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

Neil Gandal, Sarit Markovich, and Michael Riordan*

*We are grateful to Mat Rothway for research assistance and thank John Asker, Luis Cabral, Robin Lee, Mark Manuszak, Aviv Nevo, and seminar participants at various universities and conferences for helpful comments and suggestions. Riordan thanks the Toulouse School of Economics the hospitality and research support during 2012-2013. Gandal had several academic research grants from Microsoft for other academic papers written during part of the period in which we wrote this paper. Any opinions expressed are those of the authors.

Gandal: Gandal@post.tau.ac.il; Markovich: s-markovich@northwestern.edu; Riordan: mhr21@columbia.edu

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March 17, 2013

Abstract

We examine the importance of office suites for the evolution of the PC office software market. An estimated discrete demand choice model reveals strong positive correlation of consumer values for spreadsheets and word-processors and a bonus value for suites. We employ the estimates to simulate various hypothetical market structures to shed light on the welfare and competitive effects of suites. Greater correlation enhances the profitability of bundling due to 'a market expansion effect.' In a setting in which Lotus sells only a spreadsheet and WordPerfect sells only a word processor, we find that Microsoft's introduction of the suite increased consumer welfare.

1. Introduction

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

The most important office productivity software products in the 1990s were spreadsheets, word processors, and office suites—which combined a spreadsheet and a word processor with other value-added features and programs. The office productivity software market experienced dramatic structural change during the 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 strategy led by Microsoft from selling separate products to selling office suites.

We study the importance of office suites for the evolution of market structure and the performance of the PC office software market, focusing on how the correlation of consumer preferences for spreadsheets and word processors mattered for the profitability and the competitive effects of suites. To examine these issues, we estimate a parsimonious model of consumer demand for spreadsheets, word processors, and suites. The model allows for correlated common components of consumer tastes for spreadsheets and for word processors, plus an independent idiosyncratic taste component for each product in each category. The model assumes consumer tastes for suites incorporate the common taste components of spreadsheets and word processors, and includes a separate independent idiosyncratic component. Positive correlation of the common components indicates a general taste component for office productivity products in a category, while the idiosyncratic component limits the overall degree of correlation between the products. The model also allows suites to add a "bonus value" to mean consumer utility—reflecting value-added features, better integration of the components of the suite, and/or any other type of complementarity between word processors and spreadsheets. Finally, we allow for Microsoft

products to have advantages over the other vendors, possibly reflecting smoother operation with Windows.

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

The theoretical industrial organization literature includes some discussion of product complementarity in bundling models. Lewbel (1985) extended the Adams and Yellen (1976) model and showed with a crude example that separate selling could be profit maximizing even with product complementarity. Nalebuff (2004) argues that product complementary raises barriers to a single product entrant. Our model accommodates product complementarity by allowing for a bonus value for suites that could arise either from product complementarity or from value added features of the suite, and is consistent with the idea that complementarity requires some integration of the component products.[1]

Estimation of our demand model reveals a positive correlation in consumer preferences over word processors and spreadsheets,[2] a moderate bonus value for suites, and significant advantages for Microsoft products. We use the estimated demand model to simulate various hypothetical market structures in order to shed light on the welfare and competitive effects of bundling in the office productivity software market. While our empirical model is novel, we are primarily interested in the competitive and welfare effects of bundling. Consequently, our discussion focuses on the simulation results and their implications.

[1] There also is an analogy between the bonus value of suites and one-stop shopping economies. By purchasing two products at one shop instead at two, consumers receive the bonus of reduced shopping costs. See Chen and Rey (2012) for a recent analysis of the screening and exclusionary effects of loss leading by supermarkets based on one-stop shopping economies.

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

We find that the level of correlation in consumer tastes for spreadsheets and word processors plays a central role in the determination of the profitability of selling 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 assumed to be a monopolist or to be competing with rival firms in the spreadsheet and word processor markets. Furthermore, we find that pure and mixed bundling both improve both profits over separate selling for high levels of positive correlation. These results may seem surprising, especially in the monopoly case, as they run counter to the classic theoretical results that bundling is a particularly effective price discrimination strategy under negative correlation, and that bundling does not improve on separate selling under perfect positive correlation. The intuition behind our findings relies on two important effects: (1) the 'market expansion' effect; and (2) the 'suite bonus' effect.

The increased variance of preferences for the suites that results from greater correlation increases the demand for suites, illustrating what Johnson and Myatt (2006, hereafter JM) call an 'expanding niche market' effect where profits increase in consumer preference dispersion. Since our simulations show that higher correlation enhances profitability even when the bundling firm serves a relatively large share of the market, we refer to the positive effect an increase in correlation has on demand for the bundle simply as market expansion.[3] While the market expansion effect has not been emphasized in the bundling literature,[4] we find it to be a key driver of our results on the competitive as well as the welfare effects of bundling. Greater preference correlation increases the number of consumers who demand both products at given prices, which enables a multiproduct firm profitably to raise the price of the bundle.

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. We call this additional value the suite bonus and estimate it at $36. Given that we estimate that the marginal cost of Microsoft's suite was $30 higher than the sum of marginal costs of Word and Excel, our suite bonus estimate implies that the suite presented

[3] JM use the term 'expanding niche market', as in their model this effect holds only when the bundling firm serves a very small share of the market and flips otherwise. Our simulations show that in the case of pure bundling higher correlation enhances profitability even when the bundling firm serves 40 percent of the potential market, where the potential market is the number of operating systems sold or distributed via OEMs.

[4] While not explicitly analyzed, the effect is implicit in Schmalensee (1984); in particular, see Case III in Table 4.

a profit opportunity to Microsoft, independently of any price discrimination benefits from bundling. To the extent that Microsoft failed to fully extract the suite bonus, consumers benefitted as well.

We find in the case of pure bundling 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 combine to make Microsoft's bundling strategy both profitable and attractive to consumers.

In order to examine the competitive and welfare 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 had significant competitive effects. In particular, the introduction of Microsoft Office under partial competition shifts market share away from Lotus and WordPerfect and intensifies price competition. The consequences for consumers depend on correlation. On one hand, when the correlation is positive (as we verify empirically) or zero, Microsoft's introduction of an office suite benefits consumers on balance assuming its rivals remain active in the market. On the other hand, when correlation is negative, the suite reduces consumer welfare.

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' ($36) is much larger than the difference between the suite price and the sum of Microsoft's component prices when Microsoft does not offer a suite. When correlation is strong and positive, 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 in the case of strong positive correlation is robust to variations in the estimated model.

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.[5] 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 a merger between WordPerfect and Lotus, the dominant firms in the word processing and spreadsheet markets in the DOS era, might have been welfare enhancing. When we compare the setting in which the Microsoft suite competes with a merged (Lotus/WordPerfect) suite with the setting in which all three suites compete, we find that sales weighted prices are slightly lower in the 'three suite' world, but total sales are about 50% higher in the 'two suite' world. Additionally, the sales weighted quality of the products sold in the market is much higher. Welfare calculations indeed show that consumer surplus is higher in the case in which WordPerfect and Lotus merge, even though the number of firms is reduced from three to two. In these simulations, we also empirically examine the importance of two Microsoft advantages: (I) a higher observed quality of components;[6] and (II) higher unobserved quality. The second category includes potentially all of the following: better reputation, better service, better additional components in the suite, better integration with Windows, and better integration of components. Interestingly, we find that the first effect (higher observed quality of components)

[5] Nalebuff (2004) makes a similar point.
[6] By 1995, Microsoft's component products were rated higher than the high-quality components of the competing products.

played only a very small role in determining Microsoft's advantage.[7] This result is also robust to variations in the estimated model.

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

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

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,[8] 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.[9] Furthermore, when a firm serves a relatively small portion of the potential market, the JM (2006) result implies that positive correlation increases the profitability of pure bundling by increasing consumer heterogeneity.

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). On the other hand, bundling can accommodate the rival by vertically differentiating products and thereby relaxing price competition (Carbajo, deMeza and Seidman

[8] For an introduction to copulas, see Trivedi and Zimmer (2005.)
[9] 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.

1990; Chen 1997) due to vertical differentiation.[10] 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 individual channel demand. But by combining bundle data (prices and quantities) and individual channel viewing data (without prices), they are able to simulate the market with 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 individual sales, as well as sales of bundles. Further, we focus on other issues.

There are few other empirical papers on joint purchases and bundling that pay attention to correlation. Gentzkow (2007) studies joint purchases of print and online newspapers. Like us, he also allows for both correlations over preferences and complementarity among products, but he addresses different issues and uses a different identification strategy than the one we employ. His identification strategy is based on the exclusion of variables from the utility of some of the products and on employing panel data. Chu, Leslie, and Sorensen (2011) estimate the demand for bundled theater tickets with a common taste component across different shows, as a way to motivate a numerical analysis of the profitability of bundle-size pricing. Ho and Mortimer (2012a,

[10] 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.

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

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

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

1990-1992 was a period of new product introduction and improvement, as competitors adapted to the new WINDOWS platform. Microsoft was first out of the gate with WINDOWS based applications. Microsoft Excel was the first spreadsheet for WINDOWS and Microsoft Office (1990) was the first office suite for WINDOWS.[11] Competitors followed, but generally experienced more difficulty ironing out the bugs. Reviews generally agreed that the Microsoft products were superior. Nevertheless, the data clearly show that the switch in platforms from DOS to WINDOWS did not eliminate rivals in the spreadsheet and word processing markets.

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

Office suites gathered importance in 1993-94. This was a period of continuous product improvement as office software vendors adapted to an improved version of WINDOWS released in 1992. The new generation of suites were better, but still lacked significant integration.

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

Microsoft was best positioned in the office suite category because it already had highly-rated versions of key underlying components.

Microsoft's new office suite, released in early 1994, was extremely well received by computer software trade journals.[12] Microsoft Office 4.2 (including Word 6.0, Excel 5.0 and PowerPoint 4.0) was better integrated than the previous generations of suites and went beyond the standard embedding at the time. Word 6.0 offered a feature where a user could insert an Excel toolbar icon into a document, and then graphically size and place an Excel 5.0 spreadsheet object.[13] 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.[14]

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.[15] 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.[16] 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.

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[12] 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.

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

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

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

[16] 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.

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

There were essentially three firms in the office software market: Microsoft, IBM/Lotus (or Lotus)[17] 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 econometric analysis to products offered by these three firms.

4. Data

Our dataset includes the key office software products: spreadsheets, word processors, and suites. Computer hardware (operating systems) and software are complementary products and the benefit from software consumption can only be realized if consumers have an operating system capable of running the particular software package. In order to focus exclusively on software effects, the sample was restricted to spreadsheets, word processors, and office suites that were compatible with the WINDOWS operating system.[18] Packages that were compatible only with the Apple/Macintosh operating system, for example, are excluded from our analysis.

Data on prices and quantities (denoted PRICE and QUANTITY) come from two Dataquest/Gartner Reports on Personal Computing Software, one for the 1992-1995 period and one for the 1996-1998 period.[19] Dataquest/Gartner reports (worldwide) shipments and total revenues for each product; hence price is the average transaction price.[20] The variable QUANTITY is the number of units sold (in thousands), and the variable PRICE is the average

[17] IBM acquired Lotus in 1995.

[18] 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.

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

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

price.[21] The price of a mix-and-match combination is the sum of the prices of the components. Importantly, according to Liebowitz and Margolis (1999) (hereafter LM), for the period we analyze, office software products were typically sold directly to consumers rather than via the OEM market.

Data on quality of spreadsheets and word processors come from LM; they employed reviews that gave numerical ratings, and they normalized the top score to 10 in each year. Given the normalization, these scores are not comparable across years. This, however, is not important for our analysis since the choice set consumers see is the software available in a particular year.[22] We calculate quality relative to the quality of the leading product in the DOS era: Lotus and WordPerfect. Hence for spreadsheets,

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

Similarly, for word processors,

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

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 likely synergies (complementarities) among the components in computer software office suites

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

[22] 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.

because of the links between (and integration of) the components, and because of commands that are common across components.[23]

YEAR94 and *YEAR95* are yearly dummy variables for 1994 and 1995, respectively. *YEAR96-98* is a dummy variable that takes on the value 1 for the 1996-1998 period, and zero otherwise. We treat 1995 as a watershed because of the midyear introduction of Windows 95 and Office 95.

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.

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 a network effect advantage. Indeed, under full compatibility, each product would have essentially the same network size. In such a case, multicollinearity would prevent us from estimating any (common) network effect. Hence, we do not include network effects in our empirical analysis.

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

For these products (with a very tiny market share,) we calculated prices by taking our prices from the Gartner data and comparing them with prices reported by LM. LM use prices to OEM vendors; they have price data through 1997. We adjusted the LM series so the last price observation we have from the Gartner data equals that LM price. We then used the LM percentage declines in prices in order to compute the prices for the remaining years.[24] Prices for suites, word

[23] We would like to 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.

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

processors, and spreadsheets appear in figures 8, 9, and 10, respectively. Descriptive Statistics are shown in Table 1.

The potential market for office software is defined to be the number of operating systems sold or distributed via OEMs during the relevant year. Our data on operating systems for 1992 comes from Baseman et al (1995), while our data on operating systems for 1993-1998 comes from a Dataquest report on Operating System Shipments.[25] 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 the household market had increased relative to the size of the business market. Indeed, National Telecommunications and Information Administration (NTIA) data show that the percent of households with a personal computer increased in the U.S. from 24.1 percent in 1994 to 36.6 percent in 1997.[26]

Variable	Mean	Std. Dev.	Min	Max
sales000	2870.59	5549.39	33.17	32682.70
price	117.25	83.41	8	350
YEAR94	0.14	0.35	0	1
YEAR95	0.14	0.35	0	1
YEAR96_98	0.14	0.35	0	1
MICROSOFT	0.44	0.69	0	2
SS	0.67	0.48	0	1
WP	0.67	0.48	0	1
SUITE	0.33	0.48	0	1
SS*RELQUAL_SS	0.70	0.51	0	1.35
WP*RELQUAL_WP	0.69	0.49	0	1.22
MICROSOFTS*SUITE*Y96_98	0.05	0.21	0	1

Table 1: Descriptive Statistics

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

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

[25] 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.

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

5. Discrete Choice Model and Estimation

In this section, we formally specify our discrete choice model. We define a product to be a combination of a software category and a vendor. Each consumer compares products across four software categories: 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.[27] Consumers evaluate the products and purchase the one with the highest utility, or make no purchase if that is the best option.

The utility from a particular choice is

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

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

Mean Utility. The variable δ_j measures the mean utility for product j. We assume that:[28]

$$\begin{aligned}(2) \qquad \delta j = {} & \beta_0 * PRICE_j + \beta_1 * SS_j + \beta_2 * WP_j + \beta_3 * SUITE_j + \\ & \beta_4 * YEAR94_j + \beta_5 * YEAR95_j + \beta_6 * YEAR96\text{-}98_j + \\ & \beta_7 * SS_j * RELQUAL\_SS_j + \beta_8 * WP_j * RELQUAL\_WP_j + \\ & \beta_7 * MICROSOFT_j + \beta_8 * MICROSOFT_j * SUITE_j * YEAR96\text{-}98_j + \xi_j\end{aligned}$$

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

Note that the coefficient vector is restricted to be the same for all products, and does not vary by product category, and the number of year dummies is restricted by combining 1992-93 and

[27] Given the pricing of the suite and the components and the extra software contained within the suite, no consumer would purchase a spreadsheet or a word processor from the same firm, since the utility from the choice is lower than that of the suite.
[28] We could have put in a constant by leaving the SUITE variable out of the mean utility.

1996-98.[29] We do this because, with only a limited amount of data, we are unable sensibly to estimate too many parameters.

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

$$\theta_{jk} = SS_j * \mu_{1k} + WP_j * \mu_{2k} + \varepsilon_{jk} \quad (3)$$

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

These utility components are assumed to have a symmetric mean-zero bivariate normal distribution, i.e., $(\mu_{1k},\mu_{2k}) \sim N(0,0, \sigma_1, \sigma_2,\rho)$, where σ_1 and σ_2 are the standard deviations of μ_{1k} and μ_{2k} respectively and ρ is the correlation coefficient. We estimate the parameters of this distribution $(\sigma_1, \sigma_2,\rho)$, with a particular interest in the correlation coefficient. The variables μ_{1k} and μ_{2k} and their bivariate normal distribution are generated as follows: suppose that Y_1 and Y_2 are independent random variables, with a standard normal distribution, then μ_1 and μ_2 are new random variables defined by $\mu_1 = \sigma_1 Y_1$ and $\mu_2 = \sigma_2 \rho Y_1 + \sigma_2(1 - \rho^2)^{1/2} Y_2$.[30]

ε_{jk} is consumer *k*'s additional random utility for product *j*. This term introduces an additional source of consumer heterogeneity; i.e. some consumers may be more attracted to a particular product. Unobserved consumer heterogeneity in preferences over vendors in a particular software category or products involving two software categories enters only through this variable. The ε_{jk}

[29] This grouping is based on the yearly shares of the 'inside' goods, which are quite similar for 1992-1993 and for 1996-1998. See Table 2.

[30] See http://www.ds.unifi.it/VL/VL_EN/special/special7.html for details. Note that, given finite draws for Y_1 and Y_2, a change in ρ results in a different marginal distribution for μ_2. This is a source of a small (second order) amount numerical variation in our counterfactual simulations that vary ρ.

are assumed to be independently and identically distributed according to a Gumbel distribution with mean 0 and variance 1.64.[31] 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 and limits the overall correlation of tastes for different products.

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

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

and the probability that consumer k makes no purchase is

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

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

The estimation algorithm proceeds in several steps and is discussed in detail in Appendix C.

Identification of Linear Parameters. Our data set contains sales and shipments by products and by year. Thus, both variation across products and variation across time are a source of identification of the parameters of the model. The year dummy variables obviously vary over time only. Variation in the share of potential consumers who elect the outside good identify the

[31] The Gumbel distribution with mean 0 and variance 1.64 is the extreme value distribution that is typically used in this literature.

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 identify the coefficient on this variable.

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

Identification of Non-Linear Parameters. As discussed by Gentzkow (1994), identifying the correlation coefficient is not straightforward as both an increase in the correlation in preferences and an increase in product complementarity have the same qualitative effects – an increase in joint purchases of the two goods. Consequently, 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. We need additional variation in the data to identify separately these coefficients. 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 correlation. Thus variation in the price of suites identifies ρ separately from the coefficient on SUITE.[32]

Given the linear parameters and ρ, an increase in σ increases the sales of the relevant class of products (spreadsheets and word processors respectively). Hence, when sigma is high for a particular product type (say word processors) price rises for a particular word processor will lead more consumers to substitute *within* the class, i.e., to another word processor. When σ is low, more consumers will substitute away from that component, rather than purchase another product in the class when price rises. These effects combined with the fact that the ε_{jk} errors are distributed according to a standard Gumbel distribution enable us to identify the standard deviations of these preferences as well.[33]

[32] There is no analog for the suite price in Gentzkow (1994) model; the "bundle price" implicitly is the sum of the component pries.
[33] As noted above, the assumption of the Gumbel distribution is typical when estimating discrete choice models of product differentiation. If we did not know the variance of ε_{jk}, we would only be able to estimate the ratio of the standard deviations.

Instrumental Variables. Since price is endogenous, we instrument for it. Since we have three non-linear parameters, we need four instrumental variables in order to identify our model. We have the following instrumental variables:[34]

- Relative quality of the best rival product in the same category (where category means spreadsheet, word processor, or suite.)[35]
- Relative quality of best rival suite for spreadsheets or word processors; relative quality of best rival constituent product for suites
- Relative quality of firm's own other constituent product (for spreadsheets or word processors); relative quality of 'best' own constituent product (for suites)
- Dummy Variable for Year 95-98 – Prices declined beginning in 1995 due to the exogenous technological change in OS to Windows95, which made it easier (cheaper) to produce office software

6. Empirical Results

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

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

[34] There is a reasonably high correlation between price and the instrumental variables.
[35] For this instrumental variable, we define the relative quality of the suite as the sum of relative quality of the relevant spreadsheet and the relative quality of the relevant word processor.

The estimate of ρ is close to (but not quite equal to) 1.00 and is statistically significant. This indicates a strong positive correlation in preferences for word processors and spreadsheets, the two key components of the office software market. The positive correlation in preferences makes sense, given that preferences for components of office software suites are likely positively correlated through an income effect.[36] Note that although our estimate is ρ = 1, the correlation over preferences is a function of the random error term (ε_{jk}), as well as μ_1, μ_2. Using our estimates of ρ and the two estimated variances, as well as the variance of the random error term, it is straightforward to show that when ρ=1 the correlation in preferences is 0.68.[37] Hence, varying ρ between -1 and 1 allows us in our simulations to examine correlations between -0.68 and 0.68. While this means that we cannot fully explore the entire range of correlation in preferences, this does not have a qualitative effect on the results as the range we are able to study is still quite large. Furthermore, the general JM (2006) result means that profits are monotonic in the correlation coefficient when firms sell suites and serve a niche-market, so our results can be generalized for the parameter regions we are not able to directly study.

The estimated coefficient for the standard deviation over preferences for word processors (5.66) is larger than the estimated standard deviation for spreadsheets (1.23). Recall that when the standard deviation is relatively large, consumers will likely substitute within the class when price rises. This makes sense since spreadsheet use during the 1990s was primarily for simple calculations. Word processors were either used by professionals for writing manuscripts, or simply used to write letters. It is, therefore, likely that there was less variance in the value of spreadsheets compared to the variance of the value placed on word processors.

The key coefficients of the linear parameters have the expected sign. In particular the PRICE coefficient is negative and significant at the 95 percent level. The inverse of the coefficient, which arises from normalizing the variance of ε_{jk}, indicates consumer taste heterogeneity for individual products. The coefficients on the relative quality variables (WP_j*RELQUAL_WP_j for word processors for example), which measure the value associated with observed quality of components, are positive for both product categories, but not significant. Although these estimated

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

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

coefficients are not statistically significant, this suggests that the ratings on which the relative quality measures are based on product attributes consumers indeed value. The yearly dummy variables capture shifts in the difference between the value of office software products and the outside option. The coefficients associated with the yearly dummies are declining in value. This is in large part due to the fact that consumers' purchases of spreadsheets, word processors and suites divided by the number of operating systems was declining as well (see Table 2). That is, more consumers who purchased a computer elected not to purchase an office software product in later years. This could reflect the notion that as the price of personal computers (i.e., operating systems) declined significantly, more consumers who were less sophisticated in their software use entered the market. These consumers could likely manage well without a word processor or a spreadsheet. They could use a utility that came with the operating system like 'notepad' as a substitute for word processor and could use a calculator (another free utility) as a substitute for a spreadsheet. Alternatively, it could mean that as computer usage grew significantly in countries without strong intellectual property protection during the 1990s, piracy of applications software increased. Since we use these dummy variables as a control, we are neutral regarding this or other explanations for the reduction in the percentage of consumers that purchased a spreadsheet, a word processor, or suite over time.

Recall that the variable 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 and statistically significant. This suggests Microsoft benefited from some or all of the following: a better reputation, better service, better additional components in the suite, better integration of components, and higher unobserved quality of components.

Suites included additional components like presentation software. This is picked up by the dummy variable SUITE. The coefficient on the variable SUITE is positive, although not statistically significant. The positive estimate suggests that consumers value the other software components in the suite in addition to the main components and/or the complementarity or integration of the components. The dollar value of the "suite bonus" is obtained by dividing the

SUITE coefficient by the absolute value of the PRICE coefficient, which results in approximately $36.[38]

The coefficient associated with the Microsoft suite for the 1996-1998 period is positive and nearly statistically significant. Given that we control for SUITE, the coefficient of the Microsoft suite for 96-98 is likely picking up a complementarity/compatibility effect and may reflect the fact that Microsoft's components were much better integrated in the Microsoft suite than in other suites. This is consistent with the trade press (see Appendix A) which shows that, even in 2001, there is a large difference in cross-application compatibility between the Microsoft suite and other suites.[39]

Overall, with the exception of price, ρ, MICROSOFT, and the Microsoft suite for 1996-1998, the parameter estimates are not statistically significant. This is likely the result of the limited number of observations in combination with the non-linear model we employ. As we discussed earlier, our main goal is to examine the effect of the correlation coefficient on incentives to bundle and strategic interaction in the market. Hence, the fact that several of the estimated coefficients are not statistically significant is not important for our main analysis which we present in the next section – the variables associated with these estimates are primarily included for controls.

	OLS			Linear IV			Non-Linear IV		
	Coef.	**SE**	**T-Statistic**	**Coef.**	**SE**	**T-Statistic**	**Coef.**	**SE**	**T-Statistic**
σ_1							1.23	16.12	0.08
σ_2							5.66	17.51	0.32
ρ							1	0.54	1.86
Price	-0.01	0.01	-1.57	-0.09	0.05	-1.92	-0.07	0.04	-1.87
YEAR94	-0.72	0.49	-1.46	-2.92	1.66	-1.76	-2.6	4.77	-0.54
YEAR95	-1.3	0.5	-2.58	-5.55	2.63	2.12	-5.58	1.64	-3.39
YEAR96-98	-1.81	0.68	-2.66	-0.86	4.73	-2.08	-7.89	3.16	-2.49
MICROSOFT	1.31	0.37	3.52	3.02	1.27	2.37	2.59	0.92	2.81
SS	-1.27	2.12	-0.6	-4.2	5.11	-0.82	-4.14	8.36	-0.5
WP	0.12	4.28	0.03	-2.55	9.91	-0.26	1.32	39.9	0.03
SUITE	3.19	0.53	6.01	3.05	1.22	2.51	2.49	13.85	0.18
SS*RELQUAL_SS	-0.12	2.31	-0.05	13.13	9.06	1.45	10.96	8.76	1.25
WP*RELQUAL_WP	-1.64	4.12	-0.4	11.17	11.8	0.95	4.9	32.23	0.15
MICROSOFT*SUITE* YEAR96-98	1.66	1.09	1.52	2.6	2.54	1.02	2.31	1.43	1.61
63 observations	**Adj. R^2=0.31**						**GMM**	**15.75**	

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

[38] The estimated standard deviation of the coefficient associated with SUITE is quite high, but the point estimate (2.49) is not that different from the point estimate when we estimate a linear model with instrumental variables (3.05.) In that case, the estimated coefficient is significant. Furthermore, under the linear model with instrumental variables, the estimated suite bonus is very similar: $34 (3.05/.09). Finally, as we discuss in Section 7 (and report in the Online Appendix), our key simulation results remain qualitatively unchanged for the case when the coefficient on SUITE equals zero.

[39] 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."

7. Counterfactuals/Simulations

In this section we use the estimated coefficients from our random utility model to simulate market outcomes under various market settings of partial competition in order to study the welfare and competitive effects of bundling. 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.

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

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

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

The first set of simulations in Table 4 compares mixed bundling, pure bundling, and separate selling in the case of a monopolistic vendor. We first study the effect of ρ on profitability given a certain bundling strategy, and then compare profitability across the different bundling strategies: mixed bundling, pure bundling, and separate selling. The first simulation (case I in Table 4) presents the case where only Microsoft is active in the market and only sells its Office suite (pure bundling.) In this case, monopoly profit increases in ρ. The intuition is as follows: the variance of

the random utility for the suite increases in ρ. Since Microsoft serves only a relatively small portion of the potential market (20% percent in the simulation), the increased variance of preferences increases demand for the suite—illustrating what JM call an "expanding niche market." As a result, the monopoly price of the suite increases with correlation as well, as higher demand increases the incentive to raise price for a niche market (Chen and Riordan 2011), which in turn increases profitability. Interestingly, while JM find this result to hold in the case of niche markets, and flip otherwise, simulations in the Online Appendix show that this effect holds even when pure bundling serves 40 percent of potential consumers.[40] We, therefore, refer to the positive relationship between correlation and demand for suites and the 'market expansion effect'.

In case II of Table 4, Microsoft sells only Excel and Word (separate selling). Consumers can buy both products, but do not receive the suite bonus from the joint purchase. As expected, profits are independent of ρ in this case.[41] Case III turns to monopoly mixed bundling, where Microsoft sells Excel, Word, and Office. Again, consumers can purchase the components separately, but do not get the suite bonus when doing so.

The mixed-bundling simulation in Table 4 shows that Microsoft's profits increase in the correlation coefficient in this case as well. Note that while in the case of pure bundling, the market expansion effect alone is sufficient for profits to increase in correlation, the effect in the case of mixed bundling is not straightforward as additional suite sales lead to reduced sales of the individual products. Indeed, we find that in the case of mixed bundling, the market expansion effect and the suite bonus effect jointly lead to profits increasing in the correlation coefficient under mixed bundling. Specifically, the suite bonus creates additional value and thus reinforces the increase in demand for suites that results from an increase in correlation (via the market expansion effect.) It is the combination of these two effects that allows Microsoft to increase the price of the suite yet still double the number of consumers that purchase the suite from 8% to 16%. 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 does not change much. Interestingly, we find that in the case of

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

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

mixed bundling, if only the market expansion effect was present, profits may in fact decrease in correlation.[42]

Comparing profitability across the different bundling strategies, we know from theory that Microsoft's profits when it is the only firm in the market are always (weakly) higher under mixed-bundling than under pure bundling or separate selling. Compared with pure bundling, the results demonstrate two contrasting effects discussed in the literature. On the one hand, when correlation is negative, pure bundling is less profitable than separate selling because of the 'penalty' of higher marginal costs (Adams and Yellen 1976). On the other hand, with positive correlation, pure bundling is more profitable than separate selling because of the market expansion effect discussed above, in addition to incremental profits derived from the suite bonus.

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

Consumer welfare comparisons for the different cases are interesting as well.[43] With positive correlation ($\rho=1$), the predicted price of the Microsoft Office Suite under mixed and pure bundling is about the same, roughly $275, which is approximately $25 higher than the summed prices of Excel and Word under separate selling. Given that the average suite bonus is $36, a $25 price premium over the 'summed prices' makes the suite a good deal for most consumers who would purchase both products. Note that the standalone prices of Excel and Word under mixed bundling are about 5% higher than under separate selling. Thus, 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. In the case of mixed bundling, for example, table 4 shows that consumer surplus is 63.6 when $\rho=1$ and 42.2 when $\rho=-1$. The reason behind the positive relationship between consumer surplus and correlation is that even though lower correlation results in more attractive

[42] Indeed in simulations in the Online Appendix, we show that (i) when there is no suite bonus and (ii) when word processors and spreadsheets enter both the demand and supply side symmetrically, profits decrease in the correlation coefficient (i.e., the standard intuition obtains) when the firm employs a mixed bundling strategy.

[43] It is straightforward to calculate consumer surplus under the different scenarios. Using equation (4), which gives the probability a given consumer chooses each product, we calculate the expected utility for each consumer and add over all consumers in order to calculate consumer surplus. We denote consumer surplus in all tables by CS and present values in thousands of $.

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 surplus that the consumption of a bundle entails.

It is also perhaps surprising that consumer surplus is lower under mixed bundling than separate selling when ρ=-1 (42.2 vs. 46.9). This is because virtually no consumers (a 0.003 market share) buy both components under separate selling. Hence, very few consumers benefit from the switch from buying both components to buying the suite. Further, most consumers still buy components under mixed bundling when ρ=-1 and these consumers face higher prices under mixed bundling relative to the separate selling case. On the other hand, when ρ=1, many consumers purchase both components under separate selling (a .063 market share). For these consumers, the switch to the suite under mixed bundling leads to a net gain of \$36 – (\$277.4-\$130.5-\$120.2)=\$9.3 -- per consumer. Hence, when ρ=1, consumer surplus is much higher under mixed bundling than separate selling (63.6 vs. 45.6).

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

Table 4: Monopoly Market Structures and Correlation[44]

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 \$73) and the Lotus spreadsheet (marginal cost \$78) as well as Microsoft products. In these simulations, we focus on the effect of the correlation coefficient on the strategic interaction among the firms. The first result to note is that while in Table 4 the price of Microsoft Word is higher than the price of Microsoft Excel, this relationship flips in Table 5. The intuition behind this is as follows: Profit margins increase with the variance over preferences—this is illuminated in Table 4 where Microsoft is alone in the market and charges a higher price for Word than for Excel,

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

although Excel's marginal cost is lower than Word's. Microsoft finds it profitable to do so as the estimated standard deviation over preferences for word processors (5.66) is much larger than the estimated standard deviation for spreadsheets (1.23). As shown in table 5, once there is competition in the components market, competition from WordPerfect erodes the margins on Microsoft Word significantly to the point where Microsoft prices Word at a lower price than Excel.

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 \$9 and \$13 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 (72%), while the shares of Lotus and WordPerfect fall by almost 30% and their profits by almost 35%. Overall, the size of the components market decreases by more than 50%.

Assuming the rivals remain active in the market, whether the introduction of the suite (case II) is anti- or pro- competitive depends on the correlation. With independence and especially with positive correlation the introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance. This is because, in large part, the suite bonus (\$36) is much larger than the difference between the suite price and the sum of 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 \$9.6 (\$36-[250.3-104.9-119.0].) 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.[45]

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

[45] Note that every sale of a suite corresponds to a sale of one unit of word processor and one unit of spreadsheet. Consequently, the share of the inside good in Case I is 0.48 and 0.58 in Case II.

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 the introduction of the suite raises consumer surplus by 30%, from 74.2 to 96.0 when $\rho=1$. This result is robust to variations in the estimated model.

Since a decrease in correlation reduces the demand for suites, the pro-competitive effects of the introduction of a suite are attenuated as correlation decreases, and may be even reversed for negative correlation values. In particular, when $\rho=0$, the introduction of suites increases consumer welfare by only 12% (from 74.2 to 82.8), while when $\rho=-1$, the introduction of suites becomes anti-competitive and decreases consumer welfare by 6% (from 78.4 to 74.0).

Case III examines the effect of competition in the components market by simulating a market where Microsoft only sells its suite, while the components' market is monopolized by WordPerfect and Lotus, correspondingly. Comparing this structure to case II where the components market is oligopolistic, it is interesting to note that though when Microsoft is out of the components market, the competing firms face less competition, the competing firms do not necessarily benefit from a reduction in the number of Microsoft products. Specifically, a competing firm may be better off competing against a dominant firm that sells components and a bundle (mixed bundling) rather than just selling a bundle (pure bundling). This result is driven by the foreclosure effect 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.

As before, the interesting result is that 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 the correlation in consumer preferences is positive and large. Otherwise, the (standard) '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.

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

Table 5: Oligopoly competition: Louts and WordPerfect sell components

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

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

In order to better understand this result, our final two sets of simulations in Table 6 focus on the effect of a potential merger on market outcomes. In particular, we simulate a case where

Microsoft's Suite competes against a merged Lotus/WordPerfect Suite. In this setting, we assume that the merged firm's suite includes two high-quality components: the Lotus spreadsheet and the WordPerfect word processor. There are several ways in which to conduct this simulation. Perhaps the most two interesting ways are as follows:

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

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

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

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

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

Table 6: Oligopoly Competition – firms only sell suites

Robustness Analyses

In order to make sure that our main results are robust to different cost structures, we re-did all the simulations in the above three tables under the assumption that the marginal cost of the Microsoft suite is the sum of the marginal costs of the Microsoft components-- $175,[46] while retaining the estimated marginal costs of Microsoft's components and the other components. The intuition discussed in section 7 regarding the effects of correlation on profits and consumer surplus and on the strategic interaction in the market is robust to this alternative cost structure. Further, additional simulations also show that these main results are also robust to conducting the simulations for 1998.[47] Finally, given the large standard error of the SUITE coefficient, we also re-did the simulations in Tables 4 and 5 assuming that SUITE=0. Our results regarding the welfare and profitability effects of the introduction of the suite are robust to the case where there is no suite bonus. In particular, the key result that the introduction of the suite is welfare enhancing for consumers when the correlation is positive continues to hold.[48]

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. Our empirical 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 identify two important effects that determine the effect of correlation on profitability and welfare: (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, we find that specifically in the case of pure bundling it is the main driver of the positive relationship we find 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

[46] Recall that the estimated marginal costs are MS word - $74; MS Excel - $101; MS Suite - $205.
[47] Some of the results above, of course, depend on the particular cost structure. When the cost-penalty effect is attenuated enough, (i) pure bundling is more profitable than separate selling even when consumer preferences are negatively correlated, and (ii) the profits of mixed bundling are decreasing in correlation. Nalebuff (2004) argues that pure bundling as a better deterrent than mixed bundling.
[48] All simulation results that are discussed in the paper but do not appear in the paper are available in the Online Appendix.

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. Assuming the rivals remain active in the market, when the correlation is positive, 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 a merger between the second and third largest firms in the industry would have been welfare improving. These simulations also suggest that the superior observed quality of Microsoft's component products by itself was not very important for Microsoft's success in the suite market.

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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.[49] 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.

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.[50] 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:[51]

- 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?

[49] 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 .

[50] 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.

[51] The possible answers are either yes or no.

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.

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: Estimation Algorithm

The estimation algorithm proceeds in several steps.

Step 1: Take random draws of (Y_{1k} ,Y_{2k}) for 100,000 consumers per year. Each consumer makes a single choice.[52]

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

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

until convergence ($\hat{\delta}$) is obtained.[53,54]

Step 3: Given $\hat{\delta}$, run the GMM regression $\hat{\delta}$=Xβ+ξ and obtain estimates $\hat{\beta} = \left(X'ZWZ'X\right)^{-1} X'ZWZ'\hat{\delta}$, where *X* is the matrix of right hand side variables, *Z* is the matrix of exogenous right hand side variables and instrumental variables, and W=(Z'Z)$^{-1}$ is the weighting matrix.[55,56]

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

Step 5: Update the values of σ_1 , σ_2, and ρ, as discussed below and return to step 2.

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

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

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

Standard deviations were calculated in the typical manner, using the methodology described in Nevo (1998.)

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

[53] 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.

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

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

[56] Since price is endogenous, we instrument for it. See the identification section for the discussion of instruments.

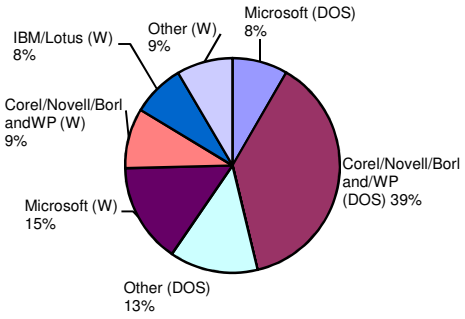

Figure 1: Word Processor Market 1991
Total Market $952M; DOS $567M; WINDOWS $385M

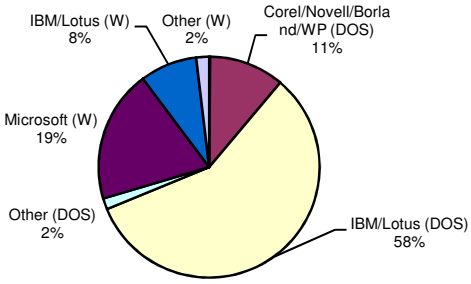

Figure 2: Spreadsheet Market:1991
Total Market $809 M; DOS $239M; WINDOWS $569M

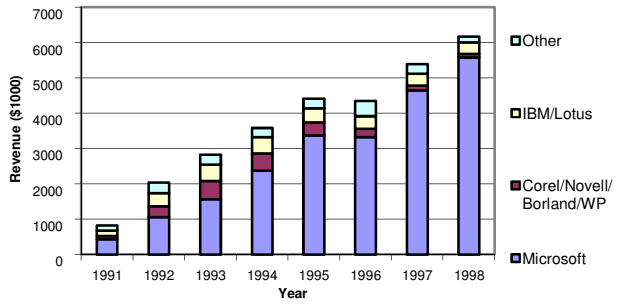

Figure 3: Office Software Revenue for WINDOWS Platform by Firm 1991-1998

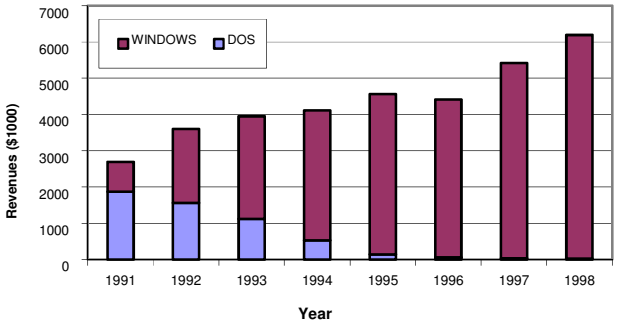

Figure 4: Office Software Revenue by Platform, 1991-1998

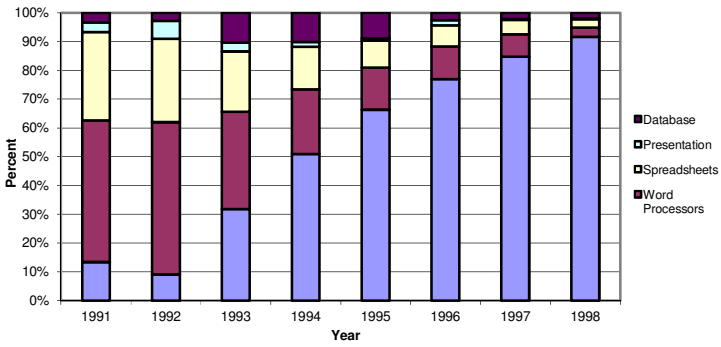

Figure 5: Windows Office Productivity (Revenue) Shares by Category, 1991-1998

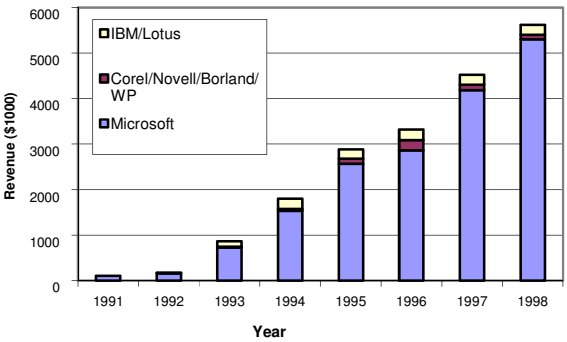

Figure 6: Office Suite Revenue by Firm 1991-1998

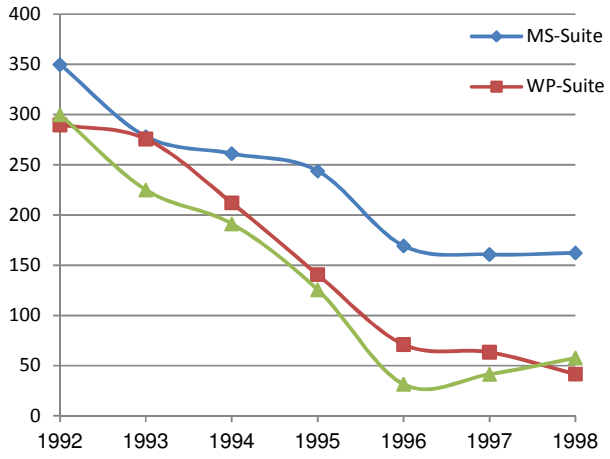

Figure 7: Suite Prices

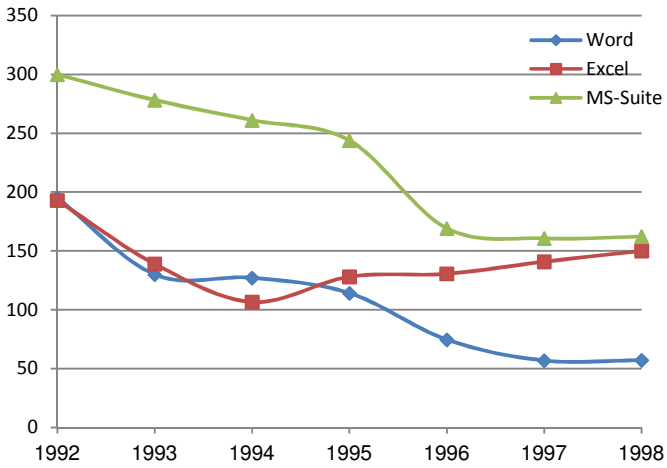

Figure 8: Microsoft Prices

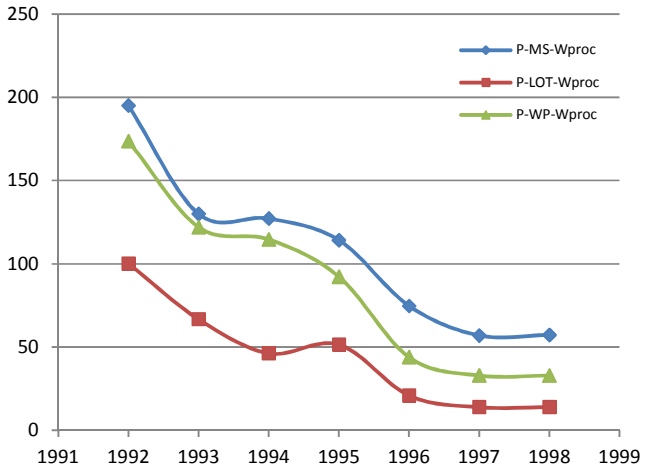

Figure 9: Word Processor Prices

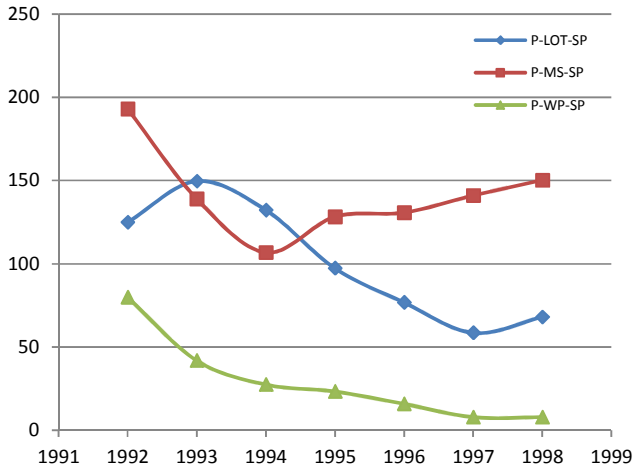

Figure 10: Spreadsheet Prices

Appendix for Online Publication

Supplementary Simulations

In this appendix, we report the additional simulations we refer to in the text. The first two sets of simulations (Tables E1-E3 and Tables E4-E6) show that our main results in Tables 4-6 in the body of the paper are robust to different cost structures. In Tables E7-E8, we show that our key results are robust to the case where there is no suite bonus. In Table E9, we show that the 'market expansion effect' obtains under pure bundling even when the market share served is close to 40%.

I. Different Cost Structures

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

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

Table E1: Monopoly Market Structures and Correlation

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

Table E2: Oligopoly competition: Louts and WordPerfect sell components

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

Table E3: Oligopoly Competition – firms only sell suites

II. Simulation Results for 1998

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

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

Table E4: Monopoly Market Structures and Correlation

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

Table E5: Oligopoly competition: Louts and WordPerfect sell components

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

Table E6: Oligopoly Competition – firms only sell suites

III. No Suite Bonus (SUITE=0)

Given the large standard error on our SUITE estimate, Tables E7-E8 present the simulations in Tables 4-5 for the case where there is no suite bonus and the coefficient of SUITE is set to 0.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling															
MS Suite	244.5	0.19	12.99	12.99	65.0	233.3	0.18	10.46	10.46	50.0	220.4	0.17	7.51	7.51	32.2
Case II: Separate Selling															
MS word	130.5	0.18	9.84	12.38	45.6	130.0	0.18	9.75	12.29	45.3	130.7	0.17	9.73	12.27	46.9
MS SS	120.2	0.13	2.54			120.2	0.13	2.54			120.2	0.13	2.54		
Case III: Mixed Bundling															
MS word	135.96	0.05	3.11	14.48	58.7	134.6	0.09	5.42	13.9	48.7	132.9	0.13	7.6	13.12	42.1
MS SS	126.5	0.04	1.11			123.95	0.09	1.93			121.2	0.12	2.46		
MS Suite	246.7	0.15	10.26			237.3	0.11	6.53			224.8	0.06	3.06		

Table E7: Monopoly Market Structures and Correlation

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Component Competition: No 'suite' bonus when purchasing both components															
MS Word	104.9	0.20	5.96	8.15	74.2	104.9	0.20	5.93	8.12	74.2	104.9	0.19	5.89	8.09	78.4
MS SS	119.0	0.12	2.19			119.0	0.12	2.19			119.0	0.12	2.19		
WP Word	92.2	0.09	1.76			92.2	0.09	1.75			92.2	0.09	1.74		
Lotus SS	94.2	0.07	1.16			94.2	0.07	1.16			94.2	0.07	1.16		
Case II: MS sells suites and components, (no suite bonus when purchasing both components)															
MS word	112.2	0.07	2.55	10.44	90.6	108.8	0.11	3.83	9.65	79.7	106.7	0.15	4.92	8.87	74.1
MS SS	124.6	0.05	1.06			121.4	0.08	1.62			119.6	0.11	2.07		
WP word	90.5	0.07	1.26			91.5	0.08	1.47			91.9	0.09	1.61		
Lotus SS	93.2	0.06	0.84			93.95	0.07	1.02			94.2	0.07	1.15		
MS suite	218.6	0.16	6.83			213.7	0.11	4.2			205.3	0.06	1.88		
Case III: MS sells only its suite (no suite bonus when purchasing both components)															
WP word	90.5	0.07	1.26		100.8	95.2	0.09	2.03		82.3	97.8	0.11	2.79		62.4
Lotus SS	93.0	0.05	0.73			95.0	0.07	1.11			95.8	0.08	1.48		
MS suite	216.7	0.22	8.7	8.7		210.3	0.19	6.59	6.59		199.3	0.16	3.88	3.88	

Table E8: Oligopoly competition: Louts and WordPerfect sell components

IV. Robustness of the Market Expansion Effect

In Table (E9) below, we show that the market expansion effect obtains under pure bundling even when the market share served is close to 40%. In order to generate this simulation, we lowered the marginal cost of the suite by $80. We also show a simulation with the suite cost reduced by $150 in order to show that when the market share served is quite large, the market expansion effect disappears – and profits decrease in correlation under pure bundling.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Pure Bundling – MS Suite															
Base case	275.6	0.20	13.97	13.97	69.8	264.4	0.19	11.4	11.4	54.5	251.4	0.18	8.4	8.4	36.2
Cost less $80	**223.6**	**0.37**	**36.8**	**36.8**	**171.3**	**212.8**	**0.4**	**35.0**	**35.0**	**157**	**200.3**	**0.45**	**33.4**	**33.4**	**140.1**
Cost less $150	185.9	0.52	68.3	68.3	291.8	177.2	0.57	69.0	69.0	279.5	168.0	0.64	71.7	71.7	265.2

Table E9: Change in market expansion effect under pure bundling when firm serves a larger market

V. Mixed Bundling, symmetry (on demand and costs) and no 'Suite Bonus'

In Table E10 below, we show that (i) when there is no suite bonus and (ii) when word processors and spreadsheets enter both the demand and supply side symmetrically, profits decrease in the correlation coefficient (i.e., the standard intuition obtains) when the firm employs a mixed bundling strategy.

1995	ρ=1					ρ=0					ρ=-1				
	Price	Share	Π	π-MS	CS	Price	Share	Π	π-MS	CS	Price	share	Π	π-MS	CS
Case I: Mixed Bundling, symmetry across components - Without Suite Bonus															
MS Word	113.9	0.12	3.2	8.5	0.49	113.2	0.15	3.8	8.9	0.46	112.3	0.18	4.3	9.4	0.56
MS SS	113.9	0.12	3.2			113.2	0.15	3.8			112.3	0.18	4.4		
MS Suite	208.5	0.06	2.1			204.4	0.05	1.3			198.4	0.03	0.7		

Table E10: Symmetry on demand and costs and no suite bonus