Ain’t it “Suite”? Bundling in the PC Office Software Market

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Abstract

We examine the importance of office suites for the evolution of the PC office software market in the 1990s. An estimated discrete demand choice model reveals a positive correlation of consumer values for spreadsheets and word processors, a bonus value for suites, and advantages for Microsoft products. We employ the estimates to simulate various hypothetical market structures to evaluate the profitability, welfare, and competitive effects of suites under alternative correlation assumptions. We find that greater correlation enhances the profitability of bundling due to the interaction of a market expansion effect and a suite bonus effect. In a partial competition setting in which Lotus sells only a spreadsheet and WordPerfect sells only a word processor, we find that Microsoft’s introduction of the suite increases consumer welfare. Furthermore, while the Lotus and WordPerfect suites gained little market acceptance, a merger that creates a new suite combining the best products of both enhances competition only if the new suite overcomes Microsoft’s unobserved quality advantage.

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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 literature on product bundling, and to a lesser extent in the subsequent empirical literature. We reconsider such questions with an empirical model 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 1990s. 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 marketing strategy led by Microsoft from selling separate products to selling office suites. By the end of the decade, Microsoft dominated the office productivity software market.

How did the shift to suites (which bundled a spreadsheet with a word processor) contribute to Microsoft's success, and what were the consequences for competitors and consumers? To examine this rigorously, we estimate a parsimonious model of consumer demand for spreadsheets, word processors, and suites. The model includes a normally-distributed common component of consumer tastes for spreadsheets and word processors, plus an idiosyncratic taste component for each product drawn independently from a Gumbel distribution, and controls for observable price and quality differences. The model also allows a "bonus value" for a suite – specifically, an increment above the sum of mean utilities for the constituent spreadsheet and word processor, capturing value-added features or better integration of the suite. Finally, the model allows Microsoft to have advantages over the other vendors, possibly reflecting smoother operation with Windows. Estimation of the model reveals a positive correlation of consumer preferences for spreadsheets and word processors,[1] a moderate bonus value, and significant Microsoft advantages. Combining the demand estimates with a conduct assumption of Bertrand-Nash price competition,

[1] Positive (negative) correlation obtained if consumers utility for the two products is comonotonic (countermonotonic).

marginal costs for each product are estimated from the first-order conditions for equilibrium profit-maximization.

We employ these estimates to calibrate alternative models of counterfactual market structure, including suite monopoly ("pure bundling"), multiproduct monopoly ("mixed bundling"), competition in spreadsheet and word processor market segments, and suite-to-suite competition. Our analysis focuses on how the correlation of preferences for spreadsheets and word processors influences the demand for suites, and thus matters for the profitability and consumer welfare under the various market structures. To accomplish this, we extend the empirical model by assuming separate common components for spreadsheets and word processors with a bivariate normal distribution. This modeling device enables us to vary the correlation coefficient while holding constant the variances estimated from the empirical model.

We find that the correlation in consumer tastes for spreadsheets and word processors plays a central role in determining the profitability of suites. In particular, our simulations show that, holding constant the other estimated model coefficients, greater correlation enhances the profitability of bundling. This property does not depend on the bundling strategy—pure or mixed—and holds regardless of whether Microsoft is a monopolist, competes with rival firms in the spreadsheet and word processor markets, or competes head-to-head in the suite market. Furthermore, we find that pure and mixed bundling both improve Microsoft's profits over separate selling for high levels of positive correlation.

Our analysis highlights three effects on profits and consumer welfare. The "market expansion effect" of greater correlation increases the demand for suites by increasing the dispersion of consumer preferences. The "suite bonus effect" refers to the value-added from suites. These two effects are complementary: the market expansion effect magnifies the suite bonus effect. The third effect is the "Microsoft advantage". Our demand estimates show consumers on average preferred Microsoft office software products, especially its Office suite, even after controlling for observable quality. Microsoft and consumers both benefit from the combination of these effects for all of our simulated market structures.

The bundling literature has paid little attention to the market expansion effect of positive correlation. The standard intuition is that product bundling better enables a monopolist to extract social surplus by reducing the dispersion of consumer values compared to separate selling (Stigler, 1963; Adams and Yellen, 1976; Schmalensee, 1982), and the fact that reduced dispersion is most pronounced under negative correlation suggests the further intuition that greater correlation lessens profitability by hindering the ability of the monopolist to extract surplus. This crude intuition, however, fails to appreciate that greater preference correlation increases the dispersion of consumer values for the bundle. Johnson and Myatt (2006) show that greater preference dispersion is profitable in a "niche market," where most consumers choose not to purchase the monopolist's product. In this case, the marginal consumer's valuation is 'above average' and greater preference dispersion increases profit by increasing the marginal consumer's willingness to pay and thus demand over the relevant range of prices. Our estimate for the office productivity software market implies that only a relatively small share of potential consumers purchase office productivity software. Greater correlation consequently improves profitability under pure bundling by increasing preference dispersion. Furthermore, a similar effect holds for mixed bundling, and under competition scenarios in which Microsoft is a dominant firm.

The second effect that drives the positive relationship between the correlation of preferences and the profitability of bundling over separate selling is the 'suite bonus'. Our model allows for consumers to enjoy extra value from the consumption of the suite, in addition to the values of a spreadsheet and a word processor. If the suite bonus exceeds the incremental marginal cost of the suite, as we estimate it does for Microsoft, then the introduction of the suite presents a profit opportunity, independently of any price discrimination benefits from bundling. To the extent that Microsoft fails to fully extract the incremental surplus from the suite, consumers benefit as well. We find in the case of pure bundling that the market expansion effect alone is sufficient to overturn the standard intuition and insure that profits increase with greater correlation. In the case of mixed bundling, the suite-bonus contributes directly to the profitability of suites even with perfect positive correlation. The market expansion effect of greater correlation magnifies this contribution. Thus, the market expansion and suite-bonus effects of positive correlation conspire to make Microsoft's bundling strategy both profitable and attractive to consumers.

In order to examine the competitive effects of bundling, we simulate a market setting of partial competition, in which Lotus sells only a spreadsheet, WordPerfect sells only a word processor, and Microsoft sells both components as well as a suite. Our results show that Microsoft's mixed bundling strategy affects its competitors adversely. In particular, the introduction of Microsoft Office under partial competition shifts market share away from Lotus and WordPerfect and intensifies price competition. Nevertheless, interpreting Microsoft advantages as unobserved quality, the consequences for consumers are positive. Specifically, regardless of the value of the correlation over spreadsheets and word processors, Microsoft's introduction of its Office suite benefits consumers on balance.

The pro-competitive effect of bundling relies substantially on the suite-bonus effect. Specifically, while Microsoft priced its suite higher than the sum of prices of its components, the suite-bonus 'value' ($23) 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. The pro-competitive effect of bundling is particularly strong when the correlation is large and positive. In this case, there are many consumers who purchase both components separately if suites are not available. All of these consumers switch to the suite when it is introduced, and thus 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, which contributes as well to the increase in consumer surplus. We find that the pro-competitive effect is robust to variations in the estimated coefficients.

Our simulations also show that competing firms can be better off when a dominant firm sells components and a bundle rather than just selling a bundle. We explain the intuition with an example: Suppose a consumer likes Microsoft Word, but also likes the Lotus spreadsheet. If Microsoft sells components, then the consumer can mix-and-match and purchase these two components. If, however, Microsoft sells only suites, the consumer cannot purchase the mix-and-match combination and may choose the Microsoft suite instead. Hence, pure bundling may have a foreclosure effect that reduces demand and profitability of those firms only selling components.[2] Since demand for mix-and-match combinations is higher under large positive correlation, we indeed find that the foreclosure effect may dominate the standard increased competition effect of mixed bundling when the correlation in consumer preferences is positive and large. In this case, competing firms are better off under mixed bundling than under pure bundling.

We also examine the effect of correlation in consumers' preferences on profitability in the case where the suite market is oligopolistic. Our simulations show that the WordPerfect and Lotus suites did not provide any more competition to the Microsoft suite than that provided by the individual components—WordPerfect's word processor and Lotus' spreadsheet. To study this further, we use the estimated parameters to predict oligopoly conduct for a hypothetical merger between WordPerfect and Lotus. Our simulations suggest that whether a merger between

[2] Nalebuff (2004) makes a similar point.

WordPerfect and Lotus, the dominant firms in the word processing and spreadsheet markets in the DOS era, would have been welfare enhancing depends on whether the merged suite closes the quality gap represented by the Microsoft advantage.

The paper proceeds as follows. In section 2, we review the economics literature on bundling and discuss the difficulty of theoretically modeling oligopoly competition under 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. Section 7 uses the estimated parameters to simulate counterfactuals, and explores robustness by taking draws from the estimated parameter distribution. Section 8 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, scope economies, or exclusion of rivals. In a monopoly 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 basic intuition from these works is that pure bundling reduces the dispersion of the reservation values (i.e., makes consumers homogenous) and hence enables greater extraction of surplus.

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's (1984) results for the bivariate normal case to show 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,[3] which allows varying dependence of random variables while holding their marginal distributions constant, Chen and Riordan (2013) 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, or 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 (1963) and Adams and Yellen (1976) illustrating this starkly for perfect negative dependence, suggests that the profitability of bundling decreases with correlation. On the other hand, using a copula that mixes independence and perfect negative dependence, Chen and Riordan (2013) provide a counterexample in which the profitability of bundling increases with correlation in the neighborhood of perfect negative correlation.[4]

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 stealing the competitor's market share (Nalebuff 2004).[5] On the other hand, bundling can accommodate the rival by vertically differentiating products and thereby relaxing price competition (Carbajo, deMeza and Seidman

[3] For an introduction to copulas, see Trivedi and Zimmer (2005.)
[4] Chen and Riordan (2013) also provide an example using the FGM copula and uniform marginal distributions in which profits from bundling decrease with correlation over the range of dependence allowed by the FGM copula family.
[5] Cabral and Villas-Boas (2005) find similar results in the case of price competition between multi-product firms. They show that under certain conditions, increased demand complementarity might lead to a reduction in industry-wide profits, and note that similar patterns of interactions occur in settings where bundling is possible.

1990; Chen 1997) due to vertical differentiation.[6] Thus the competitive effects of bundling seem to be an empirical question.

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 separate 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 à 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 separate sales of spreadsheets and word processors, as well as sales of suites. Further, we focus on other issues.

There are few other empirical papers on joint purchases and bundling that pay attention to correlation. Using individual-level survey data, Gentzkow (2007) studies joint purchases of print and online newspapers, allowing both correlations over preferences and complementarity among products, but he addresses different issues and uses a different identification strategy. His identification strategy is based on the exclusion of variables from the utility function of some of the products and on employing panel data. Lacking data on joint (i.e. mix and match) purchases, we are unable to identify complementarity separately from correlation, except for suites. Chu, Leslie, and Sorensen (2011) estimate the demand for bundled theater tickets with a common taste

[6] 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.

component across different shows, as a way to motivate a numerical analysis of the profitability of bundle-size pricing. Ho and Mortimer (2012a, 2012b) use a nested logit model to analyze welfare effects of full-line forcing in the video rental industry.

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

The PC office software market was well established in the early 1990s with WordPerfect leading the word processor category (Figure 1) and Lotus the spreadsheet category (Figure 2).[7] 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, out of which 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.

Microsoft was first out of the gate with WINDOWS based applications with Microsoft Excel and Microsoft Office.[8] 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.

The early office suites contained non-integrated word-processors, spreadsheets, database, and graphics programs. Lotus' acquisition of AmiPro in 1991 enabled it to field a WINDOWS based suite in late 1992, while WordPerfect introduced its first suite in 1993. Still, Microsoft was best positioned in the office suite category because it already had highly-rated versions of key underlying components. Suites contributed little to industry revenue during this period.

Microsoft's new office suite, released in early 1994, was better integrated than the previous generations of suites and went beyond the standard embedding at the time.[9] The suite was

[7] The presentation graphics and database management categories were led by Lotus and Borland, correspondingly.
[8] Samna's Ami (later renamed Ami Pro) was the first word processor for WINDOWS.
[9] Microsoft Office 4.2 (including Word 6.0, Excel 5.0 and PowerPoint 4.0). 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. 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. Nevertheless, Office 4.2 did not offer full integration.

extremely well received by computer software trade journals.[10] 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.[11] 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.[12] Competitors were slow 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 were 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)[13] and Borland/Corel/Novell/WordPerfect (hereafter Corel/WordPerfect or WordPerfect). These three firms accounted for 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 1991-1998 (See Figure 3.) Hence we limit our analysis to products offered by these three firms.

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[10] 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.

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

[12] 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 it intended to release Windows 95. See "Microsoft's office suite to be shipped in August," Wall Street Journal, 11 July 1995: Section B5.

[13] IBM acquired Lotus in 1995.

4. Data

Our dataset includes data on shipments and sales by vendor for the three major office software products (spreadsheets, word processors, and suites), for the three major vendors (Microsoft, IBM/Lotus, and WordPerfect), for the period 1992-1998. Since computer hardware and office software are complements, the benefit from office 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, we restrict our sample to spreadsheets, word processors, and office suites that were compatible with the WINDOWS operating system.[14] Each of the three major vendors offered the three major products in all seven years, with the exception that WordPerfect did not offer a suite in 1992. Thus, we have 62 data points. Descriptive Statistics are presented in Table 1.

Data on prices and quantities come primarily from two Dataquest/Gartner Reports on Personal Computing Software, one for the 1992-1995 period and one for the 1996-1998 period.[15] The variable QUANTITY is the number of licenses sold (in thousands), and the variable PRICE is the average revenue for each product.[16] Gartner recorded sales and shipments only for product-years with a 'non-trivial' number of sales. All three Microsoft products (word processor, spreadsheet, suite) qualified in all years, but Lotus had too small a market share in word processors for 1996-1998, and WordPerfect sold a non-trivial number of licenses only in the suite category for 1996-1998. For those products-years with no recorded data, we impute QUANTITY to be equal to one half the smallest number of units of any product shipped in 1995 - the last year for which we have complete data from Gartner. For these observations, we impute PRICE by comparing prices from the Gartner data with prices in Liebowitz and Margolis (1999; hereafter LM) as follows: LM reports prices to original equipment vendors 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 through 1997, and assumed prices

[14] 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.

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

[16] The data on unit sales (or shipments) is comprehensive and includes new licenses, upgrades, and units distributed through original equipment manufacturer (OEM) channels. In some cases we need to average over several versions of the product. For example, in some years, the Microsoft suite comes in separate versions for WINDOWS and WINDOWS95. There was little difference in price between the versions for the various generations of the Windows operating system.

were unchanged in 1998. The resulting price series for suites, word processors, and spreadsheets appear in figures 8, 9, and 10, respectively.

Data on the quality of spreadsheets and word processors are derived from quality measures from LM based on reviews that gave numerical ratings. Since the top score is normalized to 10 in each year, these scores obviously are not comparable across years, but this doesn't matter for our purposes since the choice set facing consumers is the software available in each particular year.[17] We calculate a product's quality relative to the quality of the leading product in the DOS era: Lotus and WordPerfect. Hence for spreadsheets,

$$RELQUAL\_SS_j = \text{LM rating of product } j/\text{LM rating of Lotus SS.}$$

Similarly, for word processors,

$$RELQUAL\_WP_j = \text{LM rating of product } j/ \text{ LM rating of WordPerfect word processor.}$$

SS_j, (respectively WP_j,) is a dummy variable equal to one if product j is either a spreadsheet or a suite, (respectively a word processor or a suite,) and zero otherwise.

$SUITE_j$ is a dummy variable that takes on the value one if product j is a suite. It takes on the value zero otherwise, including the case where a consumer purchases (mix and matches) a spreadsheet and a word processor from two different vendors. 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 possible 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.[18]

Time fixed effects are restricted by combining year dummies to capture three distinct periods in the evolution of the industry: the initial period characterized by component competition (1992-

[17] 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.

[18] Ideally, we would include a quality variable that measures how well integrated are the components of the suite. Unfortunately, such a variable is available only for 1994 and 1998.

93), a transition period (1994, 1995) as a result of the introduction of Windows 95,[19] and a third period (1996-98) characterized by suite competition. This partition is also supported by Table 2 which presents the shares of the 'inside' goods for 1992-1998. As shown in the table, the shares of the 'inside' good are quite similar for 1992-1993. The same holds for 1996-1998. We, therefore, define *YEAR94* and *YEAR95* to be yearly dummy variables for 1994 and 1995, respectively, and *YEAR96-98* as a dummy variable that takes on the value 1 for the 1996-1998 period, and zero otherwise.

The variable *MICROSOFT* 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. This variable is intended to capture unobserved quality advantages, including advantages possibly associated with greater compatibility with the Windows operating system.

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 WordPerfect could be read into Microsoft Word and edited -- there would not seem to be important network effects. 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 analysis.[20]

The potential market for office software is defined to be the number of operating systems sold or distributed via computer manufacturers during the relevant year. Our data on operating systems for 1992 comes from Baseman et al (1995), while our data on operating systems for 1993-1998 comes from a Dataquest report on Operating System Shipments.[21] The data in Table 2 below 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, with the release of Windows 3.1, utilities that came with the operating system, e.g., 'WordPad', filled the basic needs of less sophisticated consumers, reducing demand for office productivity software. Alternatively, it could mean that, as computer usage grew significantly in countries

[19] Windows 95, along with a new version of Microsoft Office, was released in mid-1995 and anticipated in 1994. 1994 and 1995, the transition years, have quite different shares for the inside good; hence the dummy variables for each of these years are included. When we include just a single dummy variable for 1994 and 1995, we obtain poor results.

[20] Chao and Deedenger (2013) study mixed bundling in the presence of installed base effects.

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

without strong intellectual property protection during the 1990s, piracy of applications software increased. An additional possible explanation is that consumers who upgraded their hardware might have re-installed their existing software. Since we use the yearly dummy variables only as control variables, we are neutral regarding these or other explanations for the reduction in the percentage of consumers that purchased a spreadsheet, a word processor, or suite over time.

Variable	Mean	Std. Dev.	Min	Max
QUANTITY	2914.72	5583.4	46	32682.7
PRICE	114.25	81.6	8	350
MICROSOFT	0.45	0.69	0	2
RELQUAL_SS	0.70	0.51	0	1.35
RELQUAL_WP	0.68	0.49	0	1.22

Table 1: Descriptive Statistics

Year	A: WINDOWS Operating Systems	B: Word Processors	C: Spreadsheets	D: 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	5.008	7.689	0.582
1995	54.352	4.693	3.876	12.982	0.397
1996	68.083	3.247	3.149	26.810	0.486
1997	78.406	4.526	3.142	32.977	0.518
1998	89.489	2.431	2.037	38.801	0.484

Table 2: Units of Operating Systems and Office Software Products (millions), 1992-98

5. Discrete Choice Model and Estimation

In this section, we 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: spreadsheets, word processors, office suites, or mix-and-match word processor-spreadsheet combinations from two different vendors. Hence when all three firms offer word processors, spreadsheets, and office suites, there are 15 possible "products": 3 spreadsheets, 3 word processors, 3 office suites, and 6 mix–and-match word processor and spreadsheet combinations from different vendors, plus the "outside option" of making no purchase at all. 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. 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 specify mean utilities $\delta = (\delta_1, \ldots, \delta_9)$ for each of the standalone spreadsheets, standalone word processors, and suites, and assume that mean utility of a mix-and-match purchase is the sum of mean utilities for its constituent products. For $j = 1, \ldots, 9$, we assume:[22]

(2) $$\delta_j = \beta_1 * PRICE_j + \beta_2 * SS_j * RELQUAL\_SS_j + \beta_3 * WP_j * RELQUAL\_WP_j + \beta_4 * SS_j * RELQUAL\_SS_j^2 + \beta_5 * WP_j * RELQUAL\_WP_j^2 + \beta_6 * SUITE_j + \beta_7 * YEAR94_j + \beta_8 * YEAR95_j + \beta_9 * YEAR96-98_j + \beta_{10} * MICROSOFT_j + \beta_{11} * MICROSOFT_j * SUITE_j * YEAR96-98_j + \xi_j$$

where the variable ξ_j measures the mean value of any unobserved characteristics of product j, and $\beta \equiv (\beta_1, .., \beta_{11})$ is a parameter vector to be estimated. The mean utility from the outside option is normalized to zero.

The mean utility specification is deliberately parsimonious in order to avoid "over fitting" the model given the limited amount of data. In particular, the coefficient vector is restricted to be the same for all products, and does not vary by product category. Similarly, as mentioned above, time fixed effects are restricted by combining year dummies that capture the three distinct periods in the evolution of the industry: 1992-93, 1994, 1995, and 1996-98. We allow relative quality to have a non-linear effect by including relative quality squared, and allow the Microsoft suite to have additional advantages after 1995.

Random Utility. The variable θ_{jk} represents consumer k's deviation from the mean utility of product j. We assume this variable depends on a common software component and an independent and an product component:

(3) $$\theta_{jk} = \sigma_1 * SS_j * y_k + \sigma_2 * WP_j * y_k + \epsilon_{jk}$$

[22] Since $RELQUAL\_SS$ and $RELQUAL\_WP$ are normalized to 1 for Lotus and WordPerfect respectively, for parsimony we do not include a constant or a fixed effect for the standalone software category.

The common component y_k has a standard normal distribution. The coefficients σ_1 and σ_2 contribute to a consumer-specific random utility for spreadsheets and word-processors, respectively. For example, $\sigma_2 y_k > 0$ indicates that consumer k has a higher than average value for a word processor. For suites and mix-and-match combinations, the consumer receives random utility$(\sigma_1 + \sigma_2)y_k$. The product component ε_{jk} introduces an additional source of consumer heterogeneity; i.e., some consumers are 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 standard Gumbel (or Type I extreme value) distribution. 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.

The random utility parameters (σ_1, σ_2) determine the distribution of preferences for software categories in the consumer population. Given that the variance of the standard Gumbel distribution is 1.645, the variance of preferences over spreadsheets is (σ_1^2 + 1.645), while the variance of preferences over word processors is (σ_2^2 + 1.645.) Thus (up to a constant), σ_1^2 and σ_2^2 are the variances of preferences over (respectively) spreadsheets and word processors. 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. The correlation in consumer preferences between an arbitrary spreadsheet and arbitrary word processor is $\frac{\sigma_1 * \sigma_2}{\sqrt{(\sigma_1^2 + 1.645) * (\sigma_2^2 + 1.645)}}$. Thus, in addition to the variances, the coefficients σ_1 and σ_2 (together with the variance of the Gumbel random variable) determine the correlation of utilities for a spreadsheet and a word processor. The correlation is positive if σ_1 and σ_2 have the same sign and is increasing in the magnitudes of the coefficients. The correlation is negative if σ_1 and σ_2 have opposite signs.

Market shares. We observe market shares of spreadsheets, word processors, and suites. We do not observe mix-and-match purchases, but observe the aggregate market shares of standalone spreadsheets and word processors including mix-and-match purchases. In the estimated algorithm described below, we denote the actual market shares by $S = (S_1, \dots, S_9)$. We adopt the obvious convention that δ_j refers to the standalone software and S_j to the aggregate share; e.g., if δ_1 is the mean utility of standalone consumption of the Lotus spreadsheet, then S_1 is the aggregated share of Lotus spreadsheets over standalone and mix-and-match purchases.

Given the logit structure of demand derived from the distributional assumptions on ε_{jk}, the probability that consumer *k* chooses product *j* conditional on y_k is

$$P_{jk} = \frac{e^{\delta_j + \sigma_1 * SS_j * y_k + \sigma_2 * WP_j * y_k}}{1 + \sum_{l=1}^{15} e^{\delta_l + \sigma_1 * SS_l * y_k + \sigma_2 * WP_l * y_k}}, \tag{4}$$

and the probability that consumer *k* makes no purchase is

$$P_{0k} = \frac{1}{1 + \sum_{l=1}^{15} e^{\delta_l + \sigma_1 * SS_l * y_k + \sigma_2 * WP_l * y_k}}.$$

These probabilities can be employed to simulate the market shares for suites, spreadsheets, word processors, and the outside good that correspond to our data, and to use these simulated market shares to form moment conditions. The calculations of simulated market shares for suites and the outside good are straightforward. Absent data of mix-and-match purchases, however, the relevant market share for spreadsheets and word processors must aggregate standalone purchases and mix-and-match purchases which are easy to simulate for a given parameter vector $(\sigma_1, \sigma_2, \beta)$. 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 vendors, it is straightforward to calculate simulated market shares for the word processor category, and similarly for the spreadsheet category. Thus the fifteen consumer choices are mapped into nine market shares. The validity of these calculations requires a large number of (simulated) consumers. The simulated market shares are a function of the mean utilities, and are denoted $(\delta) = (s_1(\delta), \ldots, s_9(\delta))$.

Estimation Algorithm. The estimation algorithm simulates the distribution of the common component of consumer preferences, and then searches over the parameter space to minimize a GMM objective function, adapting the methods described in Nevo (1998) to our model and data requirements. The algorithm proceeds in several steps:

<u>Step 1</u>: Take random draws of y_k for 100,000 consumers per year.

Step 2: Select initial values for (σ_1, σ_2) and for $\delta_{old} = (\delta_{1,old}, \ldots, \delta_{9,old})$.[23]

Step 3: Given the values of (σ_1, σ_2) and for δ_{old}, apply the contraction mapping

$$\delta_{new,j} = \delta_{old,j} + \ln(S_j) - ln(s_j(\delta_{old}))$$

until convergence ($\hat{\delta}$) is obtained.

Step 4: Given $\hat{\delta}$, run the GMM regression $\hat{\delta}$=Xβ+ξ to obtain estimates $\hat{\beta} = (X'ZWZ'X)^{-1} X'ZWZ'\hat{\delta}$, where X is the matrix of right hand side variables, Z is the matrix of exogenous right hand side variables and instrumental variables, and $W=(Z'Z)^{-1}$ is the weighting matrix.[24]

Step 5: Compute the implied values of the unobserved product characteristics, i.e., $\hat{\xi} = \hat{\delta} - X\hat{\beta}$, and evaluate the GMM objective function $\hat{\xi}'ZWZ'\hat{\xi}$

Step 6: Update values of σ_1 and σ_2, set $\delta_{old} = \hat{\delta}$, and return to step 2, until the GMM objective function is minimized and the search is complete.[25]

Standard deviations are calculated in the usual manner, as described in Nevo (1998).

Identification of Mean Utility Parameters: Our dataset contains sales and shipments by products and by year. Thus, both variation across products and variation across time are sources of identification of the parameters of the model. The variables RELQUAL_SS, RELQUAL_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. The year dummy variables obviously vary over time only. Variations in the share of potential consumers who elect the outside good identify the coefficients on these variables. The vendor variable (MICROSOFT) varies across products, but not over time. Variations of shares of Microsoft products relative to products of the other vendors

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[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 (1994), Berry, Levinsohn, and Pakes (1995) for details.

[24] As Nevo (1998) notes, this weighting matrix yields efficient estimates under the assumption that errors are homoskedastic.

[25] The estimates of σ_1 and σ_2 are updated by the software program "*R*" using a minimization algorithm.

identify the coefficient on this variable. The variable SUITE captures added value from suites relative to components. Hence, the market share variation of suites identifies the coefficient on this variable.

Identification of Random Utility Parameters: Given the mean utility parameters, increases in the variances $(\sigma_1^2 + 1.645)$ and $(\sigma_2^2 + 1.645)$ increase the sales of spreadsheets or word processors respectively. Hence, when the variance for a particular product type (say word processors) is high, a price increase for a particular word processor will lead more consumers to substitute *within* the class, i.e., to another word processor. When the variance is low, more consumers will substitute away from that component, rather than purchase another product in the class when price rises.

The sign of $\sigma_1 * \sigma_2$ (and thus whether the correlation is negative or positive) is identified as follows: When σ_1 and σ_2 are greater than zero, an increase in either σ_1 or σ_2 increases the correlation ($\frac{\sigma_1 * \sigma_2}{\sqrt{(\sigma_1^2+1.645)*(\sigma_2^2+1.645)}}$) and thus increases the demand for suites. Similarly, when $\sigma_1 * \sigma_2 < 0$, an increase in the magnitude (absolute value) of either sigma decreases the correlation and decreases the demand for suites.[26]

Gentzkow (2005) provides an insightful discussion of the difficulty of separately identifying product complementarity and preference correlation. Similar issues apply to our setting, even though we adopt a simplified model of correlation and only allow for complementarity in the purchase of suites. Both positive correlation and a positive coefficient on SUITE increase the demand for suites. Correlation is identified separately from complementarity because market shares of suites become less sensitive to changes in suite prices when correlation is positive. We can thus separately identify these two effects if the fall in Microsoft's suite price beginning in 1996 was exogenous. From our understanding of the industry, the fall in prices in 1996 was primarily due to an exogenous change (improvement) in technology, namely the introduction of the Windows95 operating system.

[26] For given magnitudes of $\sigma_1$and σ_2 , when $\sigma_1 * \sigma_2 < 0$, we cannot distinguish between a negative value for σ_1 and a positive value for σ_2 , or a negative value for σ_2 and a positive value for σ_1. Similarly, if $\sigma_1 * \sigma_2 > 0$, we cannot distinguish between both sigmas being positive and both sigmas being negative. This, however, is not important for our analysis.

Finally, the random parameters help determine the sensitivity of market share to prices. What identifies σ_1 and σ_2 separately from the price coefficient are *differences* in the responses of market shares of the three product categories to price changes.

Elasticities: In the full random coefficients model we employ, three parameters (β_1, σ_1 and σ_2) determine the own and cross price elasticities. In the case of the logit model (no parameters in the random utility part of the model, just ε_{jk}) own and cross price elasticities are determined exclusive by β_1 (and prices and market shares). This typically leads to unreasonable substitution effects. In the random coefficients model, on the other hand, the substitution effects are quite rich. The logit treats all products as substitutes, while in the random coefficients model, our estimates are such that many of the products are substitutes, but some of the products (like word processors and spreadsheets from different firms) are complements. We discuss this further in section 6.

Instrumental Variables: Since price is endogenous, we instrument for it.[27] We employ four instrumental variables:

- Relative quality of the best rival product in the same category (where category means spreadsheet, word processor, or suite).[28,29]
- 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 Years 95-98 – Prices declined beginning in 1995 following the introduction of the Windows95 operating system, which we interpret to an exogenous technological change that lowered the cost of marketing office software.

[27] The decisions of the firms to offer bundles may be endogenous as well. We do not have data to account for this choice. We do, however, simulate different oligopoly structures using our parameter estimates. Misra (2013) addresses decisions of retailers to choose which products to offer based on a combination of demand and cost parameters.

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

[29] While using relative qualities as instruments could mechanically violate the required orthogonally assumption, price theory suggests that quality differences rather than absolute qualities are what matter for pricing if the returns from common quality improvements are competed away. Our use of relative quality as an instrument implicitly assumes that the latter effect is more important; e.g. the effects of changes in the absolute qualities of the base product are mostly "differenced out" in the relative quality measure.

Since we have just one endogenous variable, we need only one instrument for formal identification. None of the instruments, however, are informative enough alone, or in subsets; hence we use all four together.[30] This manifests itself as follows: when we include fewer instruments in the logit estimation, we have higher standard errors on the coefficients.

6. Empirical Results

We first estimated the model using Ordinary Least Squares (OLS), in which case, 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 (-.14 versus -.0002). This suggests that our instruments are working as expected (see Table 3).

Our estimates for the full random coefficient model are also shown in Table 3. As expected, the estimates for the linear instrumental variables case and the estimates for the full random coefficients model are similar, with correlation coefficient of 0.99. 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.

The estimated coefficient for the standard deviation over preferences for word processors (σ_1 = 0.87) is larger than the estimated standard deviation for spreadsheets (σ_2 = 1.82). Given these estimates, the corresponding overall correlation of consumer preferences for spreadsheets and word processors is 0.46. Using supplementary data from the Current Population Survey Supplement (CPS) on Computer and Internet Use (see appendix B for details,) we can assess whether this estimate is reasonable. As we note in the appendix, 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: (The possible answers are yes or no.)

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

[30] An OLS regression of price on the four instruments yields an adjusted R-squared of 0.33. An F-test that all coefficients are zero yields a value of $F(4,57)=8.33$, $p<.0001$.

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

We can define dummy variables that take on the value one (zero) if the answer to a question is (yes) no. The estimate of the correlation between these variables (which is an imperfect proxy for the correlation in consumer preferences over word processors and spreadsheets) is 0.37 for home use and 0.36 for office use. This suggests that our result (correlation of 0.46) is "in the ballpark."

The key coefficients of the linear parameters have the expected sign, but are not significant. In particular the PRICE coefficient is negative. 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 (WP_j*$RELQUAL\_WP_j$ for word processors for example), which measure the value associated with observed quality of components, are negative while the coefficient on the square values are positive for both product categories. This suggests that consumers' value is convex in the ratings on which the relative quality measures are based. 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 consumers' purchases of spreadsheets, word processors and suites divided by the number of operating systems was declining as well (see Table 2 and the associated discussion).

Suites included value-added components like presentation software. This is picked up by the dummy variable SUITE. The coefficient on the variable SUITE is positive. 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 SUITE coefficient by the absolute value of the PRICE coefficient, which results in approximately $23.4.

Recall that the variable MICROSOFT 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. 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, higher unobserved quality of components, and better integration with Windows.

The coefficient associated with Microsoft suite for the 1996-1998 period is positive. Given that we already control for SUITE, the coefficient of the Microsoft suite for 96-98 might be 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 after the introduction of Windows95. The trade press (see Appendix A) shows that, even in 2001, there was a large difference in cross-application compatibility between the Microsoft suite and other suites.[31]

Overall, 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 bundle and strategic interaction in the market. As we discuss below, we validate the robustness of our simulation results by running the simulations with coefficients drawn from the estimated distribution.

	Logit (OLS)			**Logit (IV)**			**Random Coeffcients Model**		
	Coef.	**SE**	**T-Statistic**	**Coef.**	**SE**	**T-Statistic**	**Coef.**	**SE**	**T-Statistic**
σ_1							0.87	1.4	0.6
σ_2							1.82	2.5	0.7
Price	-0.0002	0.006	-0.3	-0.14	0.1	-1.3	-0.11	0.13	-0.8
YEAR94	-0.7	0.5	-1.4	-3.3	2.8	-1.2	-2.5	2.7	-0.9
YEAR95	-1.1	0.5	-2.1	-7.7	5.6	-1.4	-6.1	15.5	-0.4
YEAR96-98	-1.2	0.7	-1.7	-14.8	11	-1.4	-11.2	13.0	-0.9
MICROSOFT	1.1	0.4	2.8	3.9	2.6	1.5	3.2	3.1	1.1
SUITE	3.3	0.6	5.9	2.5	2.1	1.2	2.6	2.6	1.0
SS*RELQUAL_SS	0.3	2.0	0.2	-7.7	9.6	-0.8	-6.7	8.6	-0.8
WP*RELQUAL_WP	-1.0	3.9	-0.3	-16.1	18.6	-0.9	-12.8	20.8	-0.6
SS*RELQUAL_SS^2	-1.4	2.1	-0.7	15.4	15.2	1.0	12.2	15.7	0.8
WP*RELQUAL_WP^2	-0.2	3.9	*0.1	23.6	23.5	1.0	18.2	26.8	0.7
MICROSOFT*SUITE* YEAR96-98	2.1	1.2	1.8	2.8	4.2	0.7	2.3	2.5	0.9
62 observations	**Adj. R^2=0.84**						**GMM**	**18.45**	

Table 3: OLS, Linear IV and Non-Linear Instrumental Variable Estimates

7. Counterfactuals/Simulations

In this section we use the estimated coefficients from our random utility model to simulate market outcomes under alternative hypothetical market structures in order to study the consequences of suites for market outcomes. More specifically, we examine how the correlation of consumer preferences for spreadsheets and word processors matters for prices, market shares, profits, and

[31] 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."

consumer welfare for different monopoly and oligopoly settings. We conducted simulations for both 1995 and 1998, and find 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. The results for 1998 are presented in the Online Appendix. The simulations in Tables 4, 5 and 6 are based on the estimated coefficients from Table 3. At the end of this section, we check the robustness of our conclusions by drawing coefficients from their estimated multivariate normal distribution.

A key issue we wish to examine in the simulations is how correlation of preferences over word processors and spreadsheets affects market outcomes under alternative market structures. A convenient way to vary correlation without changing the estimates of the random utility parameters is to take two draws rather than a single draw (for each consumer) from independent standard normal random variables (denoted Y_{1k} and Y_{2k}). With these two draws, define μ_1 and μ_2 as follows: $\mu_1 = \sigma_1 Y_1$ and of $\mu_2 = \sigma_2 \rho Y_1 + \sigma_2(1 - \rho^2)^{1/2} Y_2$. Then it can be shown that $(\mu_{1k}, \mu_{2k}) \sim N(0, 0, \sigma_1, \sigma_2, \rho)$ is a bivariate normal distribution, where σ_1 and σ_2 are the standard deviations of μ_{1k} and μ_{2k} respectively and ρ is the correlation coefficient of the bivariate normal distribution. In such a case, the random utility component of the model is $\theta_{jk} = SS_j * \mu_{1k} + WP_j * \mu_{2k} + \epsilon_{jk}$. Note that when $\rho = 1$, the random utility component reduces to equation (3). Further note that in such a setting the correlation between an arbitrary spreadsheet and an arbitrary word processor is

$$\text{(5)} \qquad \frac{\rho\sigma_1 * \sigma_2}{\sqrt{(\sigma_1^2 + 1.645) * (\sigma_2^2 + 1.645)}}.$$

Thus, ρ, the correlation coefficient of the bivariate normal distribution, is essentially a scaling coefficient of the overall correlation between word processors and spreadsheets. By varying ρ we can change the correlation in preferences holding the estimated standard deviations constant. In the simulations, we examine ρ = -1, 0, and 1. Given our estimates $\sigma_1 = 0.87$ and $\sigma_2 = 1.82$, the corresponding overall correlation of consumer preferences for spreadsheets and word processors is -0.46, 0, or 0.46. Thus, our simulations model changes in correlation well away from the extremes of perfect negative or positive correlation.

As discussed by Gentzkow (1994), it is difficult to empirically identify preference correlation separately from product complementarity, because the two have similar qualitative effects on demand. In our model, it is similarly difficult to estimate both the correlation coefficient (ρ) from the SUITE coefficient because changes in the two have similar qualitative effects on the demand for suites. The suite bonus effect is different from product complementarity, because the suite bonus does not accrue for mix-and-match bundles. Nevertheless, the identification issue is similarly problematic, i.e., the share of suites at given prices does not by itself distinguish the effects of the suite-bonus from positive correlation in the taste distribution, sufficient exogenous price variation is necessary to separately identify ρ and the SUITE coefficient.[32] This difficulty is one reason why we do not include ρ as a parameter to be estimated, but rather as a scaling factor to be employed in the simulations to adjust the overall correlation between preferences over spreadsheets and word processors without adjusting our estimates of σ_1 and σ_2. Another reason is that, the estimated value of ρ in the more general model is very close to 1, although very imprecise.[33]

For our simulations, we assume that consumers' preferences (Y_{1k} and Y_{2k}) and products' marginal cost are invariant to market structure changes or whether firms adopt bundling. Estimated marginal costs are 'backed' out of the first order conditions for profit maximization. Specifically, we assume that the firms compete in prices in Nash equilibrium and choose their prices simultaneously based on the numerically calculated cross-elasticities of demand among the products they sell. For Microsoft's products in 1995, the estimated marginal costs are as follows: MS Word - \$96.7; MS Excel - \$112.5; MS Office - \$225.8. While these estimated marginal costs may seem excessive at first glance, the marginal cost of software in the 1990s included the marginal cost of CD pressing, manuals printing, packaging, distribution, marketing, as well as the marginal cost of providing consumer support (i.e., free unlimited phone support, etc.). According to the Software and Information Industry Association, in 1990, 38% of total software costs were variable costs in the form of sales costs, marketing costs, technical support, and consumer support. This by itself provides reasonable support for non-trivial point estimates of marginal costs.[34] In addition, recall that Office contained other software packages plus complementarity and integration features that may have entailed additional packaging (Microsoft Office 95 package was

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[32] An important element of price variation in our data is that Microsoft dramatically lowered the price of its suite relative to the price of the components in 1996. The effect of such a price cut is to increase the share of suites and, given the other parameters of the model, the magnitude of the increase varies with the correlation coefficient ρ. Assuming this price cut were exogenous (as it might have been the wake of Windows 95), it seems possible in theory to separately identify ρ and the SUITE coefficient, although in practice more exogenous price variation appears to be necessary for a convincing estimation of ρ.

[33] The following moment could be added to the estimation. Given our initial estimates, we could lower ρ (which is set to one) and re-estimate the model. We would again calculate the overall correlation from (5) and compare it with the correlation in the CPS data. When we do this iteratively, we find that convergence where the correlation from (5) equals the CPS estimate, is obtained when ρ=0.95. At that point, $\sigma1$ =0.75 and $\sigma2$=1.59. These are very close to our estimates of $\sigma1$ and $\sigma2$.Simulations using these values (ρ=0.95, $\sigma1$ =0.75 and $\sigma2$=1.59) are very similar to the simulations when ρ=1, $\sigma1$ =0.87 and $\sigma2$=1.82.

[34] The report is available from the authors on request.

a foot by foot cube in size), marketing or technical support expenses. It is also likely that Microsoft had made substantial marketing efforts to educate the market of the advantages of purchasing MS Office over buying only the components. Hence, it does not seem surprising that the marginal cost of the MS Suite exceeds the sum of the marginal costs for Word and Excel by approximately \$16.70.

Given the estimated suite-bonus of approximately \$23.40, the additional \$16.70 in costs implies that the suite generated approximately \$6.70 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' distinguishes our model from previous literature that focuses on the price-discrimination motive, and is key for understanding many of our simulation results.

Monopoly. The simulations in Table 4 compare market outcomes for three cases for different values of ρ under the counterfactual assumption that Microsoft is the sole vendor in the market. In Case I in Table 4—"pure bundling"—Microsoft sells only the Office suite. Under "separate selling" (Case II), consumers can buy the Excel spreadsheet or Word separately. Consumers also can construct their own bundle by buying both components, for which there is a separate ε draw, but without the additional suite bonus value included in Office. Market outcomes are independent of ρ in this case. Under "mixed bundling" (Case III), all three products are available. A striking conclusion from these simulations is that both profits and consumer surplus are increasing in correlation in all three cases.

The intuition for why profit increases in ρ under pure bundling relates to Johnson and Myatt (2006)'s analysis of preference dispersion. Specifically, given that the variance of the random utility for the suite is increasing in ρ, a higher value of ρ rotates the demand curve clockwise. Furthermore, since Microsoft serves only a fairly small portion of the potential market (23% percent in the simulation), this demand rotation increases sales of the suite in the relevant price range. Finally, the demand shift provides an incentive for the monopolist to raise price, to the point where the quantity sold is virtually unchanged across the different values of ρ. We call this positive relationship between preference correlation and demand for suites the 'market expansion effect' of bundling.

The mixed-bundling case also shows that Microsoft's profit is increasing in the correlation. The market expansion effect operates more subtly under mixed bundling, because the additional suite sales are partly at the expense of component sales. Nevertheless, the market expansion effect and the suite bonus effect conspire to make profits increasing in the correlation coefficient under mixed bundling. Specifically, the suite-bonus effect reinforces the expansion in demand for suites because it increases the incremental profit from each new sale. The combined effect allows Microsoft profitably to increase the price of the suite and yet still sell more suites. This is in contrast to the pure bundling case where the price of the suite goes up yet the percentage of consumers who buy the suite remains virtually unchanged. It is worth noting, however, that while the suite-bonus effect contributes significantly to higher profits, the market expansion effect by itself is strong enough for profit to be increasing in correlation.[35]

Comparing profitability across the different bundling strategies, we know from theory that Microsoft's monopoly profit must be (weakly) higher under mixed-bundling than under pure bundling or separate selling because the firm could duplicate the pure bundling or separate selling strategies. The profit comparison between pure bundling and separate selling, however, is theoretically ambiguous because of two possibly conflicting effects. On the one hand, especially when correlation is negative, pure bundling could be less profitable than separate selling due to the 'penalty' of higher marginal costs (Adams and Yellen 1976). On the other hand, especially with positive correlation, pure bundling is more profitable than separate selling because of the market expansion and the incremental profits derived from the suite bonus. In our simulations, the suite-bonus effect is strong enough to make pure bundling more profitable. Furthermore, since profit under separate selling does not depend on correlation, the advantage of pure bundling is increasing in correlation because of the market expansion effect. Similarly, the advantage 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.

Consumer surplus increases hand-in-hand with profit with greater correlation.[36] With positive correlation ($\rho = 1$), the predicted price of Microsoft Office under mixed and pure bundling is about the same, roughly \$248, which is approximately \$14 higher than the summed prices of Excel and

[35] In the Online Appendix, we show that profits increase with correlation even when there is no suite bonus and the cost of the suite equals the sum of costs of the components.

[36] It is straightforward to calculate consumer surplus under the different scenarios. Exploiting the properties of the Gumbel distribution we calculate for each consumer the expected maximum utility conditional on Y_{1k} and Y_{2k} and report the average.

Word under separate selling. Given that the average suite bonus is $23.4, a $14 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 4% higher than under separate selling. Thus, under mixed bundling 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. The reason behind the positive relationship between consumer surplus and correlation is driven by the number of consumers that buy the bundle. While lower correlation results in more attractive pricing, under negative correlation the market expansion effect implies that fewer consumers are attracted by the benefits of the bundle, and thus fewer consumers enjoy the suite bonus.

1995	ρ = 1				ρ = 0				ρ = -1			
	Price	Share	Profit	CS	Price	Share	Profit	CS	Price	Share	Profit	CS
Case I: Pure bundling												
Office	247.9	0.23	5.1	4.0	244.1	0.23	4.2	3.3	239.3	0.23	3.1	2.6
Case II: Separate selling												
Word	111.5	0.15	2.2	2.9	111.4	0.15	2.2	2.9	111.5	0.15	2.2	2.9
Excel	123.4	0.11	1.2		123.4	0.11	1.2		123.4	0.11	1.2	
	234.9	0.26	3.4		234.8	0.26	3.4		234.9	0.26	3.4	
Case III: Mixed bundling												
Word	115.9	0.05	0.9	4.5	115.1	0.06	1.2	4.2	114.2	0.09	1.5	3.9
Excel	127.9	0.04	0.6		126.6	0.06	0.8		125.2	0.08	1.0	
Office	248.9	0.19	4.5		245.5	0.18	3.5		241.0	0.16	2.4	
		0.27	5.9			0.30	5.5			0.33	5.0	

Table 4: Monopoly Market Structures and Correlation[37]

Partial Competition. Table 5 simulates outcomes for different modes of oligopoly competition in the components markets. To that end, we include in the market setting the WordPerfect word processor (marginal cost $81.4) and the Lotus spreadsheet (marginal cost $86.4) as well as the Microsoft products. As in the monopoly simulations, Microsoft’s profit and consumer welfare are increasing in correlation across all market structures, which is not surprising given Microsoft’s

[37] In all simulations, prices are in $, shares are based on the 100,000 potential consumers per year, and profit and consumer surplus (CS) are in $ per potential consumer. Outcomes are summed over Microsoft products where appropriate.

dominant position in the office software market. We focus our discussion on the effect of the correlation on the strategic interaction among the firms.[38]

A comparison of Cases I and II in Table 5 highlights the competitive effects of the introduction of suites. In Case I, Microsoft does not sell a suite and separately competes against Lotus in the spreadsheet market and against WordPerfect in the word processor market. Consumers who purchase both a spreadsheet and a word processor do not get the 'suite-bonus'; 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 $4 and $6 depending on ρ) for the suite over the sum of the prices of Excel and Word. When ρ = 1, suites make up a large percentage of total sales. Microsoft earns most of its profits from the suite (73%), while the shares (and profits) of Lotus and WordPerfect fall by about 30%. Overall, the size of the components market decreases by about 50%.

Interestingly, the introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance regardless of whether rivals remain active in the market. This is because the suite-bonus ($23.4) is much larger than the difference between the suite price and the sum of prices of Microsoft's Word and Excel in case I. When ρ = 1, 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 $10.8.[39] Recall that when ρ = 1, there are many such switching consumers, and these consumers reap a large benefit from purchasing the suite. Further, there is an increase in unit sales of spreadsheets and word processors (via the suite) when the suite is introduced, which also increases consumer surplus.[40] The combination of 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. As a result, as long as the rivals remain in the market, the introduction of the suite raises consumer surplus substantially. Specifically, when ρ = 1 consumer surplus increases from 4.5 to 6.1. Since a

[38] Elasticities from the random coefficients model and the logit model are reported in Appendix C. Except for the case of Microsoft Word and Microsoft Excel, word processor and spreadsheet pairs are complements which makes sense. Microsoft Word and Excel are substitutes because they have a common characteristic – namely the Microsoft characteristic)

[39] Net benefit is calculated as follows: $23.4-[246.1-109.6-123.1]. Any discrepancies in values are due to rounding errors

[40] Note that every sale of a suite corresponds to a sale of one unit of word processor and one unit of spreadsheet. Consequently, when ρ = 1, the share of the inside good in Case I is 0.37 and 0.58 in Case II.

decrease in correlation reduces the demand for suites, the pro-competitive effects of the introduction of a suite are attenuated as correlation decreases.[41] (Nevertheless the introduction of the suite is welfare improving for consumers also for $\rho=0$ and $\rho=-1$ as long as rivals remain active.)

Case III examines the effect of competition in the components market by simulating a market where Microsoft only sells its suite. Comparing this structure to Case II where the components market is oligopolistic, it is interesting to note that the competing firms do not necessarily benefit from a reduction in the number of Microsoft products. Specifically, a competing firm may be better off against a dominant firm that sells components and a bundle (mixed bundling) rather than just the bundle (pure bundling). This result is driven by the foreclosure effect that pure bundling may have in the case of oligopolistic market. In particular, suppose a consumer likes Microsoft Word, but also likes the Lotus spreadsheet. If Microsoft sells components, then the consumer can purchase the mix-and-match combination of these two components. If, however, 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 and WordPerfect word processor goes down; reducing the profitability of firms only selling components.

Whether the standard 'reduction in competition' effect dominates the 'mix-and-match effect', or vice versa, depends on the level of correlation. Our simulation results show that the 'mix-and-match effect' is stronger when $\rho = 1$. Otherwise, the reduction-in-competition effect dominates. Since the share of consumers that highly value the purchase of both components increases with correlation, 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. This together with the effect of correlation on pricing and consumer surplus demonstrates that the strategic interaction among the firms is affected significantly by the value of the correlation coefficient.

[41] The welfare gain is due to both variety and pricing effects, where, depending on ρ, pricing accounts for 35-45% of the gain.

1995	$\rho = 1$				$\rho = 0$				$\rho = -1$			
	Price	Share	Profit	CS	Price	Share	Profit	CS	Price	Share	Profit	CS
Case I: Component competition, no suite bonus when purchasing both components												
MS Word	109.6	0.14	1.8		109.5	0.14	1.8		109.6	0.14	1.8	
MS SS	123.1	0.10	1.1		123.1	0.10	1.1		123.1	0.10	1.1	
	232.6	0.24	2.9	4.5	232.6	0.24	2.9	4.5	232.6	0.24	2.9	4.5
WP Word	92.2	0.07	0.8		92.2	0.07	0.8		92.2	0.07	0.8	
Lotus SS	96.2	0.06	0.6		96.2	0.06	0.6		96.2	0.06	0.6	
Case II: MS sells suites and components; no suite bonus for mix-and-match												
MS word	113.6	0.05	0.9		112.6	0.07	1.1		111.6	0.09	1.3	
MS SS	126.5	0.04	0.6		125.4	0.06	0.7		124.3	0.08	0.9	
MS suite	246.1	0.19	3.8	6.1	243.4	0.17	3.0	5.8	239.8	0.15	2.1	5.6
		0.28	5.2			0.29	4.8			0.31	4.3	
WP word	91.3	0.05	0.52		91.6	0.06	0.60		92.0	0.08	0.7	
Lotus SS	95.9	0.04	0.38		96.1	0.05	0.45		96.3	0.07	0.5	
Case III: MS sells only its suite; no suite bonus for mix-and-match												
MS suite	245.2	0.23	4.4		242.2	0.22	3.6		238.2	0.21	2.6	
WP word	91.2	0.05	0.51	5.4	91.9	0.06	0.65	4.8	92.8	0.07	0.8	4.1
Lotus SS	95.8	0.04	0.37		96.2	0.05	0.5		96.6	0.06	0.6	

Table 5: Oligopoly competition: Lotus and WordPerfect sell components

Suite Competition: In the third set of simulations (Table 6) we examine oligopolistic competition in the suite market. Our 1995 estimated-costs for the Lotus and WordPerfect suites are \$115.8 and \$131 respectively, both considerably less than the \$225.8 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; it presents the case where Microsoft sells its suite monopolistically in the market. We first compare this case to the case where Microsoft competes against a WordPerfect suite and a Lotus suite (case II). A comparison shows that competition decreases Microsoft's price by a very small amount regardless of whether ρ=-1, 0, or 1. Further, 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.) This implies that the rival suites did not provide significant competition to Microsoft; suggesting that consumers may have put high value on only one of the components in Lotus' and WordPerfect's suites.

Cases III and IV in Table 6 simulate the effect of a potential merger between Lotus and WordPerfect on market outcomes. We assume that the merged firm's suite includes two high-quality components: the Lotus spreadsheet and the WordPerfect word processor. In this simulation, we assume that the marginal cost of the merged suite is \$184.5, which is the sum of the marginal costs for the two components (Word Perfect and the Lotus Spreadsheet) and the additional marginal cost of the suite we estimated in the case of Microsoft ($16.7). Consumers are better off in the three suite market (case II) than under the proposed merger. The sales weighted price is lower and the total market share of the inside goods is higher in the 'three suite' world for all values of ρ. The consumer surplus numbers reflect this. Hence, assuming no cost efficiencies, the merger reduces consumer welfare.

In case IV we also assume that Microsoft's suite competes against a merged Lotus/WordPerfect suite. However, in order to capture an enhanced brand effect, we assume that the merged suite gains the positive Microsoft fixed effect but also bears the higher cost of the Microsoft suite. Here the effects of the merger are quite different. While the price of the merged suite is higher than in case III, the quality is higher due to the effect of the Microsoft dummy variable. Additionally, Microsoft's price falls relative to case II. These two effects then result in a much larger market being served. As a result, welfare is higher than in case II, despite the higher price of the merged suite. This suggests that the welfare effects of a merger between Lotus and WordPerfect depend critically on the overall quality of the merged suite. Thus, Microsoft's unobserved quality advantages appear to be a significant factor behind Microsoft's success in dominating the office productivity software market.

1995	ρ=1				ρ=0				ρ=-1			
	Price	Share	Profit	CS	Price	Share	Profit	CS	Price	Share	Profit	CS
Case I: Microsoft is alone in the market – and only sells suites												
Office	247.9	0.23	5.1	4.0	244.1	0.23	4.2	3.3	239.3	0.23	3.1	2.6
Case II: All three firms sell suites												
Office	244.3	0.24	4.343	5.4	242.4	0.23	3.79	4.2	239	0.22	2.94	2.9
WP suite	140.5	0.019	0.18		140.4	0.015	0.14		140.4	0.010	0.093	
Lotus suite	125.7	0.039	0.383		125.5	0.031	0.303		125.1	0.022	0.203	
Case III: Microsoft MS competes with merged suite – marginal cost of merged suite 184.5												
Office	245.5	0.2	4.6	4.9	243.1	0.2	4.0	3.8	239.1	0.2	3.0	2.8
Merged suite	194.3	0.03	0.3		194.0	0.03	0.2		193.8	0.02	0.2	
Case IV: MS competes with merged suite – same marginal cost of $225.8 for both suites, both firms get MS bonus												
Office	241.9	0.23	3.65	6.7	240.8	0.22	3.29	5.3	238.5	0.21	2.7	3.6
Merged suite	237.5	0.12	1.36		237	0.11	1.18		236.1	0.088	0.9	

Table 6: Oligopoly Competition – firms only sell suites

Robustness Analyses

The results above are based on the coefficient estimates in Table 3. As we discuss in Section 5, our small dataset does not allow us to estimate equation 2 very accurately. In order to test for the robustness of our results, we run the simulations presented in Tables 4 and 5 on 60,000 draws taken based on the estimated variance-covariance matrix. Given that our price coefficient is not statistically significant, it is not surprising that we get a positive price coefficient in about 10% of the draws. We drop these draws. We run the simulations on the remaining 90% of the draws; however, for some of these draws the program is unable to find the equilibrium cost estimate or equilibrium prices.[42] We use all of the draws for which the program finds an equilibrium and focus our robustness analysis on the key results discussed above. Specifically, the positive and monotonic relationship greater correlation has with welfare and profitability, and the positive welfare effects of the introduction of the suite.[43]

Our results are summarized in Table 7. In the "Monopolistic Case," Microsoft is the only active vendor in the market. In the "Oligopolistic Case," Microsoft competes with the WordPerfect word processor and the Lotus spreadsheet. We consider both pure bundling and mixed-bundling settings for Microsoft. Hence, we consider four industry configurations, which correspond to Cases I and III in Table 4 and Cases II and III in table 5. As Table 7 shows, our results regarding the relationship between correlation (ρ) and welfare are robust to changes in the estimated coefficients. In virtually all cases, welfare increases in ρ.

While the positive monotonic correlation with profits is not as robust, our results are in line with Schmalensee (1984). Specifically, Schmalensee (1984) shows for the case of monopoly pure bundling that profits increase in correlation when markups are relatively low, decrease in correlation when markups are relatively high, and have a U-shaped relationship for moderate markups. Indeed, we find, both for monopoly and oligopoly models, and both for pure and mixed bundling, that the average markup in the cases where profits decrease in correlation is about three times as large as for the cases where profits increase in correlation.

[42] In this case, the program does not converge and reports that it is unable to find a solution. Convergence is a problem typically when simulated costs are unreasonably high or low.

[43] While we estimate the standard deviations of preferences over spreadsheets and word processors ($\sigma 1$ and $\sigma 2$) to be positive, given the large standard error of these estimates, in about half of our draws, either $\sigma 1$ or $\sigma 2$ are negative. If $\sigma_1 * \sigma_2 < 0$ then correlation decreases with ρ.

Share of simulation runs where	Pure Bundling	Mixed Bundling
Welfare *increases* in correlation[44]		
Monopolistic Case	0.98	0.96
Oligopolistic Case	0.97	0.92
Microsoft's Profits *increase* in correlation		
Monopolistic Case	0.88	0.73
Oligopolistic Case	0.85	0.8
Microsoft's Profits *decrease* in correlation		
Monopolistic Case	0.04	0.16
Oligopolistic Case	0.09	0.1
Microsoft's Profits *U shaped* in correlation		
Monopolistic Case	0.08	0.11
Oligopolistic Case	0.06	0.1

Table 7: Welfare and Profits Robustness Effect

In addition, we examined the robustness of our result that the introduction of the suite is pro-competitive regardless of the value of ρ and find that under both the monopolist and oligopolistic market structures, the introduction of the suite is always pro-competitive for positive and zero correlation. When ρ=-1, the introduction of the suite is pro-competitive in 99 percent of the runs.

The result that a merger between WordPerfect and Lotus is welfare improving only if the merged firms overcome Microsoft's unobserved quality advantages is not as robust. Specifically, in about 44% of the runs a merger is welfare decreasing even if the merged firm enjoys the same quality as the Microsoft suite.

We also examined the relationship between the 'mix-and-match effect' and the 'reduction in competition' effect. The table below presents the share of cases where Lotus' and WordPerfect's profits were higher under mixed bundling than under pure bundling. As expected, when the correlation is positive, it is very likely for the mix-and-match effect to dominate the reduction in competition effect (85 and 83 percent for WordPerfect and Lotus, respectively). Furthermore, the percentage of cases for which the mix-and-match effect is dominant increases in correlation.

Share of simulation runs where	ρ=1	ρ=0	ρ=-1
Higher profits under mixed bundling			
WordPerfect word processor	0.85	0.75	0.3
Lotus spreadsheet	0.83	0.62	0.2

Table 8: Reduction in Competition Effect

[44] In all other cases, welfare either decreases or is U-shaped in correlation.

Finally, in order to make sure that our main results are robust to different cost structures, we re-did all the simulations in Tables 4, 5, and 6 under the assumption that the marginal cost of the Microsoft suite is the sum of the marginal costs of the Microsoft components, while retaining the estimated marginal costs of Microsoft's components and the other components. The results are in the online appendix. They show that the effects of correlation on profits and consumer surplus and on the strategic interaction in the market are robust to this alternative cost structure. Further, additional simulations in the online appendix also show that these main results are also robust to conducting the simulations for 1998 in which the cost estimates are different.

8. Conclusion

In this paper, we examine how correlation in preferences over spreadsheets and word processors affect conduct and performance in the office software market. We used estimates from an empirical model to simulate the effects of correlation under alternative hypothetical market structures. Our results suggest that, with positive correlation of consumer preferences for word processors and spreadsheets, the introduction of the suite in the 1990s increased both profitability and consumer welfare. We focus on two key effects: (1) the 'market expansion' effect; and (2) the 'suite-bonus' effect.

The market expansion effect corresponds to the positive effect the increased variance of preferences for the suites that results from greater correlation has on demand for suites. While this effect has not been emphasized in the bundling literature, in the case of pure bundling, we find it to be the main driver of the positive relationship between correlation and profitability as well as welfare. In particular, we find that in the case of pure bundling, the market expansion effect alone is sufficient to overturn the standard 'price discrimination' 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 market expansion effect with the suite-bonus which represents the additional value consumers enjoy from consuming the suite, on top of the value from consuming a word processor and a spreadsheet.

The suite-bonus arises from the value-added of suites and/or from product complementarity that results from a better integration of the spreadsheet and word processor components. We estimate a positive net value of suites on top of the values of the separate components. This value creation of suites is a source both of increased profitability and increased consumer welfare. Furthermore, the market expansion of positive correlation enhances these benefits.

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. The introduction of the suite is 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 expands the distribution of spreadsheets and word processors, and this is beneficial to consumers as well.

Using simulations, we also show that whether a merger between the second and third largest firms in the industry would have been welfare improving depends on whether a suite combining the best products of the merged firms would overcome Microsoft's unobserved quality advantages, e.g. from better integration with Windows. Otherwise, the merger would reduce consumer welfare due to the usual adverse competitive effects.

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Appendix A: 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 components listed in the above table.[45] 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 than the other firms.

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

Appendix B: Current Population Survey Supplement on Computer and Internet Use

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.[46] 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:[47]

- 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

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.

[46] 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.
[47] The possible answers are either yes or no.

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 – a dummy variable that takes on the value one if the individual is in school and 0 otherwise.

INTERNET – 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 C: Elasticities

Cross elasticities from the logit and random coefficients models

Below, we report the cross elasticities for both the logit and random coefficients model for the oligopoly simulation in table 5. Elasticities from logit model are calculated analytically, since there is an analytical expression for market share. In the case of the random coefficients model, elasticities are calculated numerically.

For the logit model, the own elasticity for product j equals β1*(1-sj)pj. The cross elasticity (of product j with respect to changes in the price of product k) equals: (-1)β1*sk*pk.

Hence, own and cross elasticities from the logit model are:

	MS Word	MS Excel	WP Word	Lotus SS	MS Suite
MS Word	-14.96	0.61	0.46	0.53	6.48
MS Excel	0.68	-16.96	0.46	0.53	6.48
WP Word	0.68	0.61	-12.18	0.53	6.48
Lotus SS	0.68	0.61	0.46	-16.68	6.48
MS Suite	0.68	0.61	0.46	0.53	-26.93

The first column is the elasticity of the product (j) in each row with respect to changes in the price of MS Word. Since this only depends on the price and market share of MS Word, the cross elasticities are the same for all products in the column.

Own and cross elasticities from the random coefficient model are:

	MS Word	MS Excel	WP Word	Lotus SS	MS Suite
MS Word	-11.95	0.63	0.63	-0.60	0.63
MS Excel	0.58	-13.43	-0.42	0.58	0.58
WP Word	0.53	-0.70	-9.58	-0.39	0.53
Lotus SS	-0.31	0.43	-0.22	-10.18	0.43
MS Suite	5.10	5.10	5.10	5.10	-22.15

We can see that own elasticities from the random coefficients model are smaller (and more reasonable) than those from the logit model.

Further, except for the case of Microsoft Word and Microsoft Excel, word processor and spreadsheet pairs are complements (shaded in the above table) which makes sense. Microsoft Word and Excel are substitutes because they have a common characteristic – Microsoft.)

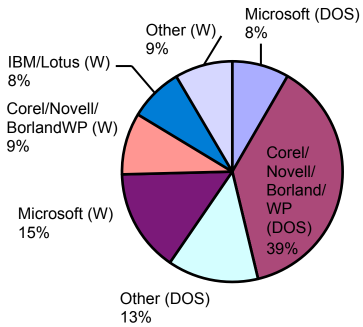

Figure 1: Word Processor Market 1991
Total Market $952M; DOS $567M; WINDOWS $385M

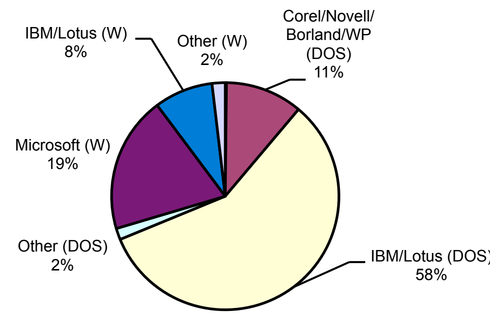

Figure 2: Spreadsheet Market:1991
Total Market $809 M; DOS $239M; WINDOWS $569M

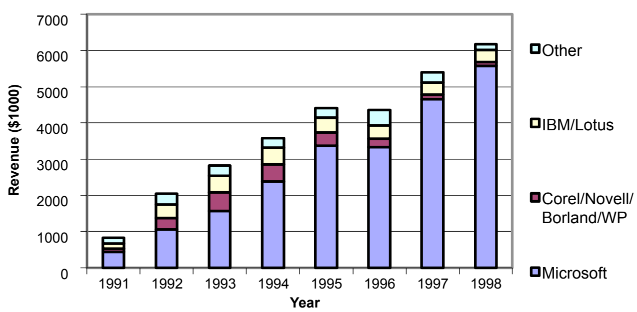

Figure 3: Office Software Revenue for WINDOWS Platform by Firm 1991-1998

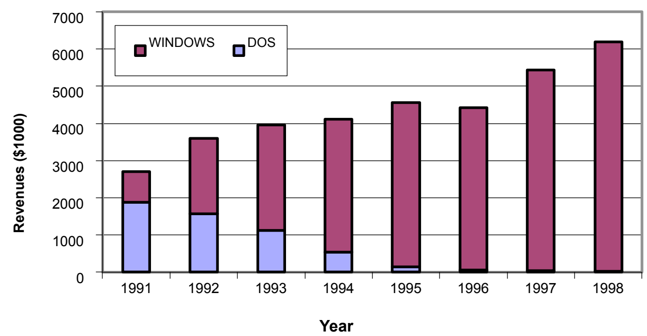

Figure 4: Office Software Revenue by Platform, 1991-1998

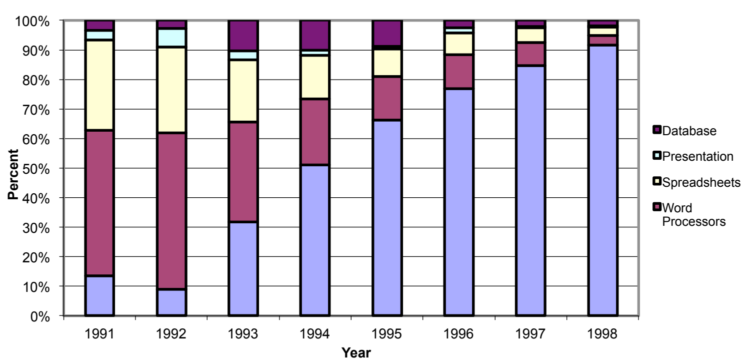

Figure 5: Windows Office Productivity (Revenue) Shares by Category, 1991-1998

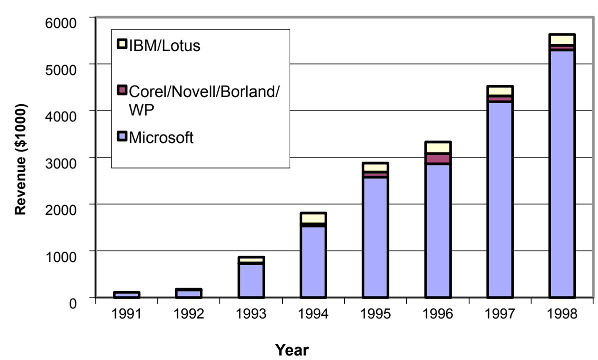

Figure 6: Office Suite Revenue by Firm 1991-1998

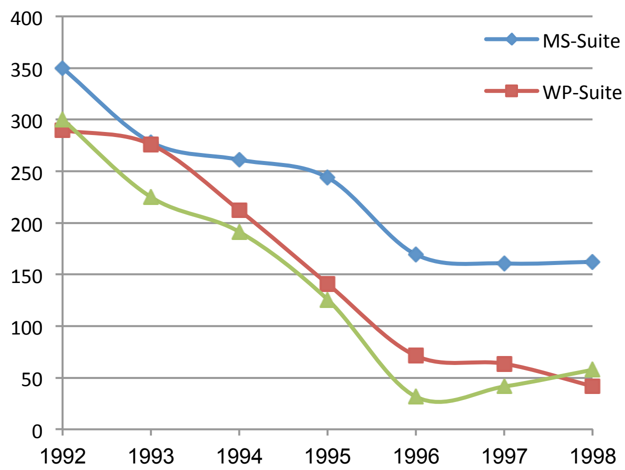

Figure 7: Suite Prices

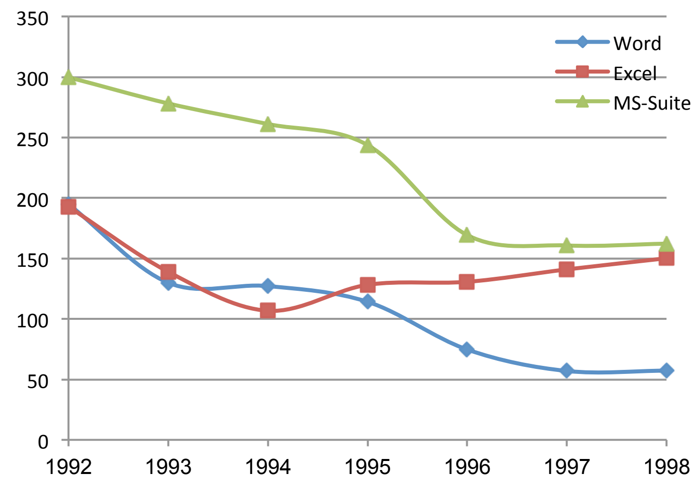

Figure 8: Microsoft Prices

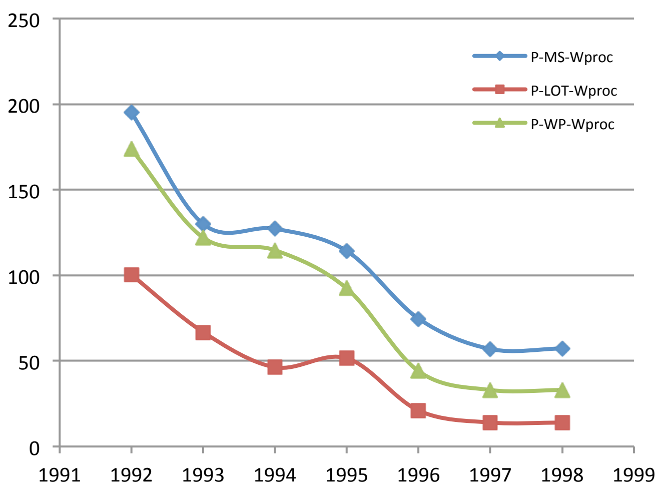

Figure 9: Word Processor Prices

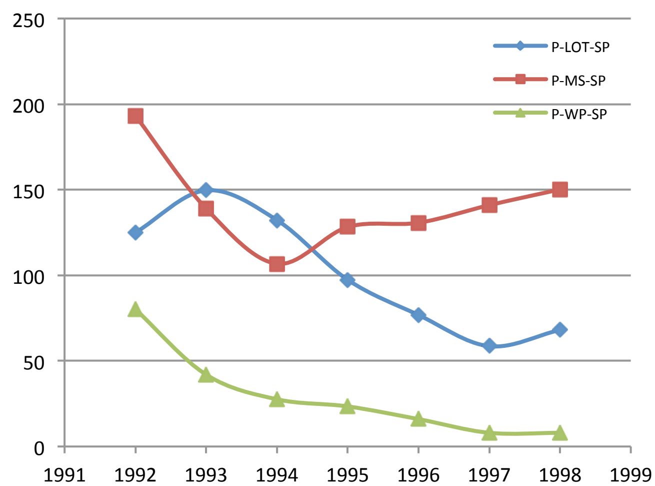

Figure 10: Spreadsheet Prices