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

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Abstract

Our paper examines the importance of strategic bundling for the evolution of market structure and the performance of the PC office software market. Using a discrete choice model of product differentiation, we find strong empirical support for negative correlation in consumer preferences over word processors and spreadsheets. Negative correlation between these components provides an explanation for why PC office software vendors adopted bundling strategies (suites). Optimal bundling adds value for a self-selected group of consumers, while sacrificing minimal revenue from other consumers.

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1. Introduction

There were dramatic structural changes in the office productivity software markets in the 1990's. The market grew tremendously from 1991-1998, the period for which we have consistent data. There was a shift from DOS based software programs to WINDOWS based software programs. There was also a shift in market leadership away from Lotus (in the spreadsheet market) and Wordperfect (in the word processor market) to Microsoft. Finally, there was a change in marketing strategy from selling components to selling office suites, where the components are integrated together in a single package.

The purpose of our paper is to analyze the importance of strategic bundling for the evolution of market structure and the performance of the PC office software market, where office software includes word-processors, spreadsheets, presentation software, database management software, and suites.

A key hypothesis we examine is whether there is negative correlation in consumer preferences over word processors and spreadsheets, the two most important components of the office software market. Our specification allows the correlation of consumer preferences over these components to be estimated without imposing any restriction on whether the goods themselves are complements or substitutes.

Using a discrete choice model of product differentiation, we find strong empirical (econometric) support that consumer preferences over word processors and spreadsheets are indeed negatively correlated. We find additional support for the negative correlation result from the Current Population Survey (CPS) Supplement on Computer and Internet use.

The negative correlation between word processors and spreadsheets provides an explanation for why the PC office software vendors adopted bundling strategies (suites). Optimal bundling adds value for a self-selected group of consumers, while sacrificing

minimal revenue from other consumers. Our empirical results are consistent with the notion that only Microsoft successfully integrated the components into a bundle.

We then perform ***

The paper extends the standard discrete choice model of product differentiation to the case when the choices potentially include more than one product. For example, the Microsoft Office suite contains both Microsoft Excel (a spreadsheet) and Microsoft Word (a wordprocessor). Hence, estimation must take account of these "combination" choices. Previous empirical work has not addressed this issue, despite the fact that this phenomenon is not unique to office software.[2]

Liebowitz and Margolis (1999) previously studied the evolution of word processor and spreadsheet markets. They heuristically argue that Microsoft's dominance of the word processor and spreadsheet markets is due primarily to the Microsoft's component products. We conduct an empirical (econometric) analysis and examine how product quality, bundling, and other factors affect demand in the office software market, a market that includes suites, as well as word processors and spreadsheets. Previous empirical work on the software industry has focused on the DOS market and on testing for the presence of network effects. See Gandal (1994) and Gandal, Greenstein, and Salant (1999).

The paper proceeds as follows. In section 2, we examine the incentives for strategic bundling. The basic model is difficult to analyze even in a monopoly setting. Extending the model to the duopoly case involves a very large parameter space. We therefore take the more modest approach of estimating a parametric model using data from PC office software market. Section 3 discusses the evolution of the PC office software market.

[2] Crawford (2001) 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 characteristics across products. Gentzkow (2004) employs a methodology similar to ours in examining the online newspaper industry.

Section 4 discusses the data we employ in our empirical analysis. In section 5, we develop the parametric model we estimate and we discuss the estimation algorithm.

Section 6 presents the empirical results. As noted before, we find strong empirical support in the data for the negative correlation hypothesis. We provide additional support for our empirical results from the Current Population Survey (CPS) Supplement on Computer and Internet.

Section 7 uses the estimated parameters to predict oligopoly conduct for two counterfactuals: (I) a merger between dominant firms in the word processing and spreadsheet markets in the DOS era and (II) a market structure in which bundling is not possible (e.g for legal reasons). Section 8 briefly concludes.

2. Incentives to Bundle in an Oligopoly

The economics literature lacks a well-developed economic theory of bundling by oligopolists selling independent products. There is substantial literature on monopoly bundling (Stigler 1963; Adams and Yellen 1976; Schmalensee 1982, 1984; McAfee, McMillan and Whinston 1989), and an established literature on oligopoly bundling of system components (Matutes and Regibeau 1988; DeNicolo 2000; Nalebuff 2000a). There is also a literature on bundling (or "tying") by an incumbent monopolist to deter entry or relax oligopoly competition in a second market (Whinston 1990; Carbajo, deMeza and Seidman 1990; Nalebuff 2000b; Choi and Stefanidis 2001). But relatively little is known about bundling by multi-product oligopolists selling independent products. There are some results about oligopoly bundling for discrete choice models in which consumer have independent utilities for different products. McAfee, McMillan, and Whinston (1989) extend their theory of monopoly bundling to argue that bundling cannot be absent in the Nash equilibrium in this case. Chen (1997) demonstrates an equilibrium incentive for an oligopolist to differentiate its product by bundling it with a competitively supplied product. But a detailed analysis of equilibrium incentives for bundling in which multi-market oligopolists sell independent products is lacking.

A possible model of duopoly bundling is as follows. Assume that Firms 1 and 2 each sell differentiated products A and B. A representative consumer's utility for product *i* sold by firm *f* is v_{if}. The four utilities have a joint distribution $F(v_{A1}, v_{B1}, v_{A2}, v_{B2})$ across the population of consumers. Consumers purchase at most one of each product depending on prices. For example, in the case of independent pricing, the firms set prices p_{if}, and a representative consumer is willing to purchase product i from Firm f if and only if $v_{if} - p_{if} = \max\{0, v_{i1} - p_{i1}, v_{i2} - p_{i2}\} \equiv w_i^*$. The demand for Firm f's product i is the mass of consumers for which this condition is true. If the firms also offer bundles at prices P_f, then the consumers demanding Firm f's bundle are those for whom $v_{Af} + v_{Bf} - P_f = \max\{W^*, w_A^* + w_B^*\}$, where $W^* = \max\{0, v_{A1} + v_{B1} - P_1, v_{B2} + v_{B2} - P_2\}$, and the consumers demanding Firm f's product A alone are those for whom $v_{Af} - p_{Af} = \max\{W^* - w_B^*, w_A^*\}$. Demands for the other product offers are similar. Given this demand structure, and the costs of producing the products, the two firms simultaneously choose prices (p_{Af}, p_{Bf}, P_f) to form a Nash equilibrium. Bundling occurs in equilibrium if $p_{Af} + p_{Bf} > P_f$ for at least one of the firms.

This is a complicated and difficult-to-analyze model, even with strong assumptions on $F(v_{A1}, v_{B1}, v_{A2}, v_{B2})$ and the cost functions. A straightforward approach is to specify $F(v_{A1}, v_{B1}, v_{A2}, v_{B2})$ and a cost function parametrically and analyze the model numerically. Schmalensee (1984) adopted this approach for the monopoly case with some success by assuming a bivariate normal distribution for consumer reservation values and constant returns to scale and scope. Extending this approach to the duopoly case obviously involves a much larger parameter space.

We take the more modest approach of estimating a parametric model using data from PC office software market, and analyze numerically the comparative static properties of the estimated model. In order to build some advance intuition for the properties of the estimated model, we discuss a simple oligopoly bundling model detailed in Appendix A. Production costs are assumed to be zero. Regarding demand, there are two types of

consumers: Type A consumers have utilities for varieties of product A according to a standard logit model, and have a small constant utility for product B. Type B consumers are similar, but with heterogeneous preferences for product category B. We show in the appendix that bundling (or mixed bundling) is a best response for an integrated firm selling in both markets.

The incentive for bundling arises in this simple model as a consequence of the structure of consumer preferences. Implicit is an assumption that the demand for the two products is negatively correlated. That is, consumers who have a high willingness to pay for product A have a relatively low willingness to pay for product B, and conversely. The assumed negative correlation in preferences enables a vendor offering a bundle to gain a competitive advantage in selling to one type of consumers without sacrificing revenues earned from the other. One way to understand this is to see that the seller effectively can increase the value of its offer to a group of consumers with a "bonus gift" of the other product. This is an attractive strategy as long as production costs are low (as is the case in computer software). It has been known since Stigler (1963) that a monopoly can earn additional revenue by either bundling or selling mixed bundles when consumer preferences for the components are negatively correlated. We extend Stigler's logic to the oligopoly case.

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.

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.[3] Competitors were later out of the gate, and 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-processor, spreadsheet, database, and graphics programs. As noted above, Microsoft was the first to sell suites; during this period, the main competition to Microsoft Office was single product applications sold by Word Perfect in the word processing market, and Lotus in the spreadsheet market.

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 improved, 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.

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

Microsoft's new office suite, released in early 1994, was extremely well received by computer software trade journals.[4] Microsoft Office 4.2 (including Word 6.0, Excel 5.0 and Powerpoint 4.0) was better integrated than the previous generation 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.[5] 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.[6]

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.[7] 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).

In the summer of 1995 Microsoft released WINDOWS95 and Office 95 simultaneously.[8] 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.

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[4] 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

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

[6] 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.

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

[8] Microsoft announced in July (1995) that it would ship its new version of its popular suite of application programs on August 24th, the same the 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.

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), causing 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 Processing and Spreadsheets are by far the most important two components of the PC office software packages — Figure 5 shows that these categories are much larger than the Presentation and Database Management Categories. During the 1991-1998 period, word processors, spreadsheets and suites accounted for more than 90% of PC Office software revenue. We focus on these products both in our simple model and in the empirical analysis.

There were essentially three firms in the office software market: Microsoft, IBM/Lotus[9] and Borland/Corel/Novell/WordPerfect (hereafter Corel/WP). 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

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

[9] IBM acquired Lotus in 1995.

system.[10] Packages that were compatible only with the Apple/Macintosh operating system, for example, were not included.

Data on prices and quantities (denoted PRICE and SALES) come from two Dataquest/Gartner Reports on Personal Computing Software, one for the 1992-1995 period and one for the 1996-1998 period.[11] Dataquest/Gartner reports (worldwide) sales and total revenues for each product; hence price is the average transaction price.[12] The variable SALES is the number of units sold (in thousands), and the variable PRICE is the average price.[13]

Data on quality of spreadsheets and word processors (denoted QUALITY) come from Liebowitz and Margolis (1999); 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. But this is not important, since the choice set is what is available in a particular year.[14] In the case of suites, QUALITY is the sum of the ratings of the relevant spreadsheet and word processor ratings.[15] For example, the rating for the

[10] 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.

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

[12] The data on unit sales (or shipments) is comprehensive and includes new licenses, upgrades, and units distributed through original equipment manufacturer (OEM) channels. For the period of our data, office software products were not typically bundled with the operating system.

[13] 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.

[14] 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.

[15] In theory, it may be preferable to employ a specification where there are two quality variables, one for spreadsheets and one for word processors. However, given the limited number of observations, we want as few parameters as possible.

Microsoft Office Suite is the sum of the rating for Microsoft Excel and Microsoft Word in the same year.[16]

We have an additional variable (denoted SCOPE) that measures the scope of the Suite. (This variable takes on the value zero for spreadsheets and word processors.) The main components of the Suites are Word Processors, Spreadsheets and Presentation programs (Powerpoint in the case of Microsoft, Presentations in the case of Corel/WP and Freelance Graphics in the case of IBM/Lotus). For each of the above three components, the variable SCOPE gets 1 point. For additional components in the Suites (such as email programs, etc.), there is an additional 0.25 points with a maximum of 0.5 points, since we don't want the measure to be affected by under-reporting or over-reporting of minor components. In later years, there is integration with Internet Browsers; in such a case, there is an additional point. By 1998, all suites obtain the maximum possible score of 4.5.

YEARXX is a yearly dummy variable for year 19XX; for example, YEAR93 is a yearly dummy for 1993. YEAR94-YEAR98 are similarly defined.

We now define some vendor variables. The variable COREL/WP takes on the value one for Corel/WP word processors and suites, since Word Perfect was the leading word processor before the switch from DOS to WINDOWS. Otherwise, this variable takes on the value zero. It's important to note that this is not a dummy variable for Corel/WP products. This variable measures a reputation effect in the word processing market.

Similarly, the variable IBM/LOTUS takes on the value one for IBM/Lotus spreadsheets and suites, since Lotus was the leading spreadsheet before the switch from DOS to WINDOWS. The variable MICROSOFT takes on the value one for Microsoft word

[16] Even if the components had little or no market share, the quality rating for the suite is still the sum of the ratings of the components. Unfortunately, we do not have quantifiable data on the quality of the suite for each year in the sample.

processors and spreadsheets, and two for Microsoft suites, since Microsoft emerged as the leader in both of these categories following the shift from DOS to WINDOWS.

We have an unbalanced panel of 52 model observations. Microsoft offered all three products in every year. In 1992, there were seven products available since only Microsoft sold suites.[17] In 1993-1995, there were nine products in the sample, as the other two firms offered suites as well. In 1996-1998, there were six products available in each year, as IBM/Lotus stopped selling word processors and Corel/WP essentially only sold Suites.[18]

Descriptive Statistics are shown in table 1.

Variable	Mean	Std. Dev.	Min	Max
SUITE	0.37	0.49	0	1
SPREADSHEET	0.34	0.48	0	1
WORD PROCESSOR	0.29	0.46	0	1
SALES (000s of units)	3449	5957	64	32683
QUALITY	9.35	0.80	7	10
PRICE ($)	126.45	71.77	23.4	350
MICROSOFT	0.77	0.72	0	2
IBM/LOTUS	0.23	0.43	0	1
COREL/WP	0.19	0.40	0	1
SCOPE	1.40	1.89	0	4.5
Y1993	0.17	0.38	0	1
Y1994	0.17	0.38	0	1
Y1995	0.17	0.38	0	1
Y1996	0.12	0.32	0	1
Y1997	0.12	0.32	0	1
Y1998	0.12	0.32	0	1

Table 1: Descriptive Statistics

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

[17] The Lotus/IBM suite was introduced late in 1992 and sales were negligible in that year.
[18] Corel/WP had a negligible share of the word processor market in 1996 and a negligible share of the spreadsheet market during the 1996-1998 period.

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.[19] The data in table 2 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.[20]

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 2: Sales of Operating Systems and Office Software Products (millions), 1992-1998.

5. Discrete Choice Model and Estimation

In this section, we formally specify our discrete choice model. 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 combination from different vendors.[21] Consumers

[19] The Dataquest reports and the Woroch et al (1995) data delineate between "DOS without WINDOWS" and "DOS with WINDOWS," so it straightforward to simply include the latter.
[20] See http://www.ntia.doc.gov/ntiahome/net2/presentation/slide14.html.
If a product is not available in some year, then the consumer discrete choice problem is modified accordingly.

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

$$U_{jk} = \delta_j + \theta_{jk}$$

where *j* indexes the product and *k* indexes the consumer. 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:

$$\delta_j = \beta_0 + \beta_1 * PRICE_j + \beta_2 * QUALITY_j + \beta_3 * YEARXX + \beta_4 * SCOPE_j + \beta_5 * VENDOR_j + \xi_j$$

The $\beta's$ are parameters to be estimated. The coefficients β_1 and β_2 capture the effect of the price and quality for a particular software product on the consumer's mean utility, where we assume that the quality of a suite or a "mix and match" spreadsheet-wordprocessor combination is the sum of the qualities of the individual components. Similarly the price of a "mix and match" combination is the sum of the prices of the components. The variable *SCOPE* measures the breadth of an office suite and therefore takes on the value zero for word processors, spreadsheets, and "mix and match" purchases. We also include year dummies (*YEARXX*) and vendor variables (*VENDOR*). Note that the coefficient vector is restricted to be the same for all products, and not vary by product category. We do this because, with only a limited amount of data, we are unable to estimate very many parameters with sufficient precision. The variable ξ_j is the mean value of any unobserved characteristics of product *j*.

Random Utility

The variable θ_{jk} is consumer *k*'s deviation from the mean utility of product *j*. Let $SPREADSHEET_j = 1$ if product *j* contains a spreadsheet and $SPREADSHEET_j = 0$ otherwise, and let $WORDPROCESSOR_j$ be a similarly defined dummy variable for wordprocessors. Then

$$\theta_{jk} = SPREADSHEET_j * \mu_{1k} + WORDPROCESSOR_j * \mu_{2k} + \varepsilon_{jk}$$

The variable μ_{ik} ($i = 1$ for a spreadsheet and $i = 2$ for a wordprocessor) 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 wordprocessor. These variables introduce consumer heterogeneity for the demand for different categories of software products. It allows that some consumers place a high value on having a wordprocessor, while other consumers have a great need of a spreadsheet. For suites and "mix and match" combinations, the consumer receives random utility $\mu_{1k} + \mu_{2k}$. An important feature of this specification is that it allows a consumer's demand for a wordprocessor to be correlated with the consumer's demand for a spreadsheet. These utility components are assumed to have a symmetric mean-zero bivariate normal distribution, i.e., $(\mu_{1k}, \mu_{2k}) \sim N(0,0,\sigma^2,\sigma^2,\rho)$, where σ^2 is the variance and ρ is the correlation coefficient. We estimate the parameters of this distribution, with a particular interest in the correlation coefficient.

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 products in a particular software category or products involving two software categories enters only through this variable. The assumptions on ε_{jk} determine substitution patterns

among the products. The ε_{jk} are assumed to be independently and identically distributed according to a standard double exponential distribution. This is the error structure employed in the usual logit demand model. It permits a convenient characterization of expected market shares, as described below.

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

$$P_{jk} = \frac{e^{\delta_j + SPREADSHEET_j * \mu_{1k} + WORDPROCESSOR_j * \mu_{2k}}}{1 + \sum_{l=1}^{15} e^{\delta_l + SPREADSHEET_l * \mu_{1l} + WORDPROCESSOR_l * \mu_{2l}}},$$

and the probability that consumer k makes no purchase is

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

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 wordprocessor. Let product *j'* refer to the standalone wordprocessor, and let *j''* and *j'''* refer to the two "mix and match" combinations that involve that wordprocessor. 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 wordprocessors of other vendor's, it is straightforward to calculate simulated market shares in the wordprocessor category. Obviously, the validity of these calculations requires a large number of consumers.

Estimation Algorithm

Let

$$\mu_{1k} = X_{1k} + \alpha X_{2k}$$

and

$$\mu_{2k} = \alpha X_{1k} + X_{2k}$$

where X_{1k} and X_{2k} are i.i.d. standard normal random variables. Then (μ_{1k}, μ_{2k})~N(0,Σ) with

$$\Sigma = \begin{bmatrix} 1+\alpha^2 & 2\alpha \\ 2\alpha & 1+\alpha^2 \end{bmatrix}$$

The correlation coefficient is $\rho = \frac{2\alpha}{1+\alpha^2}$. Thus there are two values of α that yield the same value of ρ.

The estimation algorithm proceeds in several steps.

Step 1: Take random draws of (X_{1k}, X_{2k}) for 100,000 consumers per year. Each consumer makes a single choice.[22]

Step 2: Assume an initial value for α, 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 is obtained.[23,24]

Step 3: Given δ, we compute the implied values of the unobservables, i.e., $\hat{\xi} = \hat{\delta} - X\hat{\beta}$, where X is the matrix of right hand side variables, Z is the matrix of exogenous right hand

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

[23] 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, Levinsohn, and Pakes (1995) for details.

[24] 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.

side variables and instrumental variables,[25] and $\hat{\beta} = \left(X'ZWZ'X\right)^{-1} X'ZWZ'\hat{\delta}$ is the vector of estimated parameters.[26]

Step 4: We evaluate the GMM objective function $\hat{\xi}'ZWZ'\hat{\xi}$

Step 5: We then update the guess for α, and return to step 2.[27]

Since price is endogenous, we instrument for it. Following other authors, we use the average quality of characteristics of other products as instruments. In particular, we have three instruments for price: (I) the average quality of other products sold by the same firm in the same year, (II) the average quality of other products in the category (word processor, spreadsheet, and suites) in the same year, and (III) the average scope of all other products in the same year. In years, when there are no other competing products in the category, the quality of the other products is zero.

6. Empirical Results

Table 3 contains our estimates.

[25] Since price is endogenous, we instrument for it. Following other authors, we use the average software quality of other products in the same year and category (word processor, spreadsheet, and suites) as an instrument for price. In years, when there are no other competing products in the category, the quality of the other products is zero.

[26] We employ $W=(Z'Z)^{-1}$. As Nevo (1998) notes, this matrix yields efficient estimates under the assumption that errors are homoskedastic.

[27] The estimate of α is updated by Matlab using the Golden Section search and parabolic interpolation.

Variable	Coefficient Estimates	T-Statistics
Constant	-3.45	-2.43
Price	-0.025	-1.42
Quality	0.21	0.58
Scope	0.24	0.28
Microsoft	3.11	3.12
Corel/WP	2.31	1.53
IBM/LOTUS	2.10	2.19
Correlation (ρ)	-0.70	-14.79
YEAR93	-0.78	-1.17
YEAR94	-2.40	-3.33
YEAR95	-3.87	-4.98
YEAR96	-4.23	-2.59
YEAR97	-4.62	-2.86
YEAR98	-5.00	-3.27

Table 3: Parameter Estimates and T- Statistics[28]

Notice that all coefficients have the expected sign. The estimated coefficients on PRICE and QUALITY are not statistically significant.

The coefficient estimate associated with the variables MICROSOFT are IBM/ LOTUS are statistically significant. The estimated coefficient on Microsoft is approximately 40 percent larger than the coefficients on IBM/LOTUS and COREL/WP, although the difference in magnitude among the coefficients is not statistically significant. This suggests that while IBM/Lotus provided significant competition in the spreadsheet category and Corel/WP provided strong competition in the word processor category, neither firm provided significant competition in the suite category. That is, the IBM/Lotus and Corel/WP suites were essentially viewed as offering little more than the relevant component for which the firm was successful in the DOS market. The results are consistent with the notion that only Microsoft successfully integrated the components into a bundle. (Recall that we've controlled for the quality of the components.)

[28] Since we estimate α, the standard error of ρ is found by the delta method.

Casual empiricism indeed suggests that the other suites were not integrated as well as Microsoft's suite.[29] Liebowitz and Margolis (1999) note, "When they [Microsoft's competitors] did assemble competing suites, they tended to cobble together products that had little in common." 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…"[30] Data compiled from trade journals, as summarized in Appendix B, are consistent with the above assessments.[31]

Although the estimated coefficient on SCOPE has the expected sign, it is not statistically significant. The yearly dummy variables capture the inside vs. outside valuation year by year. 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. That is more consumers elected not to purchase an office software product in later years. Indeed the correlation between the percentage of consumers choosing to purchase an office software product and the coefficients of the yearly dummy variables is 0.88.

The estimated value of α implies a correlation coefficient of -0.70. This implies that there is a strong negative correlation in preferences for word processors and spreadsheets, the two most important components of the office software market.

In order to get a feeling about the negative correlation result, we simulated the market with both zero correlation and a positive correlation of 0.70. The results show that in both cases, the simulations underestimate the market share of wordprocessors and

[29] It is not possible to formally add integration or cross application compatibility to the data set since (as noted above) we do not have data on these measures for each year to year.
[30] See "Corel's Nearly Perfect Suite Spot," available at http://www.byte.com/art/9707/sec11/art4.htm#077ev2t1.
[31] Indeed, it seems that Microsoft still retains a significant advantage in its ability to integrate the components better than its competitors. ZDNet reviews of the most recent versions of suites, as summarized in Appendix B, suggest that the Corel/WP and IBM/Lotus suites still do not integrate the components of their suites as well as Microsoft does.

spreadsheets, and overestimate the market share of suites. These effects are especially prominent in early years, when consumers indeed purchased components in relatively large numbers. (In later years, the same effects are still present, but they are much smaller, because most of the sales involve suites.)

The intuition is that positive correlation greatly reduces the probability that an individual will purchase either a word processor OR a spreadsheet but NOT both. Indeed, many consumers likely purchased just one of the two components in the early years, but positive correlation does not pick this effect up. Thus, shares of word processors and spreadsheets are underestimated under the assumption of positive correlation in consumer preferences over the components.

As expected, the "zero correlation" simulation does better than the positive correlation simulation in picking up these effects, but it does not do nearly as well as the estimated negative correlation. Thus again, the shares of word processors and spreadsheets are underestimated under a simulation with no correlation of consumer preferences.

6.1 Support for the negative correlation result from the Current Population Survey

In order to further assess whether our estimate of the negative correlation is reasonable, we obtained survey data from the Current Population Survey (CPS) Supplement on Computer and Internet use from September 2001.[32] 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 180,000 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:[33]

[32] 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.
[33] The possible answers are either yes or no.

1. Do you use the computer at home for word processing or desktop publishing?
2. Do you use the computer at home for spreadsheets or databases?

The weighted results yield the following information: 64% of the individuals answered yes to at least one of the first two questions. We'll refer to this as the relevant group. Of these individuals, 43% answered yes to both questions, 50% answered yes to question 1 and no to question 2, while 7% answered yes to question 2 and no to question 1. That is, only 43% of the relevant group used both word processors and spreadsheets. This provides strong support for our negative correlation estimate.

A similar question was asked regarding computer use at work.

3. Do you use the computer at work for word processing or desktop publishing?
4. Do you use the computer at work for spreadsheets or databases?

Here, 79% of the individuals answered yes to at least one of the first two questions. Of these individuals, 63% answered yes to both questions, 21% answered yes to question 3 and no to question 4, while 16% answered yes to question 4 and no to question 3. Again, a relatively large percentage of the relevant group used either word processors or spreadsheets (but not both) at work. This again provides strong support for our negative correlation estimate.

7. Counterfactuals

This section uses the estimated parameters to predict oligopoly conduct for two counterfactuals: (I) a merger between dominant firms in the word processing and spreadsheet markets in the DOS era and (II) a market structure in which bundling is not possible (e.g for legal reasons).

7.1 What might have happened if Lotus and Word Perfect had merged?

Here we examine how competition in the office software market might have developed if Lotus and Word Perfect had merged together into a single suite.

In order to conduct the counterfactual, in the case of the variable QUALITY, we employ the sum of the Corel/WP wordprocessor and the IBM/Lotus spreadsheet. Since the scope of both the Corel/WP and IBM/Lotus suites were identical in 1998, we use that value. We assume that the price of the merged suite is equal to the maximum of the Corel/WP and IBM/Lotus prices. The simulation shows that Microsoft still would have had the dominant share of the market, but the merged suite would have provided more competition.

Actual/Simulated Market Shares (1998)	Microsoft Share	Lotus/WP share
Actual Market Shares[34]	84%	16%
Simulated Market Shares	62%	38%

Table 4: Actual and Simulated Market Shares of the suite market in 1998

7.2 A market structure in which bundling is not possible

As noted before, a firm has an advantage when selling bundles while unintegrated rivals only sell components. In order to examine this issue, we simulated the market for the case in which suites are not offered in the market. In this simulation, we add the "same" vendor combinations (i.e., Microsoft Word and Microsoft Excel combination) to the choice set. For the simulation, we employ the prices that were charged in the component market.

The results in the table below for 1995 are quite illuminating.[35] In order to facilitate the comparison, we add the actual suite sales to the sales of components. The simulation illustrates that the "duopoly" rivalry that existed in the latter years of the DOS market (between MS Word and Word Perfect in wordprocessors and between MS Excel and Lotus 123) likely would have continued had suites not been introduced. Microsoft still would have had the dominant share of the market, but this share would not have been as large as in the case in which suites were sold as well.

[34] Actual market shares are for the two suites that competed with Microsoft.
[35] We chose 1995 because that is the last year that all products in the data set are available. Hence we have a price for each component.

Firm	Price(WP)	Wordprocessor Market Share		Price (SS)	Spreadsheet Market Share	
	Actual	Actual	Simulations	Actual	Actual	Simulations
Microsoft	$114	73%	59%	$128	74%	59%
Corel/WP	$92	16%	34%	$23	7%	12%
IBM/Lotus	$52	11%	7%	$97	19%	29%

Table 5: Actual and Simulated Market Shares of Wordprocessors and Spreadsheets: 1995

8. Further Discussion and Conclusion

In this paper, we examined the importance of strategic bundling for the evolution of market structure and the performance of the PC office software market. Using a discrete choice model of product differentiation, we found strong empirical support for negative correlation in consumer preferences over word processors and spreadsheets. Negative correlation between these components provides an explanation for why PC office software vendors adopted bundling strategies (suites). Our simulations indicate that the market may have evolved very differently had Lotus and Word Perfect merged or if bundling had not been possible. The latter simulation emphasizes the importance of bundling for the evolution of the PC office software market.

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Appendix: A Simple Bundling Model

Here we introduce a simple model of strategic bundling. The purpose of this model is to build intuition about bundling incentives and the consequences of bundling, to help explain the evolution of the PC office software market.

1. Basic Logit Model

The basic logit duopoly model is our main building block. The model features two differentiated products, a vendor for each, and an outside option. The vendors are indexed $i = 1, 2$. Consumers are willing to pay

$$\frac{1}{\lambda}\left(U_i + \theta\right)$$

for product *i*, where λ is a parameter, U_i is a common value, and θ is a private value with a standard double exponential (i.e. Type I extreme value) distribution.[36] The value of the outside option is U_0.

The share of consumers purchasing from vendor *i* is

$$S_i = \frac{e^{U_i - \lambda P_i}}{e^{U_0} + e^{U_1 - \lambda P_1} + e^{U_2 - \lambda P_2}}.$$

where the subscripted *P*'s denote prices.

Assuming zero variable costs, each vendor maximizes revenue in Nash equilibrium. The first-order conditions for equilibrium revenue maximization imply

[36] λ can be interpreted as the parameter of a general double exponential distribution function with variance $\frac{\pi^2}{6\lambda^2}$. See Anderson, dePalma, and Thisse (1992, p. 39-42.) Thus the variance of θ in the formulation above is $\frac{\pi^2}{6}$.

$$P_i = \frac{1}{\lambda(1-S_i)}.$$

Therefore, at a Nash equilibrium,

$$S_i = \frac{e^{U_i - U_0 - \frac{1}{1-S_i}}}{1 + e^{U_1 - U_0 - \frac{1}{1-S_1}} + e^{U_2 - U_0 - \frac{1}{1-S_2}}},$$

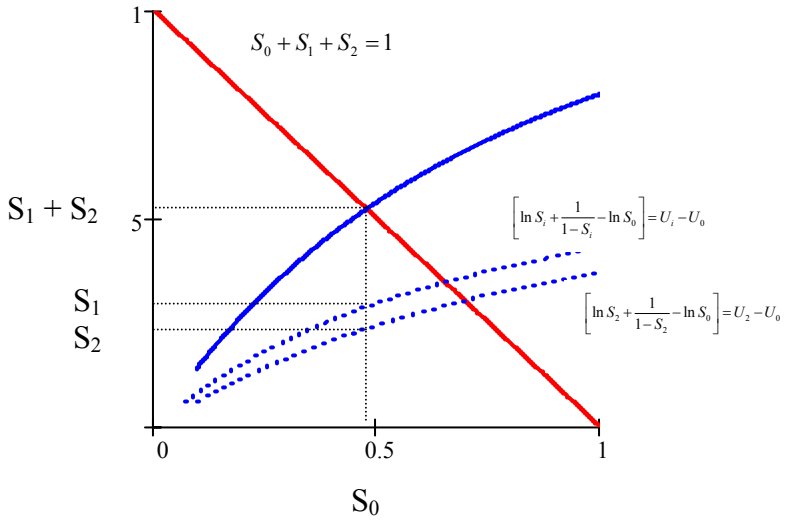
and

$$\left[\ln S_i + \frac{1}{1-S_i} - \ln S_0\right] = U_i - U_0,$$

where

$$S_0 = 1 - S_1 - S_2.$$

The accompanying graph illustrates the determination of equilibrium quantities.



The two upward sloping dotted lines graph the equilibrium consumer shares of vendors 1 and 2, respectively as a function of S_0, and the upward sloping solid line sums the two. Thus the upward sloping "market size locus" graphs $S_1 + S_2$ as a function of S_0. Equilibrium is determined by the intersection of market size locus with the downward "adding up constraint".

It can be deduced from these relationships that an increase in either U_1 or U_2 expands the market, that is, S_0 is decreasing in U_i. Moreover, S_1 is increasing in U_1, and S_2 is decreasing in U_1, and conversely. A vendor with higher quality product raises its price, but by less than the quality increment, thus causing the rival to cut its price in order to stem a loss in market share.

These comparative static results follow immediately from a graphical analysis. An increase in U_1 shifts up the (dotted line) locus labeled $\left[\ln S_1 + \frac{1}{1-S_1} - \ln S_0\right] = U_1 - U_0$, which in turn shifts up the market size locus. The new intersection of the market size locus with the adding-up constraint occurs at a lower value of S_0. Reading off the graph, S_2 must be lower at lower value of S_0, because $\left[\ln S_2 + \frac{1}{1-S_2} - \ln S_0\right] = U_2 - U_0$, and the adding-up constraint implies a higher value of S_1.

Market shares are calculated as $s_i = \frac{S_i}{S_1 + S_2}$, and

$$\left[\ln s_1 + \frac{1}{1-s_1}\right] - \left[\ln s_2 + \frac{1}{1-s_2}\right] = U_1 + U_2.$$

Thus Vendor *i* 's market share of increases with its product quality.

Proposition: An increase in the quality of a product increases its market share and expands the market. The price and purchases of the product increase, while those of the rival decrease.

2. Two Product Categories

Suppose there are two product-categories and two vendors for each kind of product. The vendors are indexed $i = A1, A2$ for product category A, and $j = B1, B2$ for category B.

There are two types of consumers. Type A consumers have a willingness to pay for product Ai equal to

$$\frac{1}{\lambda_A}\left(U_i + \theta_i\right)$$

where U_i indicates (vertical) product quality, and θ_i is an idiosyncratic preference parameter with a standard double exponential distribution. Type A consumers also have a common incremental value of β for any variety of product B. Similarly, Type B consumers have a willingness to pay for product B_j equal to

$$\frac{1}{\lambda_B}\left(V_j + \eta_j\right),$$

and incremental value of α for product A.

If the products are sold separately, and the parameters α and β are sufficiently small, then the basic logit model applies to each product category. Vendors of product A sell only to Type A consumers, and likewise for product B. In each market, the price cut necessary to attract the other type of consumer would sacrifice too much revenue.

3. Unilateral Bundling

Next suppose that Vendor 1 is integrated and offers a bundled product at price P_1. The bundle gives Type A consumers an additional value of β, and Type B an additional value of α. These "quality improvements" effectively increase U_1 and V_1. If the markets are symmetric, then the proposition applies to each market. The effect of bundling is to increase the quality of Vendor 1's product in each of the two markets.

More generally, pure bundling is a mixed blessing. On the one hand, bundling offers more value to each customer class at no cost, and thus is a source of competitive advantage. On the other hand, the bundle is sold at a single price, thus preventing price discrimination between the two types of consumers. If, however, equilibrium prices for products $A1$ and $B2$ (*sans* bundling) are sufficiently close, then unilateral bundling by Vendor 1 must be profitable.

When price discrimination is an attractive revenue-maxizing strategy, then mixed bundling is the more profitable strategy. For example, suppose that A is the high-price product category, and β exceeds α . The firm could sell a bundled product to Type A consumers, maintaining a high price, and continue to sell a stand-alone product B to Type B consumers at a discounted price.[37]

In any case, either a pure bundling strategy or a mixed bundling strategy dominates selling the two products separately.[38] The consequence of bundling is to expand the market share of whichever consumer type is attracted to the bundle. With reference to the graph above, the greater value of the bundle is equivalent to an increase in U_1. Applying the proposition, the firm gains market share while raising its price. The rival loses market share, while the market expands. If a pure bundling strategy is an equilibrium best response, and price discrimination is unimportant, then the firm gains share in both product categories.

4. Competitive Bundling

Now suppose that Vendor 2 is also vertically integrated. Bundling or mixed bundling is now a best response for both vendors. Therefore, in equilibrium, both firms offer a bundled product. The main effect here is to expand the size of the market. Both firms gain sales compared to the no-bundling case, but the effect of bundling on the market shares of the two firms is ambiguous.

5. Key Feature of the Model

The strategic incentives for bundling arise in the model as a consequence of the assumed demand structure of consumer preferences. Implicit is an assumption that the demand for two products is strongly negatively correlated. That is the consumers, who have a high

[37] Clearly the discount must exceed α. Otherwise, the two consumer classes would not separate.
[38] We are assuming that product selection and pricing decisions are simultaneously. Thus, the claim is that bundling or mixed bundling is always a best response to the prices of the rivals in each market. This claim is obvious given of the no-cost competitive advantage that a either a pure or mixed bundling strategy affords.

willingness to pay for product A have a relatively low willingness-to-pay for product B, and conversely. This negative correlation in preferences enables a vendor offering a bundle to gain a competitive advantage in selling to one group of consumers without sacrificing revenues earned from the other group.

Appendix B

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 6: 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 7: 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
Cross-Application Compatibility (CAS)	8	5	6
Overall Rating	7.8	7.2	7.2
Overall Rating without CAS	7.75	7.75	7.5

Table 8: Reviews from ZDNet 2001

ZDNet overall ratings are compiled by averaging across all five of the components listed in the above table.[39] The only real 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.

[39] 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.

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

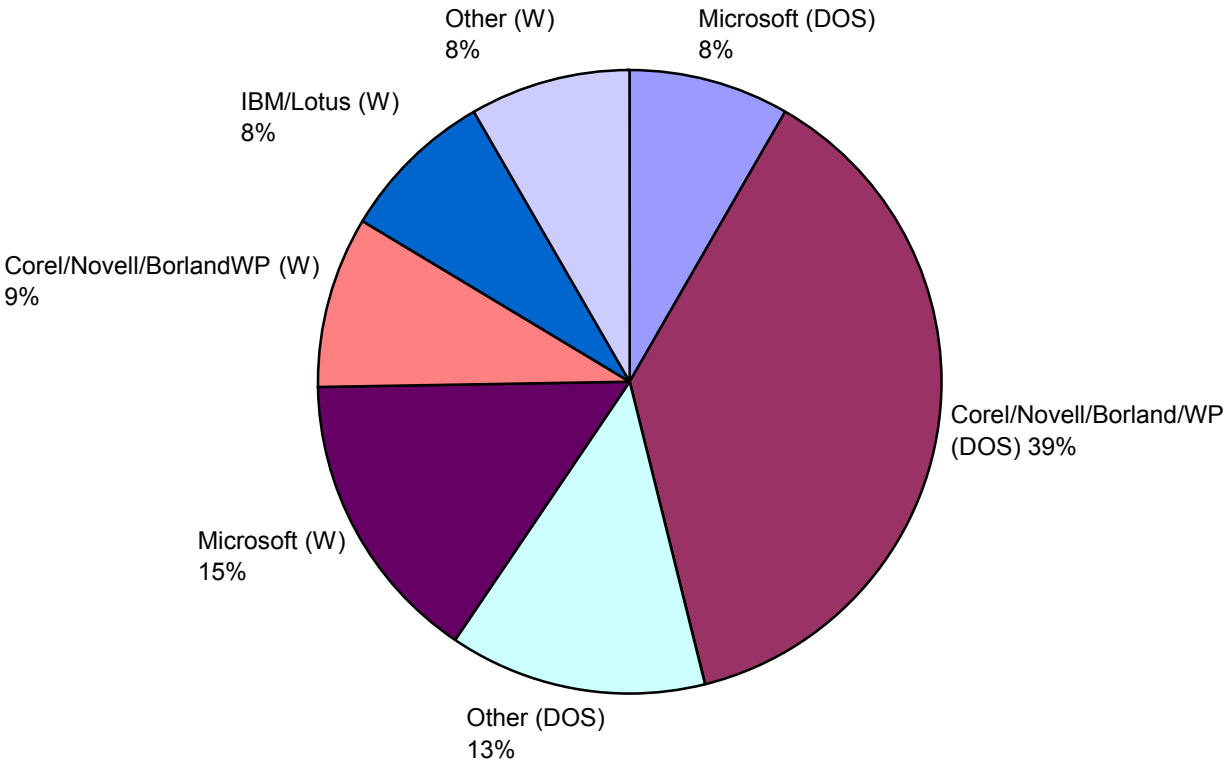


Figure 2: Spreadsheet Market:1991
Total Market $809 Million:
DOS $239 Million, WINDOWS $569 Million

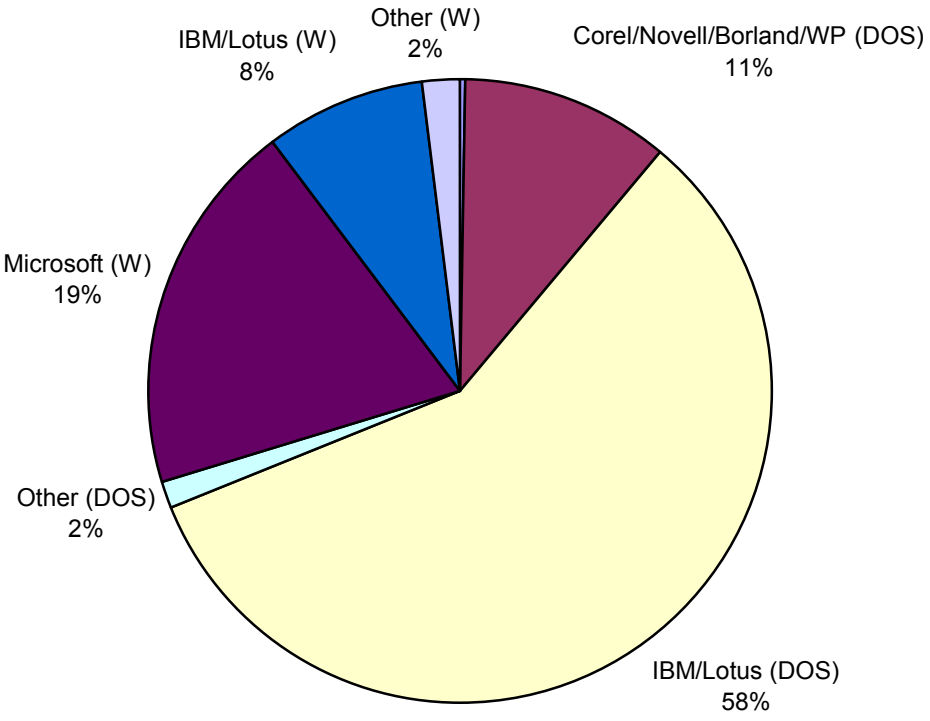


Figure 3: Office Software Revenue for WINDOWS Platform by Firm 1991-1998

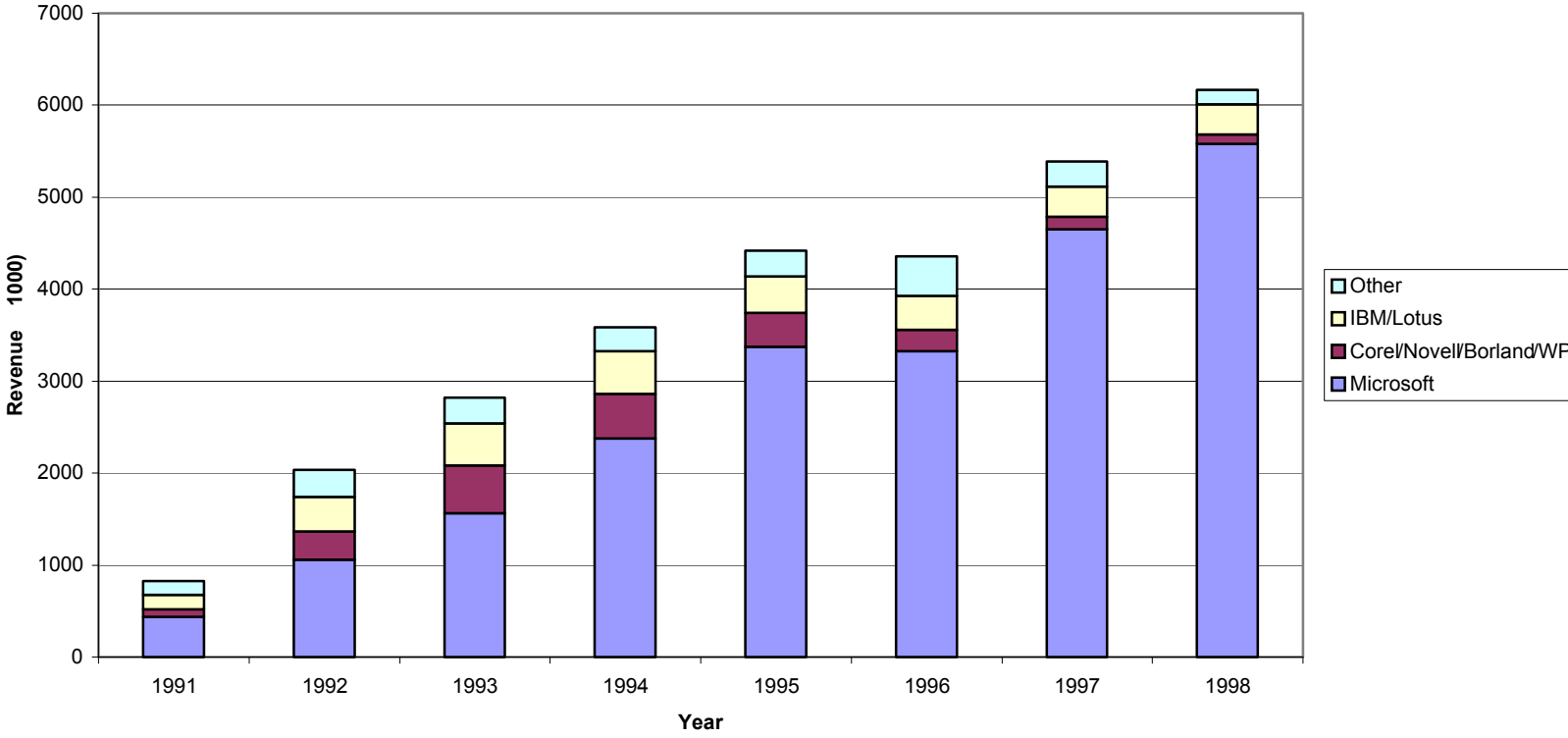


Figure 4: Office Software Revenue by Platform, 1991-1998

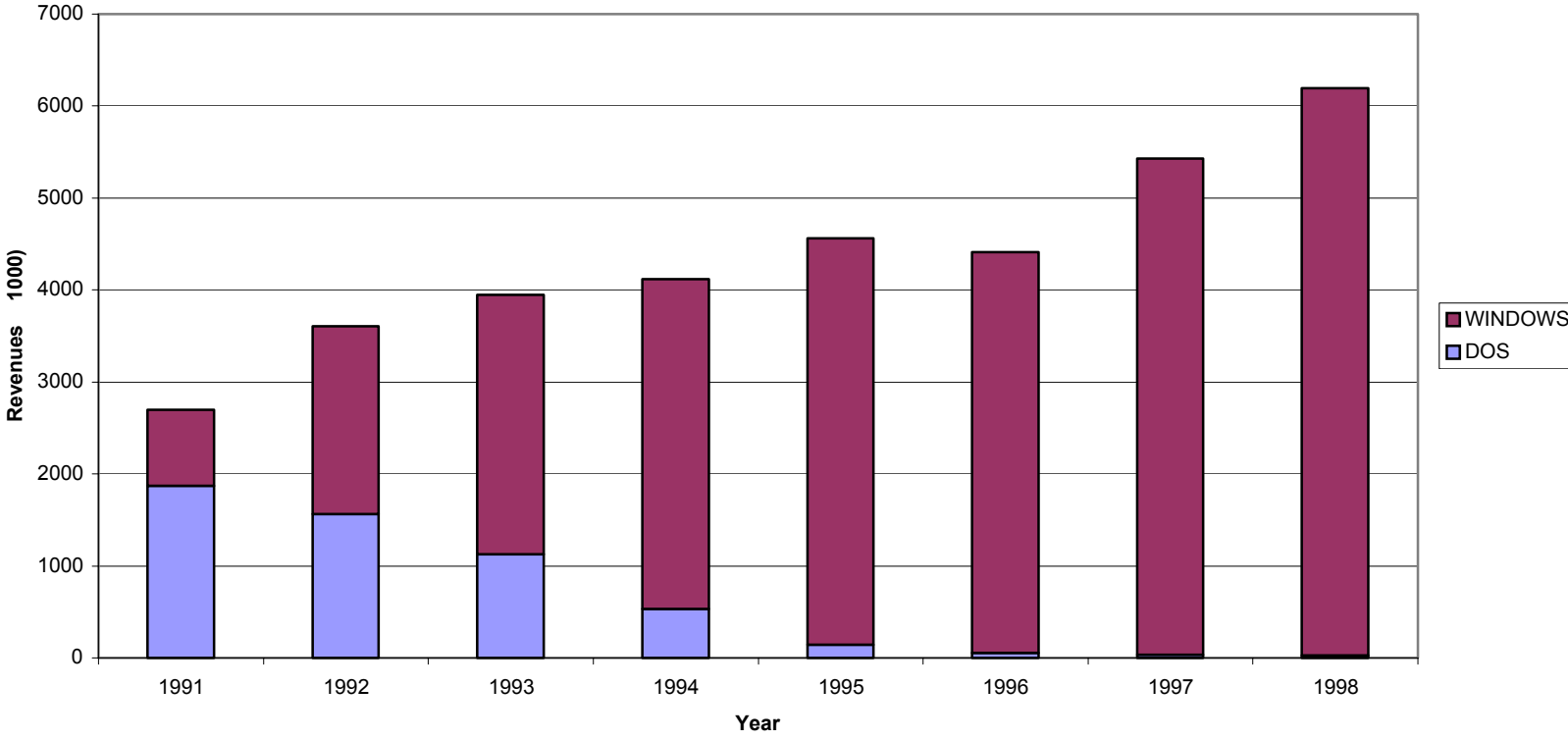


Figure 5: Windows Office Productivity (Revenue) Shares by Category, 1991-1998

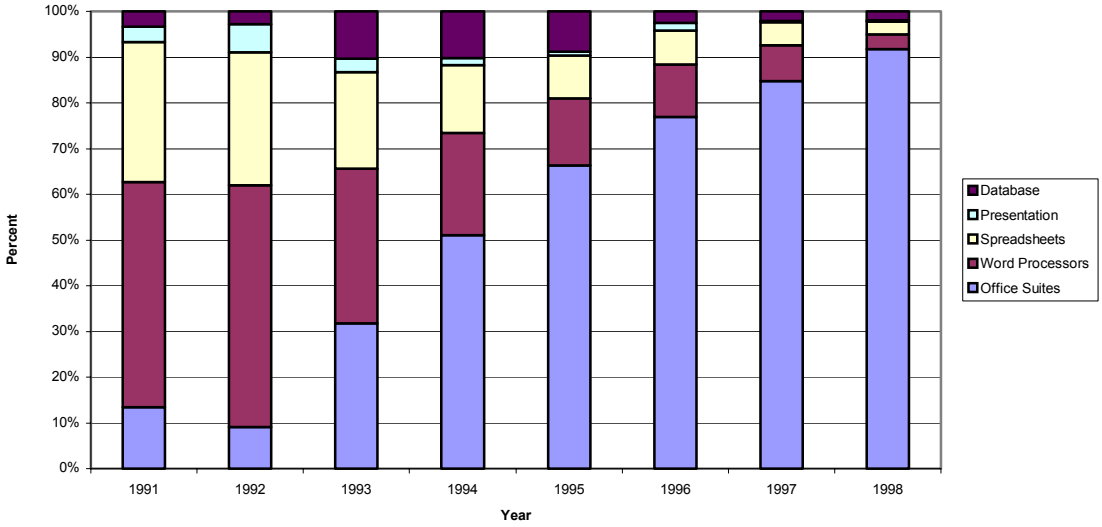


Figure 6: Office Suite Revenue by Firm 1991-1998

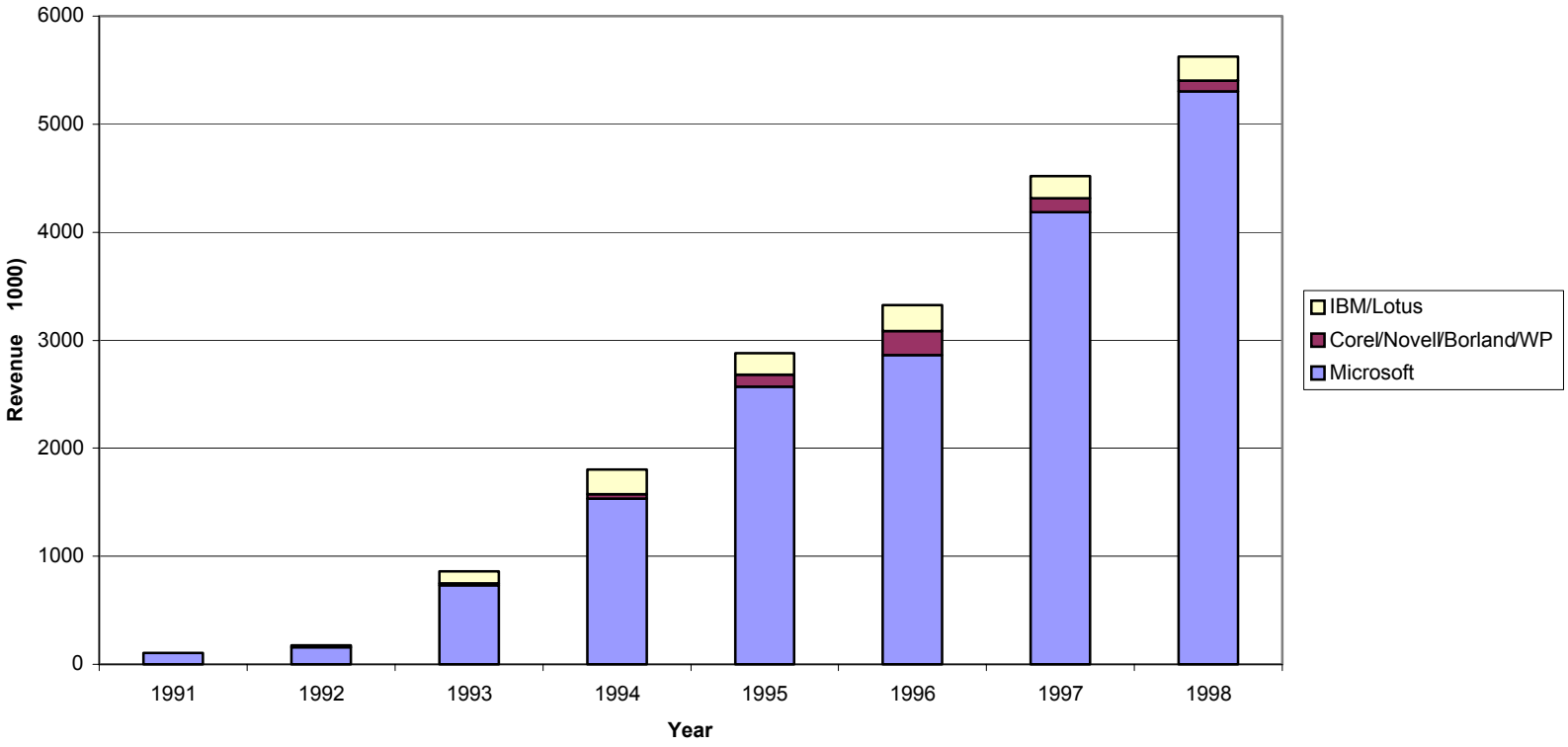


Figure 7: Suite Prices (1993-1998)

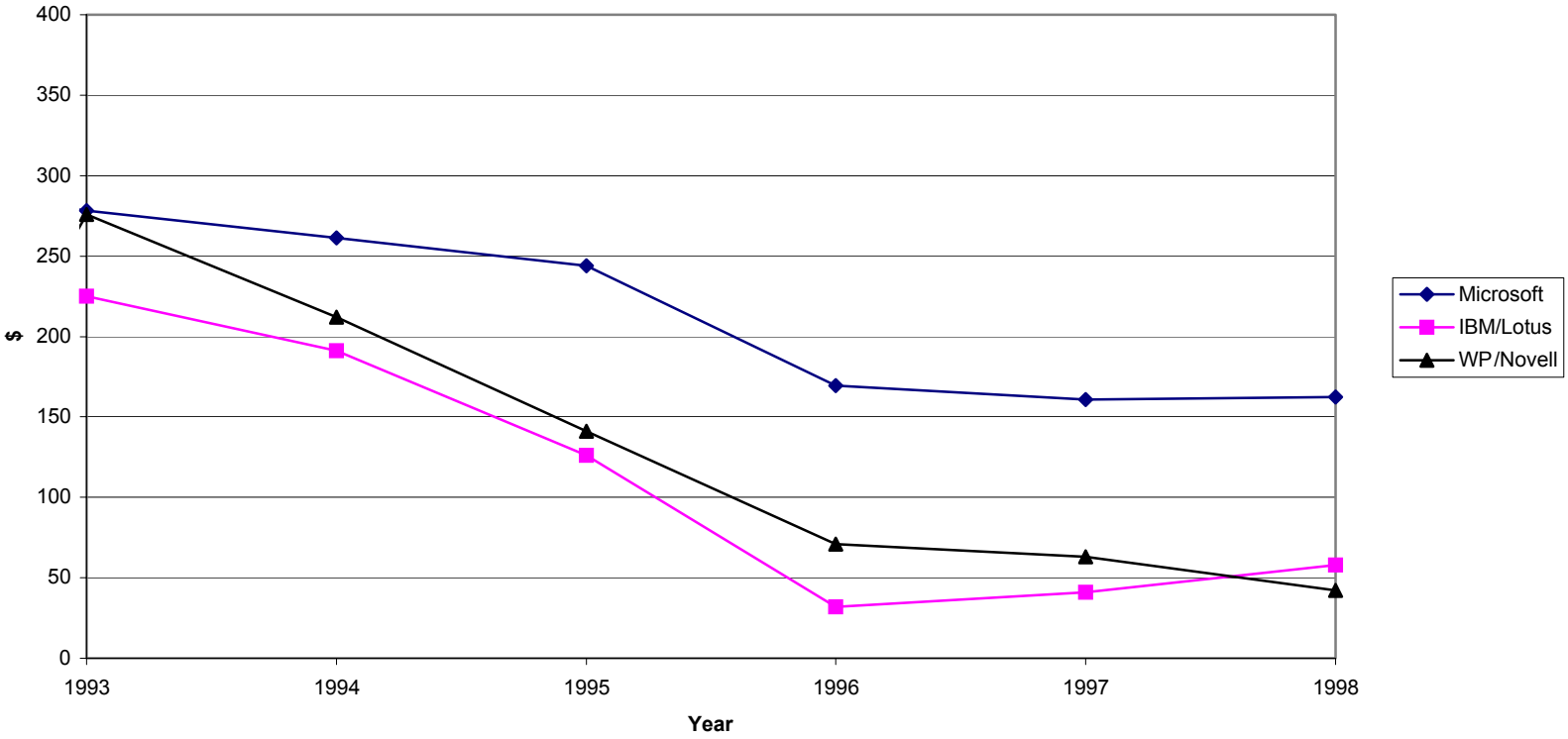


Figure 8: Microsoft Prices