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RESEARCH ARTICLE

Ain't it "suite"? Bundling in the PC office software market

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Research Summary: We examine the importance of office suites for the evolution of the personal computer (PC) office software market in the 1990s. An estimated discrete-choice model reveals a positive correlation of consumer values for spreadsheets and wordprocessors, a bonus value for suites, and advantages for Microsoft products. We employ the estimates to simulate various hypothetical market structures to evaluate the profitability, welfare, and competitive effects of suites under alternative correlation assumptions. We find that firms benefit greatly from bundling components (i.e., a spreadsheet and a word processor) when the correlation of consumer preferences over the components in the bundle is positive. Our work adds another aspect to the recent work in the strategy literature that examines benefits from bundling when there are complementary relationships across the products in the bundle.

Managerial Summary: Our research helps managers understand the conditions under which product bundling is likely to be most profitable. We show that one key to enhanced profitability is the correlation in consumer preferences over the individual products. We consider the performance implications of bundling under a variety of alternative market structures and competitive environments. Our analysis reveals that firms benefit greatly from bundling when the correlation of consumer valuations over the products is positive. Consumers benefit as well. Hence, bundling is a win-win for firms and their customers. Since profits increase by more than consumer surplus, bundling leads to increased value capture by the firms. Consequently, it may be profitable for firms to invest in actively increasing the correlation in consumer preferences over products in the bundle.

KEYWORDS
bundling, pricing, profitability, simulations, software market

1 | INTRODUCTION

When is it profitable to bundle different products rather than just sell them separately? How does product bundling affect rival firms? These and related questions gained much attention in the theoretical literature on product bundling, and to a lesser extent, in the subsequent empirical literature. We are particularly interested in how the correlation in preferences over products in the bundle affects the profitability of bundling. We examine this question empirically using the office productivity software market in the 1990s.

Bundling is a common practice by multiproduct firms that choose to sell two or more of their products in a package. The profitability of bundling has been extensively studied in the strategy and theoretical industrial organization literatures. Early literature finds that firms benefit from bundling in a setting in which consumer preferences over the components of the bundle are negatively correlated. In this case, bundling increases profits in a fashion similar to price discrimination, that is, by reducing the dispersion of consumer values compared to separate selling. A key assumption is that all consumers make purchases.

The finding that reduced dispersion is most pronounced under negative correlation may suggest that greater correlation in consumer preferences over the products in the bundle lessens profitability by hindering the ability of the monopolist to extract surplus. This crude intuition, however, fails to appreciate the benefits of increased dispersion of consumer values for the bundle. Specifically, large positive correlation suggests that a larger share of consumers has high valuation for the consumption of *both* products. This is important in settings where not all consumers make purchases. Here, bundling increases the overall share of consumers that choose to buy the bundle as opposed to choosing the outside good—we call this the *market-expansion effect.* The bundling literature has paid little attention to the market-expansion effect of positive correlation in a setting when a firm chooses to sell bundles.

Our article fills this gap. We empirically examine how the correlation in preferences over spreadsheets and word processors affects profits in the office software market. 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 is a good setting for our study since there are just two key products in the bundle. Additionally, according to the literature (e.g., Nalebuff, 2004), there is positive correlation in consumer preferences over the main components of the bundle.[1]

The office productivity software market experienced dramatic structural changes during the 1990s. The market grew tremendously from 1991 to 1998, the period for which we have consistent data. In addition, the market saw a shift in market leadership from Lotus (in the spreadsheet market)

[1]An additional example for products with positive correlation in consumer preferences are sport channels. Indeed, most cable providers bundle several sport channels and sell them as one package.

and WordPerfect (in the word processor market) to Microsoft. Finally, there was a shift in marketing strategy led by Microsoft from selling separate products to selling office suites. By the end of the decade, Microsoft dominated the office productivity software market. These structural changes allow us to study how the shift to office suites contributed to Microsoft's success as well as the consequences for competitors and consumers.

We use estimates from a parsimonious empirical model to simulate the effects of bundling under alternative hypothetical market structures. Our results suggest that (regardless of market structure), with positive correlation of consumer preferences for word processors and spreadsheets, the introduction of the suite in the 1990s significantly increased both profitability and consumer welfare. Profits go up by more than consumer surplus; hence, the value of the surplus created that is captured by Microsoft increases. We identify two key effects: (a) the "market-expansion" effect, and (b) 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 the demand for suites. While this effect has not been emphasized in the bundling literature, we find it to be the main driver of the positive relationship between correlation and profitability. We find, based on simulations, that the market-expansion effect alone is sufficient to overturn the standard intuition and insure that profits and consumer welfare increase with greater correlation, both in the case of pure bundling and in the case of "mixed bundling" (when firms sell both bundles and individual products).

In our setting, using counterfactual analysis, we find that with a correlation coefficient of 0.5, which is (approximately) our estimate, profits from introduction of the suite increased by approximately 75–80% depending on market structure. On the other hand, with a correlation coefficient of −0.5, introduction of the suite increases profits by less than 50%. Hence, given that bundling entails fixed costs (that are likely independent of the correlation of consumer preferences), we would expect to see more bundling in settings with positive correlation.

Our model also allows consumers to enjoy extra value from the consumption of the suite in addition to the values of a spreadsheet and a word processor. This "suite-bonus effect" refers to the value-added for consumers from suites. These two effects are complementary: The suite-bonus effect magnifies the market-expansion effect. If the suite bonus exceeds the incremental marginal cost of the suite, as we estimate it does for Microsoft, then the introduction of the suite creates more value, and thus, presents a profit opportunity independently of any price discrimination benefits from bundling. Our results, however, are not driven by the suite-bonus effect. Rather, in our setting, the suite-bonus effect magnifies the market-expansion effect by making suites more profitable. Our main results hold even when the suite bonus is set to zero.

In order to examine the competitive effects of bundling, we simulate a market setting of partial competition in which Lotus sells only a spreadsheet, WordPerfect sells only a word processor, and Microsoft sells both components as well as a suite. Our results show that under this setting the introduction of Microsoft Office shifts market share away from Lotus and WordPerfect. Nevertheless, consumers benefit as well, especially when there is positive correlation in preferences over the components of the bundle.

Since demand for mix-and-match combinations is higher under large positive correlation, pure bundling, which eliminates mix-and-match options, may have a foreclosure effect that reduces demand and profitability of those firms only selling components (Nalebuff, 2004). Our simulations show that this foreclosure effect may dominate the standard increased competition effect of the bundling firm selling more products (both the bundle and the components) when the correlation in consumer preferences is positive and large. In this case, firms that only sell components are better off when the firm selling bundles also sells components (mixed bundling) than under pure bundling.

We perform several robustness checks and show that our results hold under zero marginal cost and in the absence of a suite bonus. Furthermore, we test the robustness to changes in the estimated coefficients. To do that, we take draws from the coefficient distribution and run the simulations previously discussed on these draws. Our principal conclusions regarding: (a) the positive and monotonic relationship greater correlation has with profits, (b) the positive welfare effects of the introduction of the suite, and (c) the trade-off between the "mix-and-match effect" and the "reduction-in-competition" effect are robust to all of the previous variations.

The article proceeds as follows. Section 2 reviews the strategy and economics literatures on bundling. Section 3 discusses the evolution of the personal computer (PC) office software market and the data used in the empirical analysis. Section 4 develops a parametric model used to estimate the demand side of the market, discussing the estimation algorithm and identification strategy. Section 5 presents the empirical results. Section 6 uses the estimated parameters to simulate counterfactuals, while Section 7 tests for robustness of our results. Section 8 adds further discussion and concludes.

2 | CONVENTIONAL WISDOM ON BUNDLING

Pure and mixed bundling have both received much attention in the theoretical literature in strategy and economics. McIntyre and Srinivasan (2017) noted in their survey that the strategy literature has extensively examined how bundling in the presence of platform-mediated networks and complementarity can enhance the success of a firm or platform. Chao and Derdenger (2013) showed theoretically how a platform that bundles an access (base) product and a complementary application yields price discrimination benefits from segmenting the installed base and new consumers. It further segments new consumers into a group with a high value for the access product and low value for the application, and a group with a relatively high value for the whole package. Lee, Venkatraman, Tanriverdi, and Iyer (2010) examined how firms can overcome the intense competition in the office software industry by creating a portfolio of complementary products. Our article fits into this literature and is complementary to Chao and Derdenger, in particular, in that we study the benefits of bundling complementary applications to segment consumers. Our analysis contributes to the strategy literature also by showing how the correlation in preferences over products in the bundle affects firm profits from bundling in a setting where there may be product complementarities as well.

Bundling has traditionally been considered a price discrimination tool to extract more surplus from consumers who have heterogeneous valuations for different products, as illustrated in early work by Stigler (1963) on pure bundling, and Adams and Yellen (1976) in the case of mixed bundling. In the instance of negative correlation in preferences over the products, bundling reduces the heterogeneity in consumer valuations. This is because the variance of the sum of product valuations (the bundle) is lower than the sum of variances in the individual product valuations. This allows a monopolist to extract surplus in a fashion similar to price discrimination.[2] However, our article shows that when not all consumers make purchases, firms that bundle benefit more when the correlation over preferences for the components of the bundle is positive.

[2]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, while Chen and Riordan (2013) extended these results by using copulas to model correlation.

In contrast to the vast theoretical literature, there has been little empirical work on the effects of bundling. In addition to the literature previously discussed, a small empirical literature has examined the performance of bundling in the media industry, including home video games and services or cable television (Crawford, 2008; Crawford & Yurukoglu, 2012; Derdenger & Kumar, 2013). Chu, Leslie, and Sorensen (2011) estimated 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. Cottrell and Nault (2004) empirically examined how the management of product variety via the integration of complementary products affects firm success. Still, these studies are silent on the question of whether (and how) the variation in correlation of consumer preferences increases or decreases the profitability of bundling. Using individual-level survey data, Gentzkow (2007) studied joint purchases of print and online newspapers. While he allowed both correlations over preferences and complementarity among products, he examined different issues and did not examine how correlation in consumer preferences affects the profitability of bundling.

3 | PC OFFICE SOFTWARE MARKET AND DATA

3.1 | PC office software market

Our model focuses on U.S.-based firms operating in the PC office software market during the years 1991–1998. The PC office software market was well established in the early 1990s with WordPerfect leading the word processor category (Figure 1) and Lotus the spreadsheet category (Figure 2).[3] These distinct and predominantly DOS-operating system based software applications were sold separately. The total market size for PC office software was approximately $2.6 billion in revenues in 1991, 38.5% of which was captured by WINDOWS office software. The release of WINDOWS 3.0 in 1990 induced a major change in the industry, propelling Microsoft to dominate the PC office software market in 1998 (Figure 3).

There were essentially three firms in the office software market: Microsoft, IBM/Lotus (or Lotus),[4] and Borland/Corel/Novell/WordPerfect (hereafter WordPerfect). These three firms accounted for at least 90% of the WINDOWS office software market from 1993 to 1998 and 94% of all annual revenues in the spreadsheet, word processors, and suite markets combined during the 1991–1998 period, leaving remaining firms with a negligible market share in any of these markets during 1991–1998 (see Figure 3).

Microsoft enjoyed a first-mover advantage with its WINDOWS-based Microsoft Excel and Microsoft Office applications.[5] Competitors followed, but generally experienced greater difficulty with developing stable products. Consequently, reviews generally agreed on the superiority of Microsoft products. Nevertheless, the switch from the DOS to the WINDOWS platform did not eliminate rivals in the spreadsheet and word processing markets. The early office suites contained non-integrated word processors, spreadsheets, database, and graphics programs. Lotus's acquisition of AmiPro in 1991 enabled it to deliver a WINDOWS-based suite in late 1992, while WordPerfect introduced its first suite in 1993. Still, Microsoft enjoyed preferential position in the office suite category because it already had highly rated versions of key underlying components. Suites contributed little to industry revenue during this period.

[3]The presentation graphics and database management categories were led by Lotus and Borland, correspondingly.

[4]IBM acquired Lotus in 1995.

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

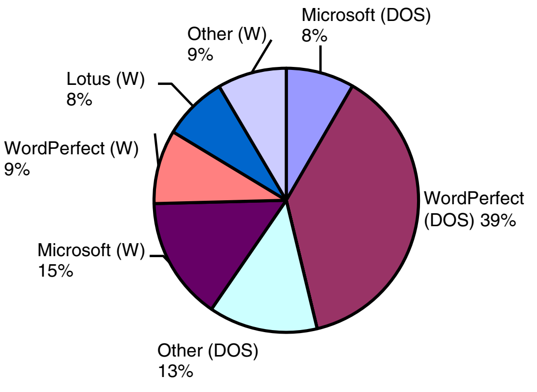

FIGURE 1 Word processor market: 1991 Total market $952M; DOS $567M; WINDOWS $385M

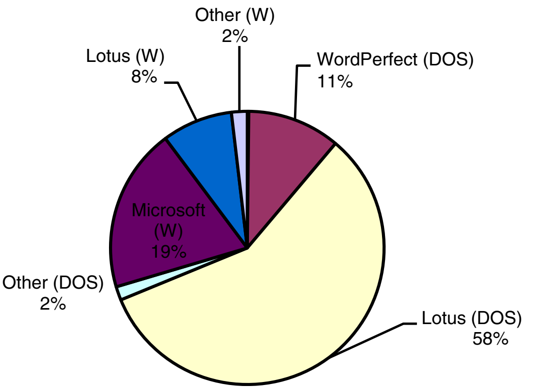

FIGURE 2 Spreadsheet market: 1991 Total market $809M; DOS $239M; WINDOWS $569M

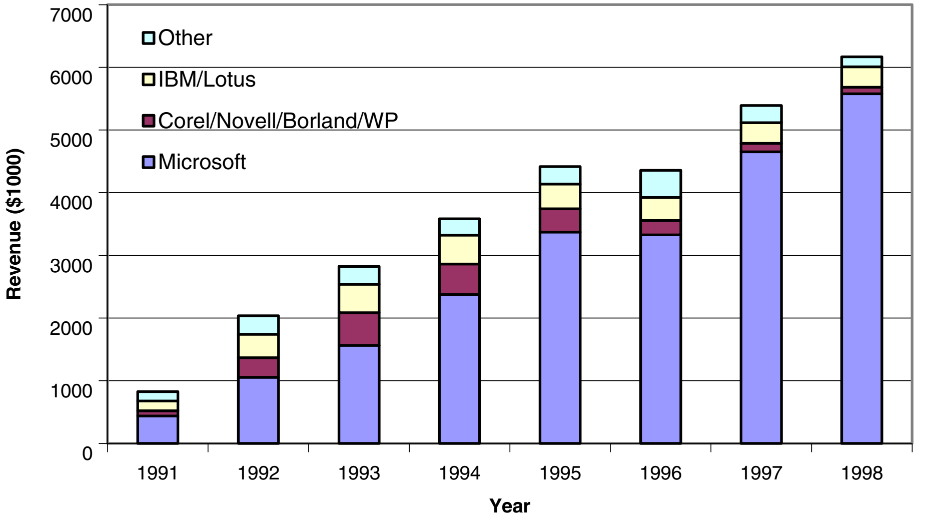

FIGURE 3 Office software revenue for WINDOWS platform by firm, 1991–1998

Microsoft's new office suite, released in early 1994, was better integrated than the previous generations of suites and went beyond the standard embedding at the time.[6] Computer software trade journals well received the suite.[7] 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.[8] By the end of 1994, WINDOWS dwarfed DOS as a platform for office applications (Figure 4), suites emerged as the most important product category (Figure 5), and Microsoft owned the dominant

[6]Microsoft Office 4.2 (including Word 6.0, Excel 5.0, and PowerPoint 4.0). Word 6.0 offered a feature where a user could insert an Excel toolbar icon into a document, and then graphically size and place an Excel 5.0 spreadsheet object. PowerPoint 4.0 included a "ReportIt" feature that took a Presentation and converted it to a Word outline. Microsoft Office 4.2 also included an updated version of Microsoft Office Manager (MOM), a tool that integrated Office applications more tightly. Nevertheless, Office 4.2 did not offer full integration.

[7]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.

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

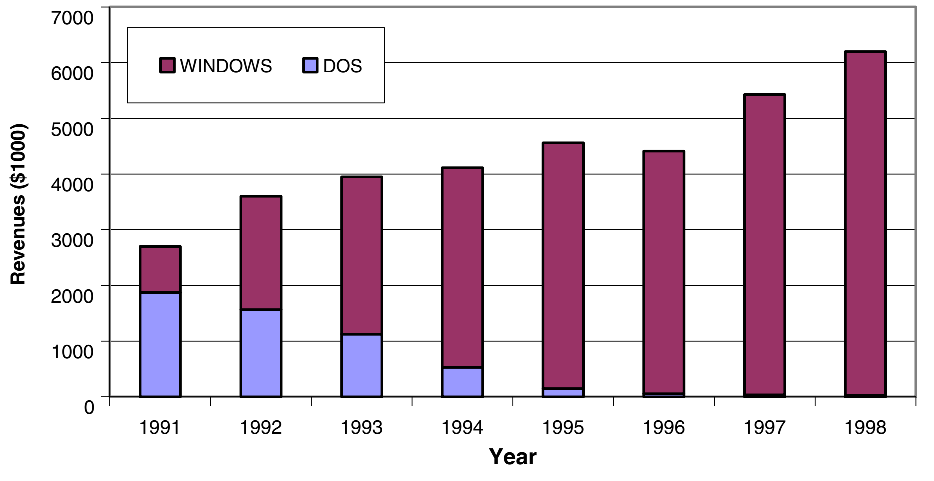

FIGURE 4 Office software revenue by platform, 1991–1998

product in this category (Figure 6). In the summer of 1995, Microsoft released WINDOWS95 and Office 95 simultaneously.[9] Competitors were slow to develop new product versions 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. In 1996, competition struck back when Corel's WordPerfect Suite and Lotus's SmartSuite found favorable market acceptance and achieved modest market shares (Figure 6). This success led to a Microsoft-initiated price competition (see Figure 7), causing revenue growth to slow for the first time. Still, Microsoft Office remained the most highly rated office suite among the three, and by the end of 1998, dominated the market. Word processors and spreadsheets were the most important components of PC office software packages (see Figure 5). Indeed, during the 1991–1998 period, suites and their two core components accounted for more than 90% of PC office software revenue.

3.2 | Data

3.2.1 | Price, quantity, and quality

Our data set includes data on worldwide shipments and sales by vendor for the three major office software products (spreadsheets, word processors, and suites), for the three major vendors (Microsoft, IBM/Lotus, and WordPerfect), for the period 1992–1998. Since computer hardware and office software are complements, the benefit from office software consumption can only be realized if consumers have an operating system capable of running the particular software package. In order to focus exclusively on software effects, we restrict our sample to spreadsheets, word processors, and office suites that were compatible with the WINDOWS operating system.[10] Each of the three major vendors offered the three major products in all seven years, with the exception that WordPerfect did not offer a suite in 1992. Thus, we have 62 data points. Table 1 presents descriptive statistics.

[9]Microsoft announced in July (1995) that it would ship its new version of its popular suite on August 24, the same day it intended to release WINDOWS95. See "Microsoft's Office Suite to be Shipped in August," *Wall Street Journal*, July 11, 1995: Section B5.

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

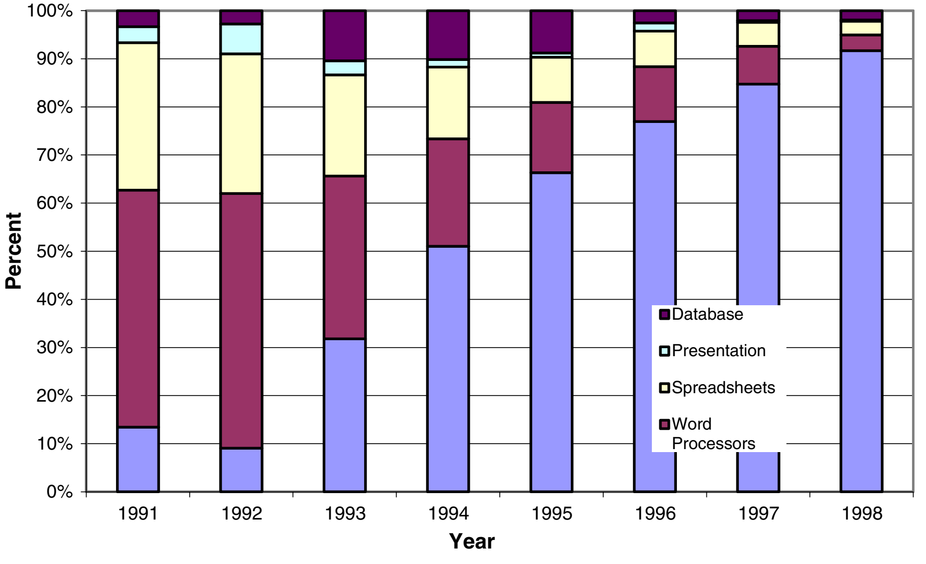

FIGURE 5 WINDOWS office productivity (revenue) shares by category, 1991–1998

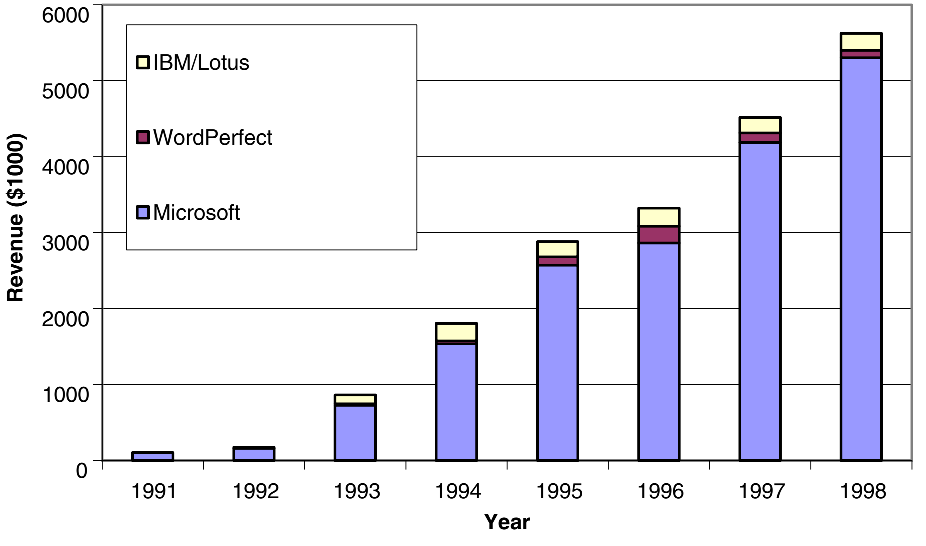

FIGURE 6 Office suite revenue by firm, 1991–1998

We use two Dataquest/Gartner Reports on Personal Computing Software, one for the 1992–1995 period and one for the 1996–1998 period, to retrieve data on prices and quantities.[11] The variable *Quantity* accounts for the number of licenses sold (in thousands), and the variable *Price* captures the average revenue for each product.[12] Gartner recorded sales and shipments only for product-years with

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

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

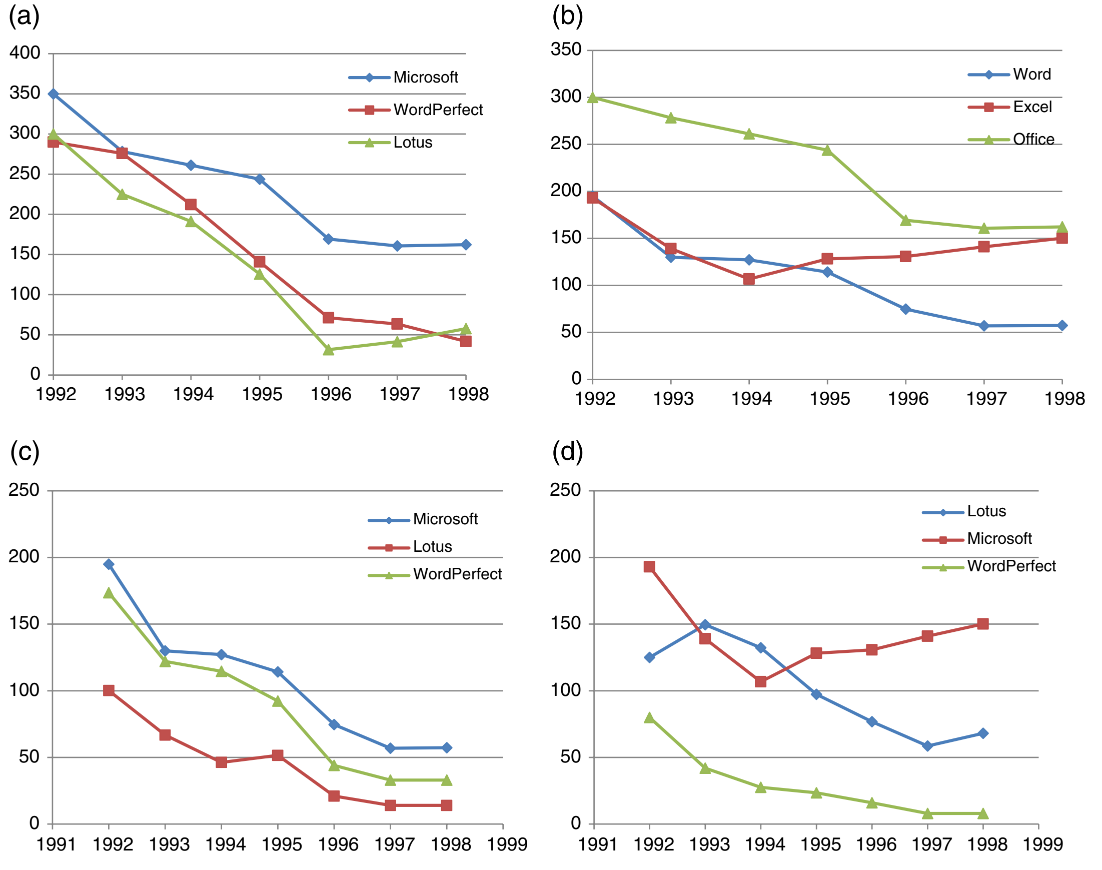

FIGURE 7 (a) Suite prices. (b) Microsoft prices. (c) Word processor prices. (d) Spreadsheet prices

TABLE 1 Descriptive statistics

Variable	Mean	Std. dev.	Min	Max
Quantity	2,914.72	5,583.4	46	32,682.7
Price	114.25	81.6	8	350
Microsoft	0.45	0.69	0	2
RELQUAL_SS	0.70	0.51	0	1.35
RELQUAL_WP	0.68	0.49	0	1.22

a "nontrivial" number of sales. All three Microsoft products qualified in all years, but Lotus had too small a market share in word processors for 1996–1998, and WordPerfect sold a nontrivial number of licenses in the suite category for 1996–1998. For those products-years with no recorded data, we impute the number of licenses sold to be equal to one half the smallest numbers of units of any product shipped in 1995—the last year for which we have complete data from Gartner. For these observations, we impute the average revenue by comparing prices from the Gartner data with prices in Liebowitz and Margolis (1999; hereafter LM) as follows: LM reports prices to original equipment vendors through 1997; we adjusted the LM series so the last price observation we have from the Gartner data equals that LM price; we then used the LM percentage declines in prices in order to compute the prices through 1997, and assumed prices were unchanged in 1998. The resulting price series for suites, word processors, and spreadsheets appear in Figures 7b–d, respectively.

We derive data on the quality of spreadsheets and word processors from normalized[13] quality measures from LM based on reviews that provided numerical ratings.[14] We calculate a product's quality relative to the quality of the leading product in the DOS era: Lotus and WordPerfect. Hence, for spreadsheets, $RELQUAL\_SS_j$ = (LM rating of product *j*)/(LM rating of Lotus SS). Similarly, for word processors, $RELQUAL\_WP_j$ = (LM rating of product *j*)/ (LM rating of WordPerfect word processor). SS_j (respectively, WP_j) is a dummy variable equal to 1 if product *j* is either a spreadsheet or a suite (respectively, a word processor or a suite), and 0 otherwise.

3.2.2 | Network effects

All office software enjoys both direct and indirect network effects.[15] However, since the three products of the three key firms in the market were "essentially" compatible during the period of our data (e.g., documents written in WordPerfect could be read and edited in Microsoft Word), we do not expect significant positive network effects. Indeed, under full compatibility, each product would have essentially the same network size. In such a case, multicollinearity would prevent us from estimating any (common) network effect. Nevertheless, in the case of office software in the mid-1990s, there was not perfect compatibility across products from different firms. Without perfect compatibility, a larger network may provide a direct network effect advantage originating by a small number of users who perform very sophisticated tasks, and thus, experience some partial incompatibility.[16] We want to capture (a) unobserved quality advantages, including advantages possibly associated with greater compatibility with the WINDOWS operating system, and (b) direct network effects associated with a larger network. To do this, we let the variable *Microsoft* take on the value of 1 for Microsoft word processors and spreadsheets, and 2 for Microsoft suites.[17]

$Suite_j$ is a dummy variable that takes on the value 1 if product *j* is a suite, and 0 otherwise (including the case where a consumer "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: (a) suites contained additional packages, such as presentation software; and (b) there are possible synergies (complementarities) among the components in computer software office suites because of the links between (and integration of) the components, and because of commands that are common across components.[18]

Additionally, in the spirit of Gandal (1995), the variable Suite captures the "indirect network effect" benefit from "data transfer" compatibility across word processors, spreadsheets, and other

[13]Since the top score is normalized to 10 in each year, these scores are not comparable across years, but this doesn't matter for our purposes since the choice set facing consumers is the software available in each particular year.

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

[15]See Gandal (1994, 1995) and Brynjolfsson and Kemerer (1996) for early work in this area.

[16]Gandal (1994) empirically showed that compatibility with the Lotus standard provided (direct) network benefits to other spreadsheets that were compatible with the Lotus standard. (This is a direct network effect since users of different but compatible spreadsheets can work on the same file.) Brynjolfsson and Kemerer (1996) also estimated direct network effects in the spreadsheet market for the period Gandal examined.

[17]To test the restrictive implications of this assumption, we simulated the case where the Microsoft variable takes the value of $1.3 < X < 2$. In all cases, our results stay qualitatively unchanged. We thank an anonymous referee for suggesting we undertake this robustness test.

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

TABLE 2 Units of operating systems and office software products (millions), 1992–1998

Year	A: WINDOWS operating systems	B: Word processors	C: Spreadsheets	D: Suites	Share of inside goods (B + C + D)/A
1992	11.056	4.650	3.442	0.578	0.784
1993	18.228	6.852	4.640	3.194	0.806
1994	32.107	5.987	5.008	7.689	0.582
1995	54.352	4.693	3.876	12.982	0.397
1996	68.083	3.247	3.149	26.810	0.486
1997	78.406	4.526	3.142	32.977	0.518
1998	89.489	2.431	2.037	38.801	0.484

office software programs included in the bundle.[19] A positive coefficient on Suite picks up these indirect network effect benefits as well as the other two effects.

3.2.3 | Additional control variables

Time-fixed effects are restricted by combining year dummies to capture three distinct periods in the evolution of the industry: the initial period characterized by component competition (1992–1993), a transition period (1994, 1995) as a result of the introduction of WINDOWS95,[20] and a third period (1996–98) characterized by suite competition. This partition is supported by data provided in Table 2, which presents similar shares of the "inside" goods for these three periods. We, therefore, define *YEAR94* and *YEAR95* to be yearly dummy variables for 1994 and 1995, respectively, and *YEAR96–98* as a dummy variable that takes on the value 1 for the 1996–1998 period, and 0 otherwise.

The potential market for office software is defined to be the number of operating systems sold or distributed via computer manufacturers during the relevant year. Our data on operating systems for 1992 comes from Baseman, Warren-Boulton, and Woroch (1995), while our data on operating systems for 1993–1998 comes from a Dataquest report on Operating System Shipments.[21] The data in Table 2 show that, on average, approximately 80% of all consumers with a computer (operating system) purchased an office software product in 1992 and 1993. By 1998, only approximately 50% of all consumers purchased an office product. One possible explanation for this decline is that, with the release of WINDOWS 3.1, utilities that came with the operating system, for example, "WordPad," filled the basic needs of less sophisticated consumers, reducing demand for office productivity software. Alternatively, significant computer usage growth in countries without strong intellectual property protection during the 1990s may have increased piracy of applications software. An additional possible explanation is that consumers who upgraded their hardware might have re-installed their existing software. Since we use the yearly dummy variables only as control variables, we are neutral regarding these or other explanations for the reduction in the percentage of consumers that purchased a spreadsheet, word processor, or suite over time.

[19]Gandal (1995) showed that database management system (DMS) software products that were compatible with the Lotus file compatibility standard were able to extract a higher price than other DMS software products. This is evidence for indirect network effects.

[20]WINDOWS95, along with a new version of Microsoft Office, was released in mid-1995 and anticipated in 1994. The transition years, 1994–1995, have quite different shares for the inside good; hence, the dummy variables for each of these years are included. When we include just a single dummy variable for 1994 and 1995, we obtain poor results.

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

4 | ESTIMATION

Our estimation is performed in two steps. We first estimated the model using Ordinary Least Squares (OLS) and a linear instrumental variables regression that estimates products' market shares on the variables previously defined (see the following Equation (2)). Using these estimation techniques, it is not possible to estimate the correlation of consumers' preferences. Consequently, in the following section, we develop a random coefficient discrete choice model that explicitly models the correlation in consumers' preferences over spreadsheets and word processors.

4.1 | Discrete choice model

We define a product to be a combination of a software category and a vendor. Each consumer compares products across four software categories: spreadsheets, word processors, office suites, or mix-and-match word processor-spreadsheet combinations from two different vendors. Hence, when all three firms offer word processors, spreadsheets, and office suites, there are 15 possible "products": 3 spreadsheets, 3 word processors, 3 office suites, and 6 mix–and-match word processor and spreadsheet combinations from different vendors, plus the "outside option" of making no purchase at all. Consumers evaluate the products and purchase the one with the highest utility, or make no purchase if that is the best option.

The utility from a particular choice is

$$U_{jk} = \delta_j + \theta_{jk}, \tag{1}$$

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 that is identical to all consumers (δ_j) and a random component that is consumer k specific (θ_{jk}).

4.2 | Mean utility

The variable δ_j measures the mean utility for product j. We specify mean utilities $\delta = (\delta_1, \ldots, \delta_9)$ for each of the stand-alone spreadsheets, stand-alone word processors, and suites, and assume that mean utility of a mix-and-match purchase is the sum of mean utilities for its constituent products. For $j = 1, \ldots, 9$, we assume:[22]

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

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

Given the limited amount of data, the mean utility specification is as simple as possible. Time-fixed effects are restricted by combining year dummies that capture the three distinct periods in the evolution of the industry: 1992–1993, 1994–1995, and 1996–1998. We allow relative quality to have a nonlinear effect by including relative quality squared, and allow the Microsoft suite to have additional advantages after 1995.

[22] Since *RELQUAL_SS* and *RELQUAL_WP* are normalized to 1 for Lotus and WordPerfect, respectively, for parsimony, we do not include a constant or a fixed effect for the stand-alone software category.

4.3 | Random utility

The variable θ_{jk} introduces consumer heterogeneity. We assume this variable depends on a common software component (y_k) and an independent product component (ε_{jk}):

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

where y_k has a standard normal distribution. The coefficients σ_1 and σ_2 allow for a consumer-specific random utility for spreadsheets and word processors, respectively. For example, $\sigma_2 y_k > 0$ indicates that consumer k has a higher than average value for a word processor. For suites and mix-and-match combinations, the consumer receives random utility$(\sigma_1 + \sigma_2)y_k$. The product component ε_{jk} introduces an additional source of consumer heterogeneity; that is, some consumers are more attracted to a particular product. Unobserved consumer heterogeneity in preferences over vendors in a particular software category or products involving two software categories enters only through this variable. The ε_{jk} are assumed to be independently and identically distributed according to a standard Gumbel (or Type I extreme value) distribution. This captures an idiosyncratic preference for individual products,[23] and is the error structure typically employed in discrete choice demand models. It permits a convenient characterization of expected market shares, as the following describes.

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

Our estimation algorithm adapts the methods described in Nevo (1998). More specific details can be found in Appendix D.

4.4 | Identification of mean utility parameters

Our data set contains sales and shipments by products and by year. Thus, both variation across products and variation across time are sources of identification of the parameters of the model. The variables RELQUAL_SS, RELQUAL_WP, and PRICE vary both by product and by year. Consequently, shifts in market shares of products over time identify the coefficients on these variables. The year dummy variables vary over time only. Variations in the share of potential consumers who elect the outside good identify the coefficients on these variables. The vendor variable (Microsoft) varies across products, but not over time. Variations of shares of Microsoft products relative to products of the other vendors identify the coefficient on this variable. The variable Suite captures added value from suites relative to components. Hence, the market share variation of suites identifies the coefficient on this variable.

[23] Piracy may be higher for products with greater installed base. Any differential privacy effect is included in the idiosyncratic preference for individual products in the error structure of the model.

4.5 | Identification of random utility parameters

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

The sign of $\sigma_1 * \sigma_2$ (and thus, whether the correlation is negative or positive) is identified as follows: When σ_1 and σ_2 are greater than zero, higher σ_1 or σ_2 increases the correlation ($\frac{\sigma_1 * \sigma_2}{\sqrt{\left(\sigma_1^2+1.645\right) * \left(\sigma_2^2+1.645\right)}}$), and thus, increases the demand for suites. Similarly, when $\sigma_1 * \sigma_2 < 0$, higher absolute value of either sigma decreases the correlation and decreases the demand for suites.[24]

Gentzkow (2007) provided an insightful discussion of the difficulty of separately identifying product complementarity and preference correlation. Similar issues apply to our setting, even though we adopt a simplified model of correlation and only allow for complementarity in the purchase of suites. Both positive correlation and a positive coefficient on Suite increase the demand for suites. Correlation is identified separately from complementarity because market shares of suites become less sensitive to changes in suite prices when correlation is positive. We can thus separately identify these two effects if the fall in Microsoft's suite price beginning in 1996 was exogenous. From our understanding of the industry, the fall in prices in 1996 was primarily due to an exogenous change (improvement) in technology, namely, the introduction of the WINDOWS95 operating system. Finally, the random parameters help determine the sensitivity of market share to prices. What identifies σ_1 and σ_2 separately from the price coefficient are *differences* in the responses of market shares of the three product categories to price changes.

4.6 | Elasticities

In the full random coefficients model we employ, three parameters (β_1, σ_1, and σ_2) determine the own and cross price elasticities. In the case of the logit model (only ε_{jk} in the random utility part of the model), own and cross price elasticities are determined exclusive by β_1 (and prices and market shares). This typically leads to unreasonable product substitution effects. In the random coefficients model, on the other hand, the substitution effects are quite rich. The logit treats all products as substitutes, while in the random coefficients model, our estimates are such that many of the products are substitutes, but some of the products (like word processors and spreadsheets from different firms) are complements. We discuss this further in Section 6.

4.7 | Instrumental variables

Since price is endogenous, we instrument for it.[25] We employ four instrumental variables: (a) relative quality of the best rival product in the same category (where category means spreadsheet, word

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

[25]The decisions of the firms to offer bundles may be endogenous as well. We do not have data to account for this choice. We do, however, simulate different oligopoly structures using our parameter estimates. Further, this decision was made before our data started. Hence, we think that this is reasonable. Misra (2013) addressed decisions of retailers to choose which products to offer based on a combination of demand and cost parameters.

processor, or suite);[26,27] (b) relative quality of best rival suite for spreadsheets or word processors; relative quality of best rival constituent product for suites; (c) relative quality of firm's own other constituent product (for spreadsheets or word processors); relative quality of "best" own constituent product (for suites); and (d) a dummy variable for the years 1995–1998. Prices declined beginning in 1995 following the introduction of the WINDOWS95 operating system, which we interpret to an exogenous technological change that lowered the cost of marketing office software.

Since we have just one endogenous variable, we need only one instrument for formal identification. None of the instruments, however, are informative enough alone, or in subsets; hence, we use all four together.[28] This manifests itself as follows: When we include fewer instruments, we have higher standard errors on the coefficients.

5 | ESTIMATION RESULTS

The OLS regression results are presented in the first column of Table 3. Because price is endogenous, we expect the estimated negative coefficient on price to be biased upward. Re-estimating the model using linear instrumental variables (IVs) results in a more negative and statistically significant estimated coefficient on price compared to the OLS estimation (−.14 versus −.0002) reaffirming our specification (see Table 3).

Since these are linear regressions, they cannot estimate the nonlinear parameters (i.e., the correlation coefficient). Consequently, we follow the algorithm presented in Appendix D to estimate the full random coefficients model. The results are presented in the third column in Table 3. Given the small sample and the large demands the model puts on the data, unfortunately, many of our GMM estimation coefficients are not statistically significant. We test the validity of these estimates in two ways; First, we look at the correlation between the two sets of estimates. As expected, the estimates for the linear IV case and the estimates for the full random coefficients model are similar, with a correlation coefficient of 0.99. Second, in our robustness checks, we run thousands of additional simulations using draws taken based on the estimated variance–covariance matrix. The main counterfactual results are qualitatively similar. The rest of the discussion in this section focuses on the estimates from the full random coefficients model. We begin with the nonlinear parameters.

The estimated coefficient for the standard deviation over preferences for word processors ($\sigma_1 = 0.87$) is smaller than the estimated standard deviation for spreadsheets ($\sigma_2 = 1.82$). Given these estimates, the corresponding overall correlation of consumer preferences for spreadsheets and word processors is 0.46. Using supplementary data from the Current Population Survey Supplement (CPS) on Computer and Internet Use (see Appendix B for details), we can assess whether this estimate is reasonable. Questions about spreadsheet and word processor usage were only asked starting 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, respondents were asked two questions about spreadsheet and word processors for both home and office use: (a) Do you use the computer at home (at the office) for word-processing or desktop publishing (Yes/No)? (b) Do you use the

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

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

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

TABLE 3 OLS, linear IV, and nonlinear instrumental variable estimates

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

computer at home (at the office) for spreadsheets or databases (Yes/No)? We define dummy variables that take on the value 1 if the answer to a question is yes, and 0 otherwise. The correlation between these variables (which is an imperfect proxy for the correlation in consumer preferences over word processors and spreadsheets) is 0.37 for home use, and 0.36 for office use. This suggests that our result (correlation of 0.46) is well "in the ballpark."[29]

The key coefficients of the linear parameters, and particularly, the variable Price have the expected sign, but are not statistically significant. This is likely because of the limited number of observations in combination with the nonlinear model we employ. The coefficients on the relative quality variables (WP_j*$RELQUAL\_WP_j$ for word processors, for example), which measure the value associated with observed quality of components, are negative, while the coefficient on the square values are positive for both product categories. This suggests that consumers' value is convex in the ratings on which the relative quality measures are based. The yearly dummy variables capture shifts in the difference between the value of office software products and the outside option. The coefficients associated with the yearly dummies are declining in value partly 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).

The coefficient on the variable Suite is positive, suggesting either that consumers also value the additional software components (i.e., Presentation software), that consumers value the complementarity or integration of the components, that there are indirect network effects or a combination of the three.

Recall that the variable Microsoft takes on the value 1 for Microsoft component products (word processors and spreadsheets), and 2 for suites, and is thus intended to capture the unobserved quality of Microsoft component products. The estimated coefficient associated with the variable is positive. This suggests Microsoft benefited from some or all of the following: better reputation, better service,

[29]Unfortunately, the CPS data cannot be used to derive additional "micro moments" as "use" is not a good proxy for purchasing. Because our estimate of correlation is close to that obtained from the CS data and since we vary the values in order to study the effect of changes in correlation, we believe that our correlation estimates are valid for use as benchmark in our simulations.

better additional components in the suite, better integration of components, higher unobserved quality of components, and better integration with WINDOWS. It also may suggest that Microsoft had a network effect advantage.

The coefficient associated with Microsoft Suite for the 1996–1998 period is positive. Given that we already control for Suite, the coefficient of the Microsoft Suite for 96–98 might be picking up a complementarity/compatibility effect, and may reflect the fact that Microsoft's components were much better integrated in the Microsoft Suite than in other suites after the introduction of WINDOWS95. The trade press (see Appendix A) shows that, even in 2001, there was a large difference in cross-application compatibility between the Microsoft Suite and other suites.[30] Finally, 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 a value of approximately $23.40.[31]

6 | COUNTERFACTUALS/SIMULATIONS

6.1 | Preliminaries

In this section, we use the estimated coefficients from our random utility model to simulate market outcomes under alternative hypothetical market structures in order to study the consequences of suites for market outcomes. More specifically, we examine how the correlation of consumer preferences for spreadsheets and word processors matters for prices, market shares, profits, and consumer welfare for different monopoly and oligopoly settings. We conducted simulations for both 1995 and 1998, and found little qualitative difference in the simulations' results between these years. Hence, we present and discuss the results for 1995 in the body of the article and leave the results for 1998 for the Appendix S1 (Tables E4–E6). The simulations in Tables 4 and 5 are based on the estimated coefficients from Table 3. At the end of this section, we check the robustness of our conclusions by drawing coefficients from their estimated multivariate normal distribution.

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

[30] Stan Miastkowski wrote 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. LM noted: "When they [Microsoft's competitors] did assemble competing suites, they tended to cobble together products that had little in common."

[31] We ran the Hansen-Sargan over-identification test of all instruments, and got a Hansen J-statistic value of J = 0.896. The p-value for a Chi-squared with three degrees of freedom is 0.863. Thus, we clearly do not reject the null hypothesis that our over-identifying restrictions are valid. By construction, "J" is a Wald statistic—and it converges in distribution to a χ^2 (Chi-squared) with three degrees of freedom since we have one endogenous variable (price) and four instruments.

$$\frac{\rho\sigma_1 * \sigma_2}{\sqrt{\left(\sigma_1^2+1.645\right)*\left(\sigma_2^2+1.645\right)}}. \tag{4}$$

Thus, ρ, the correlation coefficient of the bivariate normal distribution, is essentially a scaling coefficient of the overall correlation between word processors and spreadsheets. By varying ρ we can change the correlation in preferences holding the estimated standard deviations constant. In the simulations, we examine $\rho = -1$, 0, and 1. Given our estimates $\sigma_1 = 0.87$ and $\sigma_2 = 1.82$, the corresponding overall correlation of consumer preferences for spreadsheets and word processors is as follows: (I) when $\rho = -1$, the correlation is -0.46, (II) when $\rho = 0$, the correlation is 0, and (III) when $\rho = 1$, the correlation is 0.46. Thus, our simulations model changes in correlation well away from the extremes of perfect negative or positive correlation. We do not estimate ρ, but rather employ it as a scaling factor in the simulations in order to adjust the overall correlation between preferences over spreadsheets and word processors without adjusting our estimates of σ_1 and σ_2.[32]

For our simulations, we assume that consumers' preferences (Y_{1k} and Y_{2k}) and products' marginal cost are invariant to market structure changes or whether firms adopt bundling. Assuming a differentiated goods competition model, estimated marginal costs are calculated based on the first order conditions for profit maximization. Specifically, we assume that the firms compete in prices in Nash equilibrium and choose their prices simultaneously based on the numerically calculated cross elasticities of demand among the products they sell. For Microsoft's products in 1995, the estimated marginal costs are as follows: MS Word—$96.70; MS Excel—$112.50; MS Office—$225.80. While these estimated marginal costs may seem excessive at first glance, the marginal cost of software in the 1990s included the marginal cost of CD pressing, manuals printing, packaging, distribution as well as the marginal cost of providing consumer support (e.g., free unlimited phone support, etc.). According to the Software and Information Industry Association, in 1990, 38% of total software costs were variable costs in the form of sales costs, technical support, and consumer support. This by itself provides reasonable support for nontrivial point estimates of marginal costs.[33] In addition, recall that Office contained other software packages plus complementarity and integration features that may have entailed additional packaging (Microsoft Office 95 package was a foot by foot cube in size) and technical support expenses. It is also likely that Microsoft had made substantial marketing efforts to educate the market of the advantages of purchasing MS Office over buying only the components. Hence, it does not seem surprising that the marginal cost of the MS Suite exceeds the sum of the marginal costs for Word and Excel by approximately $16.70.

Given the estimated suite-bonus of approximately $23.40, the additional $16.70 in costs implies that the suite increased the value created for the average consumers by approximately $6.70. Thus, the suite presented a profit opportunity to Microsoft independent of any price discrimination benefits from bundling. This "suite-bonus effect" distinguishes our model from previous literature that focuses on the price-discrimination motive, and is key for understanding many of our simulation results.

[32]As discussed by Gentzkow (2007), it is difficult to empirically identify preference correlation separately from product complementarity because the two have similar qualitative effects on demand. In our model, it is similarly difficult to estimate both the correlation coefficient (ρ) from the Suite coefficient because changes in the two have similar qualitative effects on the demand for suites. The suite-bonus effect is different from product complementarity because the suite bonus does not accrue for mix-and-match bundles. Nevertheless, the identification issue is similarly problematic. That is, the share of suites at given prices does not by itself distinguish the effects of the suite bonus from positive correlation in the taste distribution, sufficient exogenous price variation is necessary to separately identify ρ and the Suite coefficient.

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

TABLE 4 Monopoly market structures and correlation

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

Note. In all simulations, prices are in $, shares are based on the 100,000 potential consumers per year, and profit and consumer surplus (CS) are in $ per potential consumer. Outcomes are summed over Microsoft products where appropriate. The underlines are representing the summation of the values above the underlined number.

TABLE 5 Oligopoly competition: Lotus and WordPerfect sell components

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

Note. The underlines are representing the summation of the values above the underlined number.

We first discuss monopoly simulations (Table 4) and then oligopoly simulations (Table 5). Before we do so, we summarize the main simulation results, which are robust to market structure:

6.2 | Counterfactual summary: Positive correlation increases the profitability of bundling

One of the main questions we study is how the correlation in preferences over spreadsheets and word processors affects profits from bundling. Since profit under separate selling (i.e., no bundling) does not depend on correlation, we take separate selling to be our base case. In order to study changes in value created and value captured, we compare the change in profits and consumer surplus when Microsoft competes under pure bundling and mixed bundling strategy to this base case. We find that regardless of the underlying market structure, both pure bundling and mixed bundling increase profits and consumers' surplus. Furthermore, this advantage is increasing in correlation because of the market-expansion effect. Looking at the changes in outcome across the different levels of correlations reveals that correlation has a crucial effect on the benefits of bundling. Specifically:

- Our simulations in Tables 4 and 5 show that the percentage change in profits from the introduction of the suite increases in correlation—and the differences are large. We find that with a correlation coefficient of 0.46 (which is our point estimate) and corresponds to ρ=1, profits from the introduction of the suite increase by more than 70%, and this is robust to industry structure (+74% under monopoly in Table 4, and +79% under oligopoly in Table 5).
- When the correlation coefficient is −0.46 (ρ=-1), profits from the introduction of the suite increase profits by less than 50% (+47% under monopoly, and +48% under oligopoly).
- An additional key result of the simulations in Tables 4 and 5 is that the percentage increase in profits is always greater than the percentage change in consumer surplus. Hence, while both Microsoft and consumers gain, value capture by Microsoft increases. This is especially true in the case of oligopoly competition, where the percentage increase in profits from the introduction of the suite (+79% when the correlation coefficient is 0.46) is more than twice as large as the percentage increase in consumer surplus (+36% when the correlation coefficient is 0.46).

We now discuss the simulations in more detail.

6.3 | Monopolistic structure

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

It is clear from these simulations that both profits and consumer surplus are increasing in correlation in all three cases. As previously noted, a striking conclusion is the percentage increase in profits is always much greater than the percentage change in consumer surplus.

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

The mixed-bundling case also shows that Microsoft's profit is increasing in the correlation. The market-expansion effect operates more subtly under mixed bundling because the additional suite sales are partly at the expense of component sales. Nevertheless, profits are increasing in the correlation coefficient under mixed bundling. The suite-bonus effect magnifies the expansion in demand for suites because it increases the incremental profit from each new sale. It is worth noting, however, that while the suite-bonus effect contributes significantly to higher profits, the market-expansion effect by itself is strong enough for profit to be increasing in correlation.[34]

Consumer surplus increases hand-in-hand with profit with greater correlation.[35] With positive correlation ($\rho = 1$), the predicted price of Microsoft Office under mixed and pure bundling is about the same, roughly $248, which is approximately $14 higher than the summed prices of Excel and Word under separate selling. Given that the average suite bonus is $23.40, a $14 price premium over the "summed prices" makes the suite a good deal for most consumers who would purchase both products. The reason behind the positive relationship between consumer surplus and correlation is driven by the number of consumers who buy the bundle. While lower correlation results in more attractive pricing, under negative correlation the market-expansion effect implies that fewer consumers are attracted by the benefits of the bundle, and thus, fewer consumers enjoy the suite bonus.

6.4 | Partial (oligopoly) competition

Table 5 simulates outcomes for different modes of oligopoly competition in the components markets. To that end, we include in the market setting the WordPerfect word processor (marginal cost $81.40) and the Lotus spreadsheet (marginal cost $86.40) as well as the Microsoft products. Similar to the monopoly simulations, Microsoft's profit and consumer surplus are increasing in correlation under both pure and mixed bundling. We focus our discussion on the effect of the correlation on the strategic interaction among the firms.[36]

In the case of oligopoly competition with positive correlation, the percentage increase in profits from the introduction of the suite (+79% when $\rho = 1$) is more than twice as large as the percentage increase in consumer surplus (+36% $\rho = 1$).

The introduction of the suite is pro-competitive (i.e., beneficial for consumers) on balance as long as rivals remain active in the market. This is because, similar to the monopoly simulation in Table 4, the suite bonus ($23.40) is much larger than the difference between the suite price and the sum of prices of Microsoft's Word and Excel in Case I.

6.5 | Effect on rivals

Case III in Table 5 examines the effect of competition in the components market by simulating a market where Microsoft only sells its suite. Comparing this structure to Case II where the components market is oligopolistic, it is interesting to note that the competing firms do not necessarily benefit from a reduction in the number of Microsoft products. Specifically, a competing firm may be better off against a dominant firm that sells components and a bundle (mixed bundling) rather than just the bundle (pure bundling). This result is driven by the foreclosure effect that pure bundling may have in

[34]In Appendix S1, we show that profits increase with correlation even when there is no suite bonus and the cost of the suite equals the sum of costs of the components.

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

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

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 that only sell components.

Whether the standard "reduction in competition" effect dominates the "mix-and-match effect," or vice versa, depends on the level of correlation. Our simulation results show that the "mix-and-match effect" is stronger when $\rho = 1$. Otherwise, the reduction-in-competition effect dominates. Since the share of consumers that highly value the purchase of both components increases with correlation, increases in the correlation coefficient make it more likely that consumers purchase both products, and thus, that consumers may choose to mix and match. 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.

7 | ROBUSTNESS ANALYSES

In this section, we examine the robustness of our simulation results.

7.1 | Changes in marginal cost

In order to make sure that our main results are robust to different cost structures, we re-did all the simulations in Tables 4 and 5 under the assumption that the marginal cost of the Microsoft suite is the sum of the marginal costs of the Microsoft components, while retaining the estimated marginal costs of Microsoft's components and the other components. The results are in Tables E1–E2 in Appendix S1. They show that the effects of correlation on profits and consumer surplus and on the strategic interaction in the market are robust to this alternative cost structure. Further, additional simulations in Appendix S1 (Tables E3–E4) also show that these main results are also robust to conducting the simulations for 1998 in which the cost estimates are different.

7.2 | No suite bonus

Tables E5 and E6 in Appendix S1 present the same simulation as in Tables 4 and 5 except there is no suite bonus—the Suite coefficient is set to 0—and the marginal cost of the Microsoft suite is set equal to the sum of the marginal costs of the Microsoft components. Our results remain qualitatively unchanged. Hence, Tables E5 and E6 in Appendix S1 show that results are not driven by the suite bonus (e.g., the addition of the PowerPoint to the bundle), but rather by the bundling itself.[37] As previously noted, the suite bonus does "magnify" the market-expansion effect and make the introduction of the suite more profitable.[38]

[37]Economies of scope in production provide an incentive to offer a bundle. Our article shows that "independent of any economies of scope in production," there is a benefit to offer a bundle due to the market-expansion effect. The benefit is especially high when the correlation in consumer preferences over the components is positive. Thus, our article shows that strategic incentives for bundling exist even without economies of scope in production.

[38]For example, with a correlation coefficient of 0.46, profits from introduction of the suite increase by "just" 43% under monopoly when there is no suite bonus versus the 74% increase when there is a suite bonus.

7.3 | Robustness of market-expansion effect

Table E7 in Appendix S1 presents a simulation that fixes marginal cost and increases mean consumer utility. Since price increases by less than mean utility, more consumers buy the suite. The market-expansion effect vanishes if market coverage becomes too high. A similar effect is achieved by lowering marginal cost since market coverage increases in response to a lower price (see Table E8 in Appendix S1). Sufficiently low market coverage, due to a sufficiently low mean utility or sufficiently high marginal cost, corresponds to what Johnson and Myatt called a "niche market," for which an increase in the variance of valuations results in higher profit.[39] In our base case, market coverage is relatively low and a rise in correlation increases the variance of valuations for the suite resulting in higher profit. This is what we call the market-expansion effect.

7.4 | Robustness to estimated coefficients

Our results are based on the coefficient estimates in Table 3. As we discuss in Section 5, our small data set does not allow us to estimate Equation (2) very accurately. In order to test for the robustness of our results, we run the simulations presented in Tables 4 and 5 on 500,000 draws taken, based on the estimated coefficient variance–covariance matrix. Given that our price coefficient is not statistically significant, it is not surprising that we get a positive price coefficient in about 10% of the draws. We drop these draws and we run the simulations on the remaining 90% of the draws; however, for some of these draws the program is unable to find the equilibrium cost estimate or equilibrium prices.[40] We use all of the draws for which the program finds an equilibrium and focus our robustness analysis on the key results previously discussed. Specifically, the positive and monotonic relationship greater correlation has with welfare and profitability, and the positive welfare effects of the introduction of the suite.[41]

In Appendix S1, we present the distribution of the change in profits and welfare as we move from (a) negative correlation to no correlation (from $\rho = -1$ to $\rho = 0$); (b) no correlation to positive correlation (from $\rho = 0$ to $\rho = 1$); and (c) negative correlation to positive correlation (from $\rho = -1$ to $\rho = 1$).

The graphs in Appendix S1 present the distribution of changes in profits and consumer welfare for the monopolistic and competitive cases both for pure and mixed bundling. The results from the analysis are summarized in Table 6.

In the "Monopolistic Case," Microsoft is the only active vendor in the market. In the "Oligopolistic Case," Microsoft competes with the WordPerfect word processor and the Lotus spreadsheet. We consider both pure bundling and mixed-bundling settings for Microsoft. Hence, we consider four industry configurations, which correspond to Cases I and III in Table 4, and Cases II and III in Table 5. As Table 6 shows, our results regarding the relationship between correlation (ρ) and welfare are robust to changes in the estimated coefficients. In virtually all cases (with the exception of the independent selling case), welfare increases in ρ.

While the positive monotonicity of correlation with profits is not as robust, our results are in line with Schmalensee (1984). Specifically, Schmalensee (1984) showed for the case of monopoly pure bundling that profits increase in correlation when markups are relatively low, decrease in correlation

[39]Clearly, "niche market" is not ideal terminology since the "market-expansion effect" applies even when the share of the inside goods is relatively large, as we show in our robustness simulations.

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

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

TABLE 6 Welfare and profits robustness effect

Share of simulation runs where	Pure bundling	Mixed bundling
Welfare *increases* in correlation		
Monopolistic case	0.99	0.97
Oligopolistic case	0.99	0.98
Microsoft's profits *increase* in correlation		
Monopolistic case	0.93	0.86
Oligopolistic case	0.9	0.88
Microsoft's profits *decrease* in correlation		
Monopolistic case	0.04	0.08
Oligopolistic case	0.07	0.08
Microsoft's profits *U shaped* in correlation		
Monopolistic case	0.03	0.06
Oligopolistic case	0.03	0.04

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

when markups are relatively high, and have a U-shaped relationship for moderate markups. Indeed, we found both for monopoly and oligopoly models, and both for pure and mixed bundling that the average markup in the cases where profits decrease in correlation is about three times as large as for the cases where profits increase in correlation.

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

We also examined the relationship between the "mix-and-match effect" and the "reduction in competition" effect. Table 7 that follows presents the share of cases where Lotus's and WordPerfect's profits were higher under mixed bundling than under pure bundling. As expected, when the correlation is positive, it is very likely for the mix-and-match effect to dominate the reduction in competition effect (85 and 83% for WordPerfect and Lotus, respectively). Furthermore, the percentage of cases for which the mix-and-match effect is dominant increases in correlation.

Even though our individual parameter estimates are imprecise, the distributions in Appendix S1 and the previous summaries in Tables 6 and 7 show that our estimated profit and consumer welfare effects are robust to variations in the parameter vector.[42]

8 | DISCUSSION AND CONCLUSION

The article examines how correlation in preferences over spreadsheets and word processors affects conduct and performance in the office software market. We used estimates from an empirical model to simulate the effects of correlation under alternative hypothetical market structures. The key take-away from our results is that the introduction of a bundle is much more profitable when consumer preferences over components of the bundle are positively correlated. While introducing the bundle always leads to an increase in profits (as compared to selling only components), regardless of the correlation, the increase in profits is dramatically higher when the correlation is positive.

[42]We are very grateful to the associate editor for encouraging us to perform this robustness analysis.

TABLE 7 Reduction in competition effect

Share of simulation runs where	$\rho = 1$	$\rho = 0$	$\rho = -1$
Higher profits under mixed bundling			
WordPerfect word processor	0.62	0.25	0.17
Lotus spreadsheet	0.8	0.38	0.18

We find that bundling also benefits consumers. This "pro-competitive" effect is particularly strong when the correlation is large and positive. In this case, many consumers 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 benefit.

Regardless of the market structure, the percentage increase in profits is always greater than the percentage change in consumer surplus. Hence, while both Microsoft and consumers gain, the value captured by Microsoft increases.

Our analysis adds to the strategy literature on bundling in the presence of "interdependencies" across the demand for the products in the bundle (e.g., Chao & Derdenger, 2013). We distinguish between two different types of interdependencies: (a) synergies across the attributes of the different products that increase the value from the consumption of one product if one also consumes the other product;[43] and (b) correlation in the valuation consumers have for the different products irrespective of the products' attributes. For example, from the CPS data we examine in Appendix B, consumers with higher income are more likely to have higher valuation for both word processors and spreadsheets; the positive correlation of preferences over these products derives from income.[44] Following the literature (Nalebuff, 2004), we think about the first type of interdependency as *complementarity* across products, and the second type as the *correlation* in preferences effect. Our main contribution is to demonstrate the effect changes in the *correlation in preferences* have on demand for the bundle, and thus, on profitability. Most importantly, we show that bundling may benefit firms not only as a result of the increase in profitability due to reduced dispersion associated with negative correlation, as typically discussed in the literature, but rather since higher dispersion increases both value creation and capture.

Our findings regarding the effect of correlation on profits is related to Lee et al. (2010,) which found that firms benefits from an increase in industry level complementarities (cosine similarity) across the products in the bundle. Lee et al. (2010) defined a measure based on the share of revenues coming from consumers who purchase all products in the bundle, either from the same vendor or from different vendors. Consequently, their definition of industry level complementarity is related to our correlation coefficient. Similarly, our suite dummy variable reflects their idea of firm level complementarities. Our finding expands on the finding in Lee et al. (2010) by explicitly modeling the demand effects that provide the derivation for the positive relationship they find and explicitly measuring the increase in profits associated with an increase in the correlation of consumer preferences over the products.

Our results are also related to Cottrell and Nault (2004), who found evidence that products benefit from economies of scope in consumption. Specifically, we show that demand side effects (correlation in consumer preferences over products in the bundle) are important and can greatly affect the profitability of bundling.

Our analysis focuses on the consumers' side of the WINDOWS95 platform. Mixed bundling in the context of two-sided markets was studied by Chao and Derdenger (2013). Their analysis focused on the bundling of what they call "access to the platform" (WINDOWS95, in our case) with

[43]These synergies also include the integration of features, that is, putting spreadsheets into word processing documents.

[44]Thus, positive correlation in preferences is not necessarily driven by common features.

"integrated content" (in our case, word processors, spreadsheets, and suites). Their analysis focuses on bundling in the presence of a very specific complementarity as content has no value in the absence of access to the platform. Hence, consumers must purchase, at some point, the two components of the bundle. While, the difference in the settings does not allow us to compare our results with theirs, we believe that our key results about the market-expansion effect are applicable to two-sided markets and represent an interesting question for future research.

Our research has important managerial implications as it helps managers understand the conditions under which bundling may pay off. We show that key to enhanced profitability is the consideration of the correlation in consumers' preferences when making decisions to integrate these otherwise independent products. Specifically, it may be profitable for firms to invest in actively increasing the correlation in consumer preferences over products in the bundle as it could lead to an increase in the profitability of bundling.

More generally, our research has important implications for platforms and other intermediaries selling complementary products or services in markets with network effects. Since bundling increases value creation, bundling their services can help attract additional customers to their platform. Furthermore, an intermediary in a two-sided market may want to encourage its "sellers" side to partner and offer bundled services as this could potentially increase the "sellers" profitability as well as attract more users to the other side of the market.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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APPENDIX A: SUPPLEMENTARY PRODUCT REVIEWS

ZDNet overall ratings are compiled by averaging across all five components listed in the table below.[45] The main difference between the Microsoft suites and the other suites is the difference in cross application compatibility. Here, Microsoft continues to receive significantly higher rankings than the other firms.

TABLE A1 Reviews from *PC World*, February 1994

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 A2 Reviews from *PC World*, February 1998

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 A3 Reviews from ZDNet 2001

	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

APPENDIX B: CURRENT POPULATION SURVEY SUPPLEMENT ON COMPUTER AND INTERNET USE

In order to further assess whether our estimates of positive correlation and positive complementarity are reasonable, we obtained survey data from the Current Population Survey (CPS) Supplement on Computer and Internet use from September 2001.[46] The supplemental data on computer and Internet use were first collected in 1998. However, questions about spreadsheet and word processor usage were only asked beginning in 2001. There were approximately 160,000 individuals in the 2001 CPS Supplement. The CPS uses weights to produce basic demographic and labor force estimates.

In 2001, the following questions were asked about spreadsheet and word processors for both home and office use:[47]

[45]ZDNet Microsoft review from April 20, 2001, available at 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, available at http://www.zdnet.com/supercenter/stories/review/0,12070,476275,00.html

[46]The CPS is a joint project of the U.S. Bureau of Labor Statistics and the U.S. Bureau of the Census. See http://www.bls.census.gov/cps/ for more details.

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

TABLE B1 CPS supplement on computer and internet

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 B2 Regressions of use on income and other factors

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	

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

The weighted results are shown in the following table.

As Table B1 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.

In table B2 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.

In the following regressions, we use the individual data from the CPS Supplement on Computer and Internet Use (2001). In the following table, 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 and 14 that correspond to ranges of yearly family income. For example, 1 = less than $5,000, 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 1 if the individual is in school, and 0 otherwise.

Internet—a dummy variable that takes on the value 1 if the household has internet service, and 0 otherwise.

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

APPENDIX C: ELASTICITIES

CROSS ELASTICITIES FROM THE LOGIT AND RANDOM COEFFICIENTS MODELS

In the following, we report the cross elasticities for both the logit and random coefficients model for the oligopoly simulation in Table 5. Elasticities from logit model are calculated analytically since there is an analytical expression for market share. In the case of the random coefficients model, elasticities are calculated numerically. For the logit model, the own elasticity for product j equals $\beta_1*(1 - s_j)p_j$. The cross elasticity (of product j with respect to changes in the price of product k) equals: $(-1)\beta_1*s_k*p_k$.

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

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

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

Own and cross elasticities from the random coefficient model are:

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

We can see that own elasticities from the random coefficients model are smaller (and more reasonable) than those from the logit model. Further, except for the case of Microsoft Word and Microsoft Excel, word processor and spreadsheet pairs are complements (shaded in the above table), which makes sense. Microsoft Word and Excel are substitutes because they have a common characteristic—Microsoft).

APPENDIX D: ESTIMATION TECHNIQUE

ESTIMATION ALGORITHM

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

Step 1: Take random draws of y_k for 100,000 consumers per year.
Step 2: Select initial values for (σ_1, σ_2) and for $\delta_{old} = (\delta_{1,\ old}, \ldots, \delta_{9,\ old})$.[48]
Step 3: Given the values of (σ_1, σ_2) and for δ_{old}, apply the contraction mapping

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

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

Step 4: Given $\hat{\delta}$, run the GMM regression $\hat{\delta} = X\beta + \xi$ to obtain estimates $\hat{\beta} = (X'ZWZ'X)^{-1}X'ZWZ'\hat{\delta}$, where X is the matrix of right hand side variables, Z is the matrix of exogenous right hand side variables and instrumental variables, and $W = (Z'Z)^{-1}$ is the weighting matrix.[49]
Step 5: Compute the implied values of the unobserved product characteristics, that is, $\hat{\xi} = \hat{\delta} - X\hat{\beta}$, and evaluate the GMM objective function $\hat{\xi}' ZWZ' \hat{\xi}$.
Step 6: Update values of σ_1 and σ_2, set $\delta_{old} = \hat{\delta}$, and return to Step 2 until the GMM objective function is minimized and the search is complete.[50]

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

MARKET SHARE CALCULATIONS

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

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

$$P_{jk} = \frac{e^{\delta_j + \sigma_1 * SS_j * y_k + \sigma_2 * WP_j * y_k}}{1 + \sum_{l=1}^{15} e^{\delta_l + \sigma_1 * SS_l * y_k + \sigma_2 * WP_l * y_k}}, \tag{D1}$$

and the probability that consumer k makes no purchase is

[48] The initial value of δj comes from δj = ln(Sj) − ln(S_o), where s_o is the share of the outside good. See Berry (1994) and Berry, Levinsohn, and Pakes (1995) for details.
[49] As Nevo (1998) noted, this weighting matrix yields efficient estimates under the assumption that errors are homoskedastic.
[50] The estimates of σ_1 and σ_2 are updated by the software program "*R*" using a minimization algorithm.

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

These probabilities are employed to simulate the market shares for suites, spreadsheets, word processors, and the outside good that correspond to our data, and to use these simulated market shares to form moment conditions. The calculations of simulated market shares for suites and the outside good are straightforward. Absent data of mix-and-match purchases, however, the relevant market share for spreadsheets and word processors must aggregate stand-alone purchases and mix-and-match purchases that are easy to simulate for a given parameter vector (σ_1, σ_2, β). Consider, for example, a particular vendor's word processor. Let product *j'* refer to the stand-alone word processor, and let *j"* and *j"'* refer to the two mix-and-match combinations that involve that word processor. Then the probability that consumer k purchases this vendor's word processor (separately from the suite) is $P_{j'k} + P_{j''k} + P_{j'''k}$. Making similar calculations for the word processors of other vendors, it is straightforward to calculate simulated market shares for the word processor category, and similarly for the spreadsheet category. Thus, the 15 consumer choices are mapped into 9 market shares. The validity of these calculations requires a large number of (simulated) consumers. The simulated market shares are a function of the mean utilities and are denoted $(\delta) = (s_1(\delta), \ldots, s_9(\delta))$.