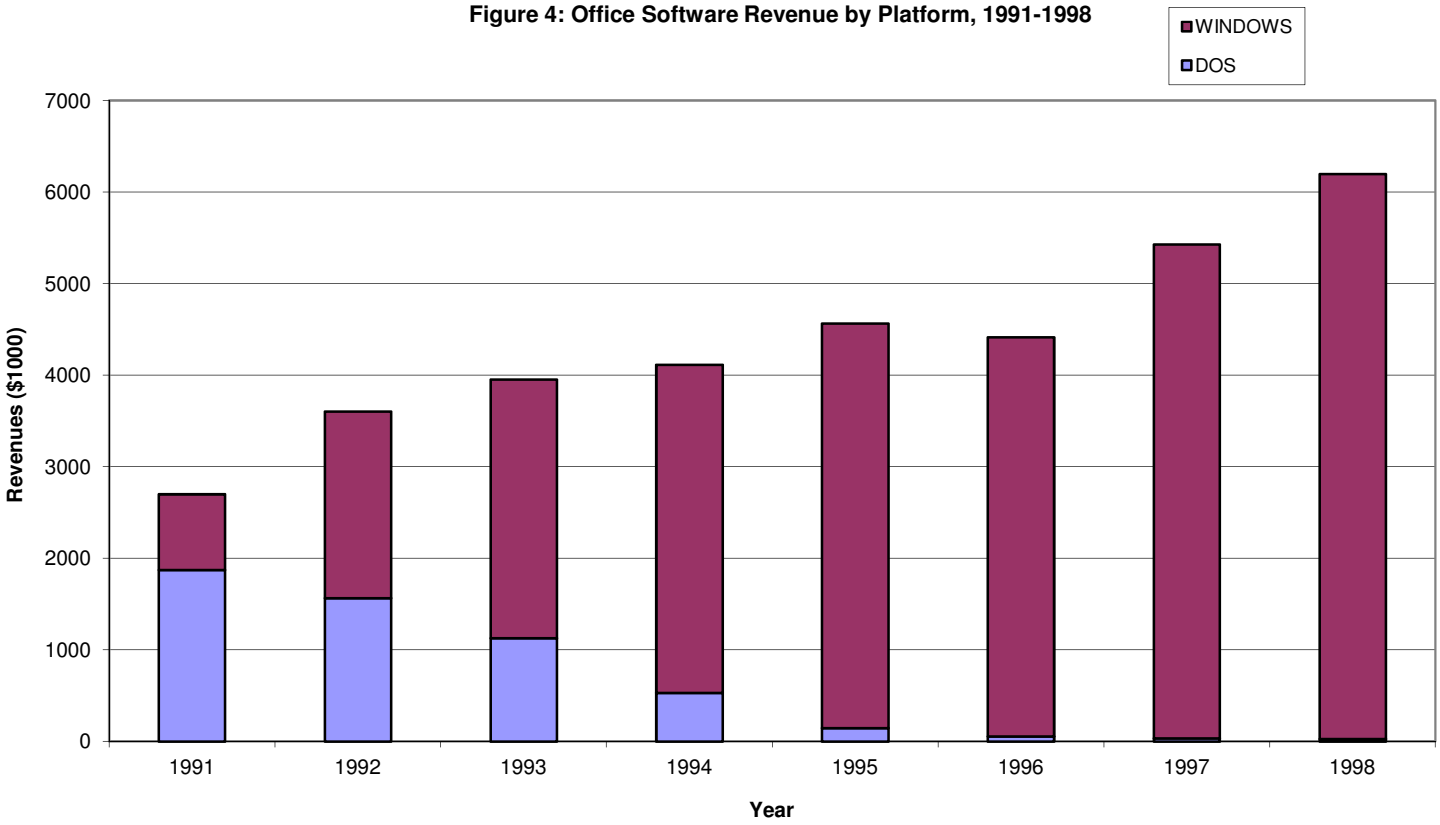


Figure 5: Windows Office Productivity (Revenue) Shares by Category, 1991-1998

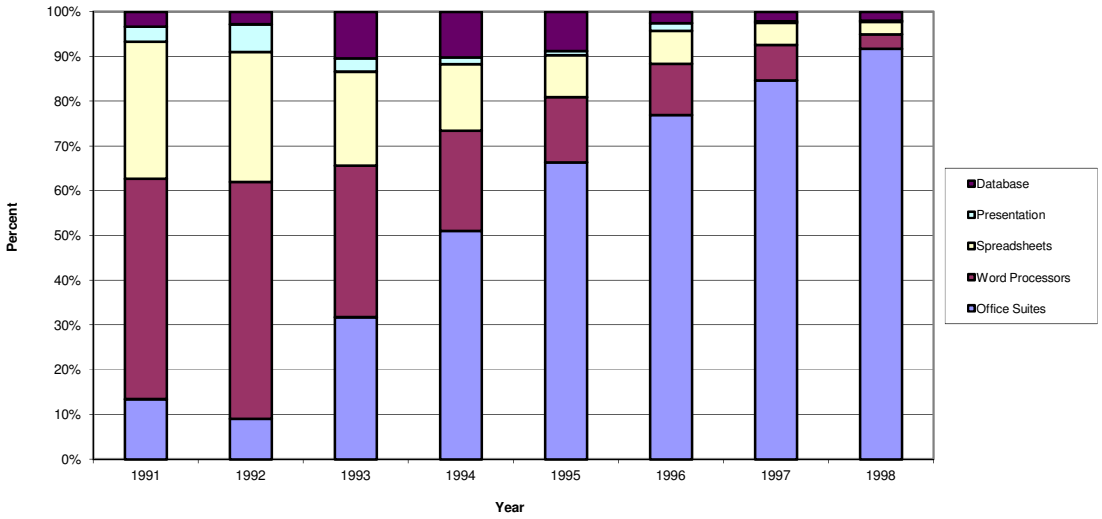
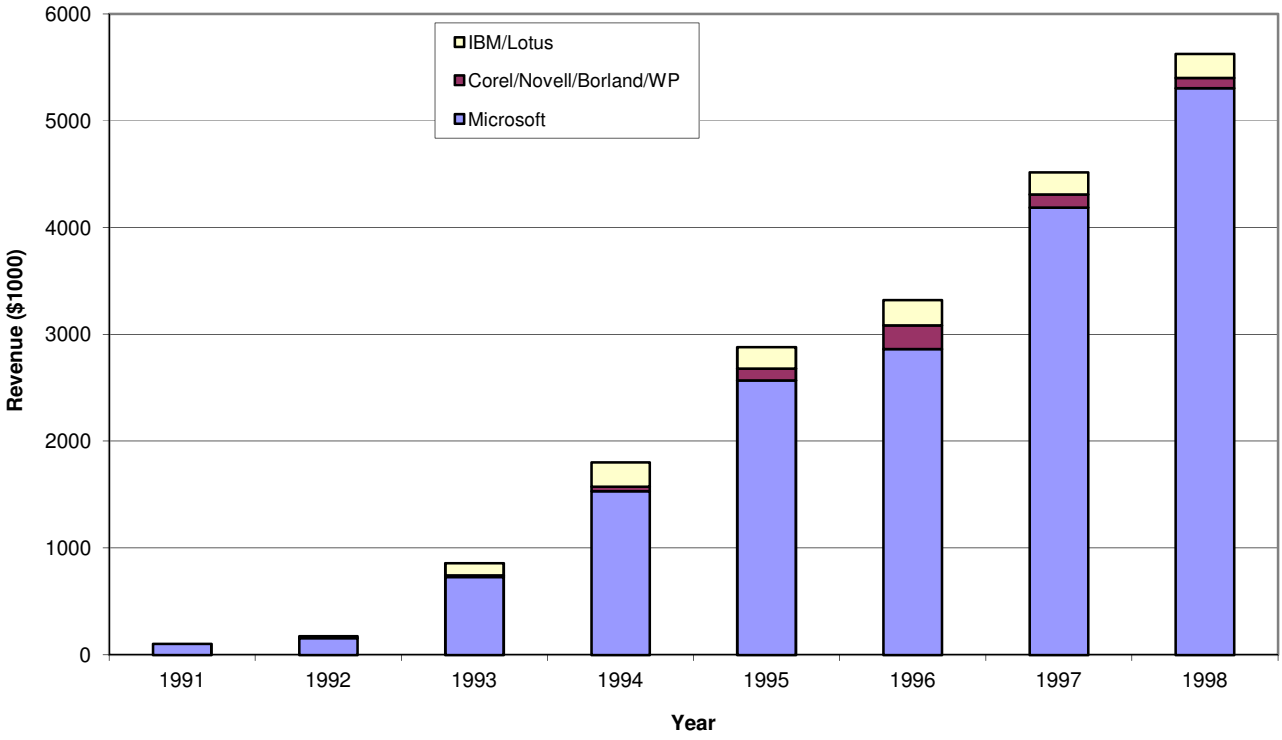


Figure 6: Office Suite Revenue by Firm 1991-1998



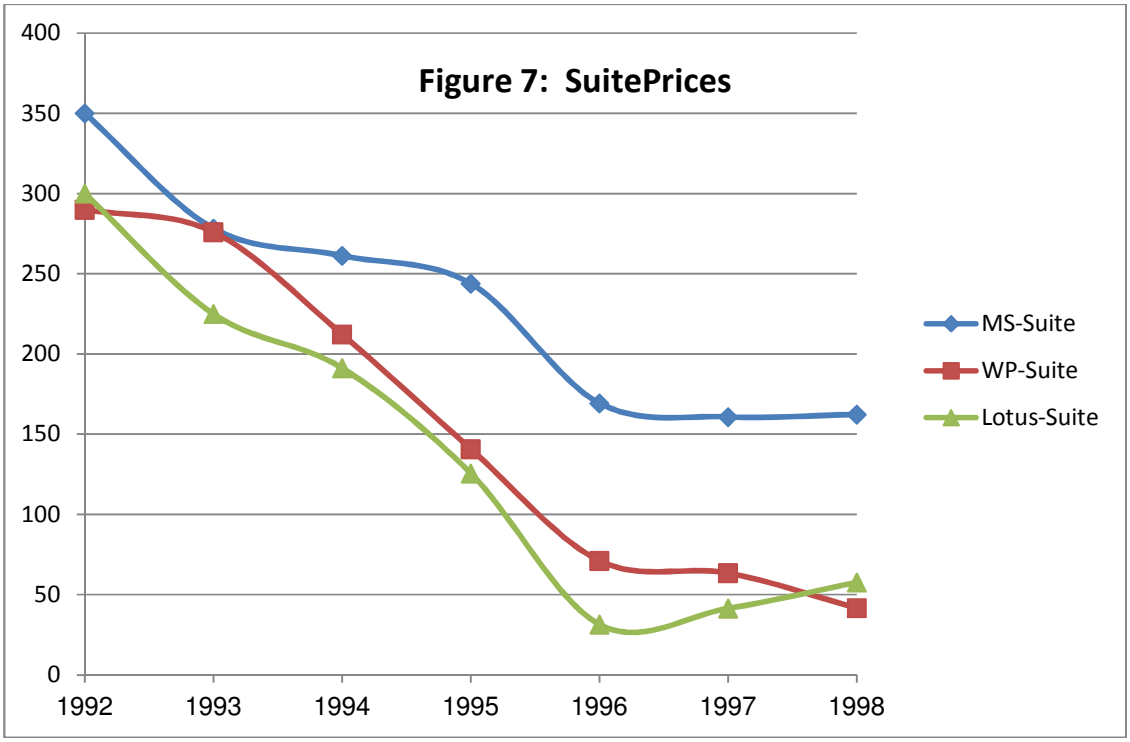


Figure 7: SuitePrices
400
350
300
250
200
150
100
50
0
1992
1993
1994
1995
1996
1997
1998
MS-Suite
WP-Suite
Lotus-Suite

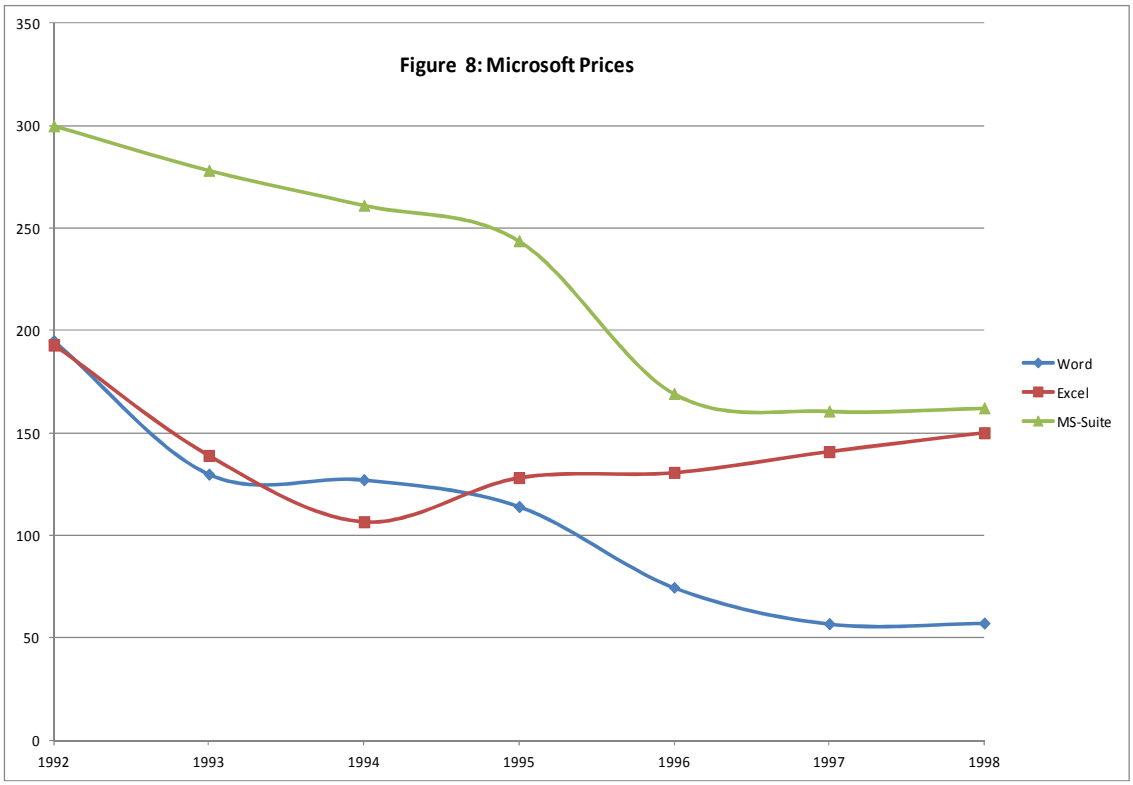


Figure 8: Microsoft Prices
350
300
250
200
150
100
50
0
1992
1993
1994
1995
1996
1997
1998
Word
Excel
MS-Suite

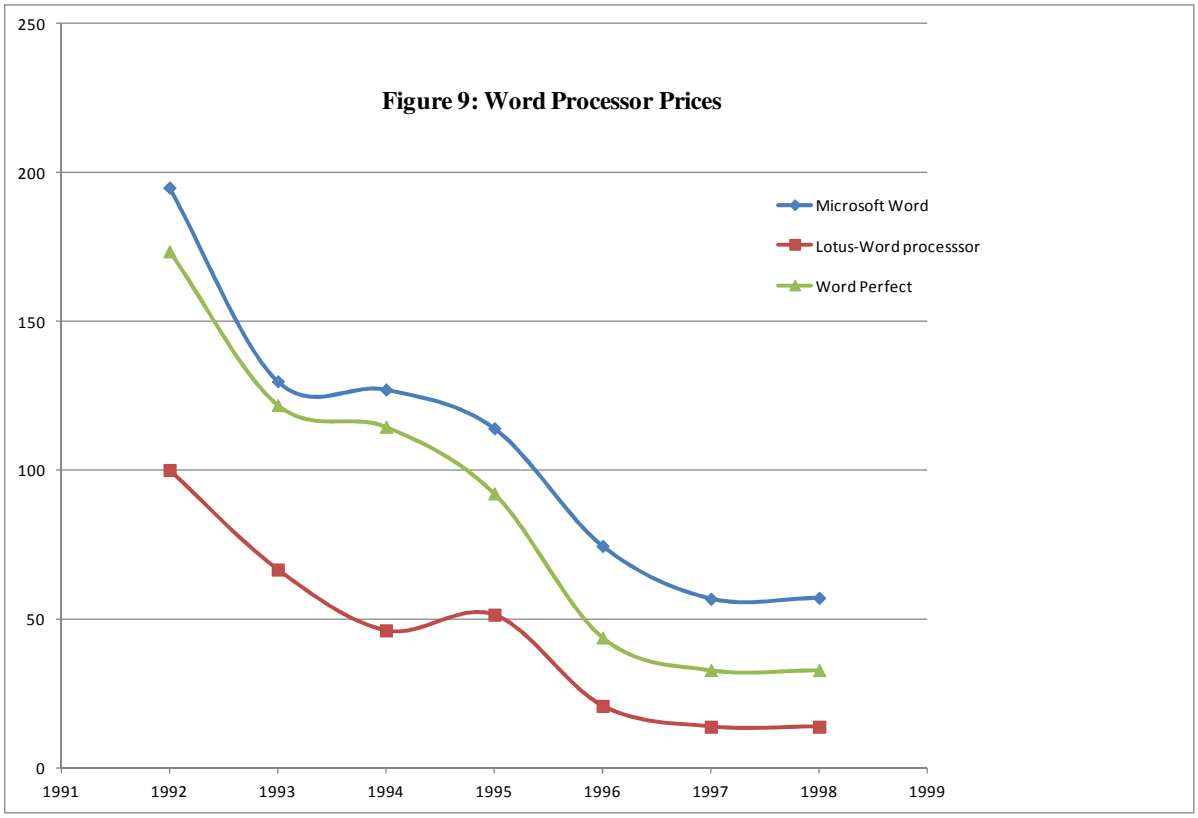


Figure 9: Word Processor Prices
250
200
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
Microsoft Word
Lotus-Word processsor
Word Perfect

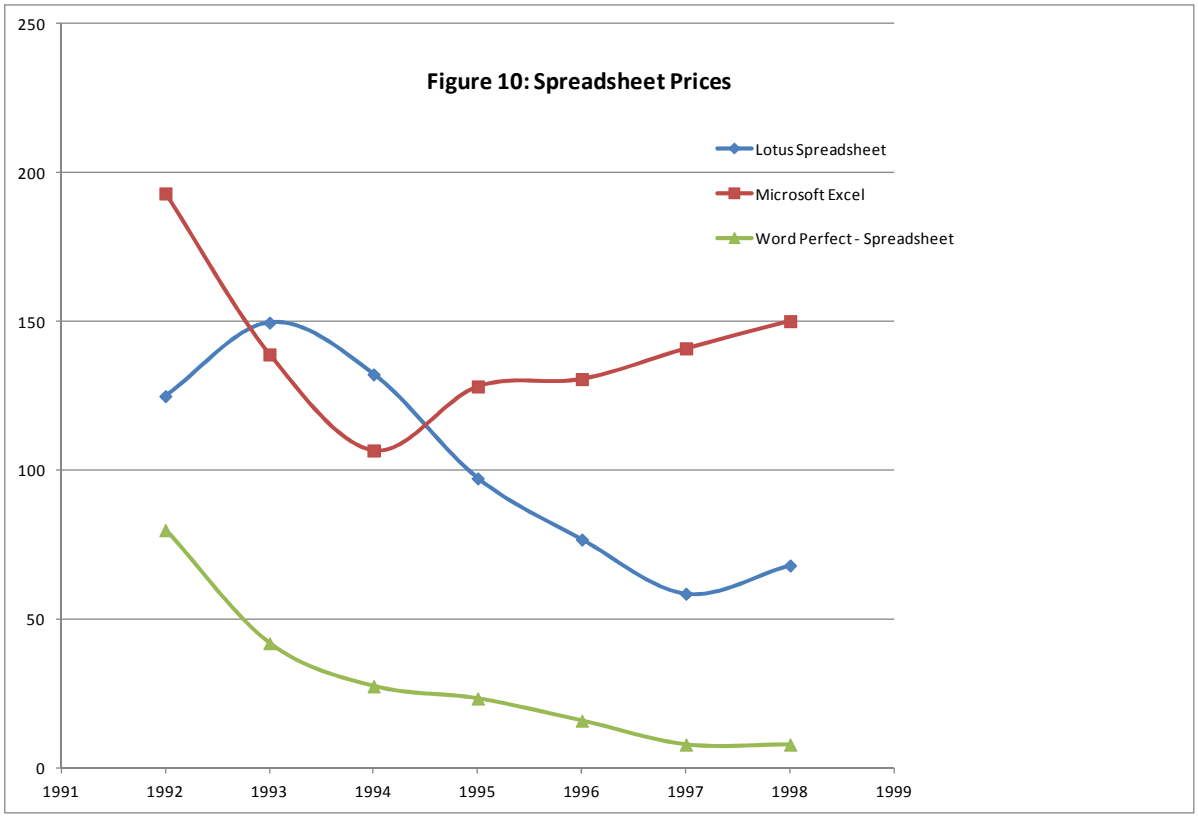


Figure 10: Spreadsheet Prices
Lotus Spreadsheet
Microsoft Excel
Word Perfect - Spreadsheet
250
200
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998
1999