Ain’t It ‘Suite’?
Bundling in the PC Office Software Market

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Take yourself back to the 90s
Take yourself back to the 90s

- What Office software did you use?
- Did you use a word processor?
  - Word? WordPerfect?
- Did you use a spreadsheet?
  - Excel? Lotus? Quattro-Pro?
- When did you buy your first suite?
  - Microsoft’s? WordPerfect’s?
Question

- When is bundling profitable?
- Does bundling raise or lower consumer surplus?
- When does product bundling discourage or accommodate competition from rival firms?
- Focus:
  - The effect of correlation of consumer preferences for spreadsheets & word processors on profitability and strategic interaction
What do we do/find?

- Estimate correlation in consumer preferences across spreadsheets and word processors using a discrete choice model
- Modeling + Econometric analysis are inputs. Use parameter values to conduct simulations/counterfactuals

Main estimation results:
- Positive correlation of consumer values for spreadsheets and word processors
- Bonus value for suites
- An advantage for Microsoft products.

Main simulations results:
- Greater correlation enhances the profitability of bundling
  - Market expansion and suite bonus effects
- The introduction of Microsoft’s Office increased consumer welfare
- Competitors may be better off under mixed bundling, relative to pure bundling
Evolution of the PC Office Software Market

- The 1990’s saw dramatic structural shifts in office software market
- Shift from DOS to Windows operating system.
- Shift in market leadership away from Lotus (in spreadsheets) and WordPerfect (in word processors) to Microsoft.
- Change in marketing strategy from selling components to suites.
- LM: for the period we analyze, most 'sales' of office software were direct to consumers rather than via OEM market.
The market grew steadily. Windows quickly replaced DOS.
Word Processor Market: 1991
Total Market $952 Million:
DOS $567 Million, WINDOWS (W) $385 Million

- Microsoft (DOS): 8%
- Other (DOS): 13%
- Microsoft (W): 15%
- IBM/Lotus (W): 8%
- Corel/Novell/Borland/WP (DOS): 39%
- Corel/Novell/Borland/WP (W): 9%
- Other (W): 8%
- Other (DOS): 13%
Figure 2: Spreadsheet Market: 1991
Total Market $809 Million:
DOS $239 Million, WINDOWS $569 Million

- IBM/Lotus (DOS) 58%
- Other (DOS) 2%
- Microsoft (W) 19%
- IBM/Lotus (W) 8%
- Corel/Novell/Borland/WP (DOS) 11%
- Other (W) 2%
- IBM/Lotus (DOS) 58%
Office suites became increasingly important.
Microsoft dominated the market for suites
Related Literature

- **Bundling**
  - **Theory:**
  - **Empirical:**
    - Crawford (2008), Discriminatory Incentives to Bundle in CATV
    - Crawford & Yurukoglu (2011), Welfare Effects of Bundling in Multi-channel TV Markets
      - Channels sold in large bundles, but not enough data to estimate individual channel demand. Channels

- **Computer software industry:**

- **Discrete choice models of product differentiation:**
Three basic products
- Word processors
- Spreadsheets
- Suites

Allow for mix-and-match combinations

Sample period 1992-1998
- Dataquest/Gartner Reports: Annual Revenue and shipments by product, vendor, and platform

Three Firms:
- MS
- Corel/WP
- Lotus/IBM
- After 1996, IBM/Lotus sold very few word processors, and Corel/WP sold very few word processors and spreadsheets

63 observations

**Data**

**Products characteristics**

Price and quantity:
- Dataquest/Gartner Reports

Quality (scale of 10)
- Liebowitz and Margolis: Indices constructed from product reviews
  - Rel qual spread = (j-lotus)/lotus
  - Rel qual word proc = (j-wp)/wp

**Microsoft**
- = 1 if MS word proc or spreadsheet
- = 2 if MS suite

**Product type dummies**
- \( k_{ss} \) = spread or suite
- \( k_{wp} \) = word processor or suite

**Suite dummy** - 0 for mix/match

**Year dummies**
YEARXX Dummy variable = 1 in year XX

**No network effects** – compatibility
Potential market for office software is defined to be the # of operating systems sold/distributed via OEMs.

<table>
<thead>
<tr>
<th>Year</th>
<th>(A) Windows OS sales</th>
<th>(B) Word processor sales</th>
<th>(C) Spreadsheet sales</th>
<th>(D) Suite sales</th>
<th>(B+C+D)/A Share of inside goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>11.056</td>
<td>4.650</td>
<td>3.442</td>
<td>0.578</td>
<td>0.784</td>
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<tr>
<td>1993</td>
<td>18.228</td>
<td>6.852</td>
<td>4.640</td>
<td>3.194</td>
<td>0.806</td>
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<td>1994</td>
<td>32.107</td>
<td>5.987</td>
<td>5.233</td>
<td>7.689</td>
<td>0.589</td>
</tr>
<tr>
<td>1995</td>
<td>54.352</td>
<td>4.693</td>
<td>3.876</td>
<td>12.982</td>
<td>0.397</td>
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<tr>
<td>1996</td>
<td>68.083</td>
<td>2.908</td>
<td>2.979</td>
<td>26.810</td>
<td>0.480</td>
</tr>
<tr>
<td>1997</td>
<td>78.406</td>
<td>4.186</td>
<td>2.972</td>
<td>32.977</td>
<td>0.512</td>
</tr>
<tr>
<td>1998</td>
<td>89.489</td>
<td>2.091</td>
<td>1.867</td>
<td>38.801</td>
<td>0.478</td>
</tr>
</tbody>
</table>
Discrete choice model

- Each consumer compares “products” across four categories
  - Spreadsheets
  - Wordprocessors
  - Suites
  - Mix-and-match bundles
- Unobservable taste for spreadsheets is correlated with unobservable taste for wordprocessor. (Bivariate-normal)
- Idiosyncratic preference for individual products. (Independent double exponential)
  - For suites, can be interpreted as an unobservable degree of product complementarity or additional components of suite
- Unobserved product characteristics
Econometric model

- Product utility: \( U_{jk} = \delta_j + \theta_{jk} \)

- (1) Mean utility:
  \[
  \delta_j = \beta_0 \times \text{PRICE}_j + \beta_1 \times \text{SS}_j + \beta_2 \times \text{WP}_j + \beta_3 \times \text{SUITE}_j + \\
  \beta_4 \times \text{YEAR94}_j + \beta_5 \times \text{YEAR95}_j + \beta_6 \times \text{YEAR96-98}_j + \\
  \beta_7 \times \text{SS}_j \times \text{RELQUAL_SS}_j + \beta_8 \times \text{WP}_j \times \text{RELQUAL_WP}_j + \\
  \beta_7 \times \text{MICROSOFT}_j + \beta_8 \times \text{MICROSOFT}_j \times \text{SUITE}_j \times \text{YEAR96-98}_j + \xi_j
  \]

- (2) Random utility: \( \theta_{jk} = \sigma_1 \times \text{SS}_j \times y_k + \sigma_2 \times \text{WP}_j \times y_k + \varepsilon_{jk} \)
  \[
  \varepsilon_{jk} \sim \text{i.i.d. double exponential}, \text{ which implies}
  \]

\[
P_{jk} = \frac{e^{\delta_j + \text{K}_{SS} \times \mu_{1k} + \text{K}_{WP} \times \mu_{2k}}}{1 + \sum_{l=1}^{15} e^{\delta_l + \text{K}_{SS} \times \mu_{1l} + \text{K}_{WP} \times \mu_{2l}}}
\]

\( j \) indexes the product; \( k \) indexes the consumer; time subscript is suppressed
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 (CWPSS) in consumer preferences between spreadsheet and arbitrary word processor is:

\[
\frac{\sigma_1 \times \sigma_2}{\left(\sigma_1^2 + 1.645\right)^{1/2} \times \left(\sigma_2^2 + 1.645\right)^{1/2}}
\]
Instrumental Variables

- Instrument for price. We have four IVs:
  - Relative quality of best rival product in the same category
  - Relative quality of best rival suite (for spreadsheets or word processors); best rival constituent product (for suites)
  - Relative quality of firm’s own other constituent product (for spreadsheets or word processors); relative quality of ‘best’ own constituent product (for suites)
  - Dummy Variable for Year 95-98 – Prices declined beginning in 1995 due to the exogenous technological change in OS to Windows95, which made it easier (cheaper) to produce office software
- Reasonably high correlation between IVs and price
Intuition for Identification: Linear Parameters

- Our data set contains sales and shipments by products and by year.
  - Variation across products and time

- Year dummies: Variation in the share of potential consumers who elect the outside good.

- Microsoft dummy: varies across products, but not over time. Variations of shares of Microsoft products relative to other products.

- Suite dummy: variation in market share of suites.

- Price & Quality: shifts in market shares of products over
Intuition for Identification: Non-Linear Parameters

- $\sigma$ - an increase in $\sigma$ increases the sales of the relevant class of products (spreadsheets and word processors).
- High $\sigma$ (say word processors): an increase in (say) WordPerfect’s price leads more consumers to substitute within the class, i.e., to another word processor.
- When $\sigma$ is low, more consumers will substitute away from that component, rather than purchase another product in the class when price rises.
## Empirical Results

OLS, Linear IV and Non-Linear Instrumental Variable Estimates

<table>
<thead>
<tr>
<th></th>
<th>Logit (OLS)</th>
<th>Logit (IV )</th>
<th>Random Coefficients Model (IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>SE</td>
<td>T-Statistic</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_2$</td>
<td>1.82</td>
<td>2.52</td>
<td>0.72</td>
</tr>
<tr>
<td>Price</td>
<td>-0.01</td>
<td>0.01</td>
<td>-1.57</td>
</tr>
<tr>
<td>YEAR94</td>
<td>-0.72</td>
<td>0.49</td>
<td>-1.46</td>
</tr>
<tr>
<td>YEAR95</td>
<td>-1.3</td>
<td>0.5</td>
<td>-2.58</td>
</tr>
<tr>
<td>YEAR96-98</td>
<td>-1.81</td>
<td>0.68</td>
<td>-2.66</td>
</tr>
<tr>
<td>MICROSOFT</td>
<td>1.31</td>
<td>0.37</td>
<td>3.52</td>
</tr>
<tr>
<td>SS</td>
<td>-1.27</td>
<td>2.12</td>
<td>-0.6</td>
</tr>
<tr>
<td>WP</td>
<td>0.12</td>
<td>4.28</td>
<td>0.03</td>
</tr>
<tr>
<td>SUITE</td>
<td>3.19</td>
<td>0.53</td>
<td>6.01</td>
</tr>
<tr>
<td>SS*RELQUAL_SS</td>
<td>-0.12</td>
<td>2.31</td>
<td>-0.05</td>
</tr>
<tr>
<td>WP*RELQUAL_WP</td>
<td>-1.64</td>
<td>4.12</td>
<td>-0.4</td>
</tr>
<tr>
<td>MICROSOFT<em>SUITE</em>YEAR96-98</td>
<td>1.66</td>
<td>1.09</td>
<td>1.52</td>
</tr>
<tr>
<td>63 observations</td>
<td>Adj. $R^2=0.31$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Empirical Results

- $\sigma_2 (1.82)$ is much than $\sigma_1 (0.87)$ : correlation = 0.46
  - Spreadsheet use during the 1990s was primarily for simple calculations; likely less variance in that value than in the variance of the value placed on word processors.

- Coefficients on the relative quality variables are positive for both product categories, but not significant.

- Coefficient on Microsoft dummy is positive but not significant
  - Microsoft benefited from better reputation, better service, additional components in the suite, better integration of components

- Coefficient on the variable SUITE is positive, although not statistically significant. Value of “suite bonus” is obtained by dividing the SUITE coefficient by the absolute value of the PRICE coefficient, i.e. approximately $23.4$
Elasticities – Logit Model

- Own and cross elasticities from the logit model are:

<table>
<thead>
<tr>
<th></th>
<th>MS Word</th>
<th>MS Excel</th>
<th>WP Word</th>
<th>Lotus SS</th>
<th>MS Suite</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS Word</td>
<td>-14.96</td>
<td>0.61</td>
<td>0.46</td>
<td>0.53</td>
<td>6.48</td>
</tr>
<tr>
<td>MS Excel</td>
<td>0.68</td>
<td>-16.96</td>
<td>0.46</td>
<td>0.53</td>
<td>6.48</td>
</tr>
<tr>
<td>WP Word</td>
<td>0.68</td>
<td>0.61</td>
<td>-12.18</td>
<td>0.53</td>
<td>6.48</td>
</tr>
<tr>
<td>Lotus SS</td>
<td>0.68</td>
<td>0.61</td>
<td>0.46</td>
<td>-16.68</td>
<td>6.48</td>
</tr>
<tr>
<td>MS Suite</td>
<td>0.68</td>
<td>0.61</td>
<td>0.46</td>
<td>0.53</td>
<td>-26.93</td>
</tr>
</tbody>
</table>

- 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.
### Elasticities – Random coefficients Model

- Own and cross elasticities from the random coefficient model are:

<table>
<thead>
<tr>
<th></th>
<th>MS Word</th>
<th>MS Excel</th>
<th>WP Word</th>
<th>Lotus SS</th>
<th>MS Suite</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS Word</td>
<td>-11.95</td>
<td>0.63</td>
<td>0.63</td>
<td>-0.60</td>
<td>0.63</td>
</tr>
<tr>
<td>MS Excel</td>
<td>0.58</td>
<td>-13.43</td>
<td>-0.42</td>
<td>0.58</td>
<td>0.58</td>
</tr>
<tr>
<td>WP Word</td>
<td>0.53</td>
<td>-0.70</td>
<td>-9.58</td>
<td>-0.39</td>
<td>0.53</td>
</tr>
<tr>
<td>Lotus SS</td>
<td>-0.31</td>
<td>0.43</td>
<td>-0.22</td>
<td>-10.18</td>
<td>0.43</td>
</tr>
<tr>
<td>MS Suite</td>
<td>5.10</td>
<td>5.10</td>
<td>5.10</td>
<td>5.10</td>
<td>-22.15</td>
</tr>
</tbody>
</table>
Simulations

- Conducted simulations for 1995 & 1998. Results presented are for 1995
- Marginal costs are 'backed' out of the first order conditions under the assumption that the firms are competing in prices and there is a Nash equilibrium.
- Marginal cost includes MC of marketing and of providing consumer support
- Estimated marginal costs for 1995:
  - MS Word - $97; MS Excel - $112; MS Suite - $226
  - WordPerfect word processor - $81
  - Lotus spreadsheet - $86.
- Suite Bonus:
  - MC of MS Suite exceeds the sum of the marginal costs for Word and Excel by $16.7
  - Given an estimated suite bonus of $23.4, the suite generated $6.7 social surplus
  - The suite presented a profit opportunity to Microsoft independently of any price discrimination benefit from bundling.
Simulations

- We wish to examine how correlation of preferences over word processors and spreadsheets affects profitability in oligopoly settings.
- One convenient way of varying correlation 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 $\mu_1$ and $\mu_2$ as follows: $\mu_1 = \sigma_1 Y_1$ and $\mu_2 = \sigma_2 \rho Y_1 + \sigma_2 (1 - \rho^2)^{1/2} Y_2$.
- Then $(\mu_{1k}, \mu_{2k}) \sim N(0, 0, \sigma_1, \sigma_2, \rho)$ is a bivariate normal distribution, where $\sigma_1$ and $\sigma_2$ are the standard deviations of $\mu_{1k}$ and $\mu_{2k}$ respectively and $\rho$ is the correlation coefficient of the bivariate normal distribution.
- In such a case, the random utility of the model is $\theta_{jk} = SS_j \mu_{jk} + WP_j \mu_{jk} + \varepsilon_{jk}$.
- Note that when $\rho=1$, this random utility reduces to equation (2).
- Correlation in preferences = $\rho^* (CWPSS)$
Simulations
Monopoly Market Structures
No Bonus for Mix-and-Match Combinations

- **Table 4**

<table>
<thead>
<tr>
<th>1995</th>
<th>( \rho = 1 )</th>
<th>( \rho = 0 )</th>
<th>( \rho = -1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Share</td>
<td>Profit</td>
</tr>
<tr>
<td>Office</td>
<td>247.9</td>
<td>0.23</td>
<td>5.1</td>
</tr>
<tr>
<td>Word</td>
<td>111.5</td>
<td>0.15</td>
<td>2.2</td>
</tr>
<tr>
<td>Excel</td>
<td>123.4</td>
<td>0.11</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>234.9</td>
<td>0.26</td>
<td>3.4</td>
</tr>
<tr>
<td>Word</td>
<td>115.9</td>
<td>0.05</td>
<td>0.9</td>
</tr>
<tr>
<td>Excel</td>
<td>127.9</td>
<td>0.04</td>
<td>0.6</td>
</tr>
<tr>
<td>Office</td>
<td>248.9</td>
<td>0.19</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>248.9</td>
<td>0.27</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Table 4: Monopoly Market Structures and Correlation

- Pure bundling: profits increase in \( \rho \).
  - Market expansion effect (JM 2006, “expanding niche market”)

- Separate Selling (no suite bonus for mix-and-match): Profits are independent of \( \rho \)

- Mixed bundling: profits increase in \( \rho \).
  - Interaction of the niche market and the suite bonus effects.
Simulations
Monopoly Market Structures – welfare effects

- For $\rho=1$
  - Separate selling—Excel + Word = $235$
  - Office price (under mixed or pure bundling) = $\approx$248
  - Suite bonus ($23.4) > $13 = $248-$235
  - Mixed bundling:
    - Net gain = $9.6$
    - Excel & Word prices are higher than in separate selling
      - Consumers are “encouraged” to buy the suite
      - Price penalty increases with $\rho$

- Welfare increases by more when $\rho=1$, despite higher prices
  - The higher $\rho$, the larger the share of consumers that buy the suite; the higher the share of consumers that enjoy the $9.6$ net gain the suite creates
  - $\rho =1$: 6.3% purchase both components separately when suites are not available; $\rho=-1$: 0.3%
Simulations
Oligopolistic Competition
No Bonus for Mix-and-Match Combinations

\[ \rho = 1: \text{MS sells mostly suites; 73\% of its profits come from suites; size of the component market falls by at least 50\%} \]

<table>
<thead>
<tr>
<th>1995</th>
<th>(\rho = 1)</th>
<th>(\rho = 0)</th>
<th>(\rho = -1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Share</td>
<td>Profit</td>
</tr>
<tr>
<td>Case I: Component competition, no suite bonus when purchasing both components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS Word</td>
<td>109.6</td>
<td>0.14</td>
<td>1.8</td>
</tr>
<tr>
<td>MS SS</td>
<td>123.1</td>
<td>0.10</td>
<td>1.1</td>
</tr>
<tr>
<td>WP Word</td>
<td>92.2</td>
<td>0.07</td>
<td>0.8</td>
</tr>
<tr>
<td>Lotus SS</td>
<td>96.2</td>
<td>0.06</td>
<td>0.6</td>
</tr>
<tr>
<td>Case II: MS sells suites and components; no suite bonus for mix-and-match</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS word</td>
<td>113.6</td>
<td>0.05</td>
<td>0.9</td>
</tr>
<tr>
<td>MS SS</td>
<td>126.5</td>
<td>0.04</td>
<td>0.6</td>
</tr>
<tr>
<td>MS suite</td>
<td>246.1</td>
<td>0.19</td>
<td>3.8</td>
</tr>
<tr>
<td>WP word</td>
<td>91.3</td>
<td>0.05</td>
<td>0.52</td>
</tr>
<tr>
<td>Lotus SS</td>
<td>95.9</td>
<td>0.04</td>
<td>0.38</td>
</tr>
<tr>
<td>Case III: MS sells only its suite; no suite bonus for mix-and-match</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS suite</td>
<td>245.2</td>
<td>0.23</td>
<td>9.96</td>
</tr>
<tr>
<td>WP word</td>
<td>91.2</td>
<td>0.05</td>
<td>0.51</td>
</tr>
<tr>
<td>Lotus SS</td>
<td>0.04</td>
<td>0.04</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Table 5: Oligopoly competition: Lotus and WordPerfect sell components
Suite increases welfare regardless of $\rho$

- $\rho=1$: **Net gain over components** $= $ $9.5$
- Prices under bundling are higher, but:
  1. With strong positive correlation, many consumers who purchase both components separately when suites are not available buy now the suite and enjoy the net gain of $9.5$
  2. More products are sold overall
- Combinations of both effects increases welfare

Competing firms may be better off under mixed bundling rather than pure bundling

- Under mixed bundling, consumers can mix-and-match Microsoft product with Lotus/WordPerfect product
- When correlation in consumers preferences is high, there is higher demand for consuming both products, and thus the mix-and-match effect dominates the ‘reduction in competition’ effect
Robustness Analysis

- In order to test for the robustness of our results, we run the simulations presented in Tables 4 and 5 based on 60,000 draws taken based on the estimated variance-covariance matrix.
- Given that our price coefficient is not significant, we get a positive price coefficient in about 10% of the draws. We drop these draws.
- We run the simulations on the remaining 90% of the draws; however, for some of these draws the program is unable to find the equilibrium cost estimate or equilibrium prices.
We then examine the robustness of our result that the introduction of the suite is pro-competitive regardless of the value of ρ. In all cases, welfare is higher with the introduction of the suite than it is in the case when the firms sell components only. This result holds regardless of whether σ1*σ2 is positive.

<table>
<thead>
<tr>
<th></th>
<th>σ1*σ2&gt;0</th>
<th></th>
<th>σ1*σ2&lt;0</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of simulation runs where</td>
<td>Pure Bundling</td>
<td>Mixed Bundling</td>
<td>Pure Bundling</td>
<td>Mixed Bundling</td>
</tr>
<tr>
<td>Welfare increases in correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopolistic Case</td>
<td>0.993</td>
<td>0.994</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Oligopolistic Case</td>
<td>0.990</td>
<td>0.996</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Welfare decreases in correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopolistic Case</td>
<td>--</td>
<td>--</td>
<td>0.97</td>
<td>0.95</td>
</tr>
<tr>
<td>Oligopolistic Case</td>
<td>--</td>
<td>--</td>
<td>0.91</td>
<td>0.9</td>
</tr>
<tr>
<td>Profits increase in correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopolistic Case</td>
<td>0.71</td>
<td>0.63</td>
<td>0.18</td>
<td>0.32</td>
</tr>
<tr>
<td>Oligopolistic Case</td>
<td>0.51</td>
<td>0.48</td>
<td>0.4</td>
<td>0.43</td>
</tr>
<tr>
<td>Profits decrease in correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopolistic Case</td>
<td>0.21</td>
<td>0.28</td>
<td>0.75</td>
<td>0.59</td>
</tr>
<tr>
<td>Oligopolistic Case</td>
<td>0.4</td>
<td>0.41</td>
<td>0.44</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 7: Share of simulation runs
We then examined the relationship between the ‘mix-and-match effect’ and the ‘reduction in competition’ effect. The table below presents the share of cases where Lotus’ spreadsheet (WordPerfect’s) profits were higher under mixed bundling than under pure bundling.

<table>
<thead>
<tr>
<th>Share of simulation runs where $\rho=1$</th>
<th>$\rho=0$</th>
<th>$\rho=-1$</th>
<th>$\rho=1$</th>
<th>$\rho=0$</th>
<th>$\rho=-1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher profits under mixed bundling</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>WordPerfect word processor</td>
<td>0.89</td>
<td>0.75</td>
<td>0.65</td>
<td>0.58</td>
<td>0.68</td>
</tr>
<tr>
<td>Lotus spreadsheet</td>
<td>0.69</td>
<td>0.5</td>
<td>0.39</td>
<td>0.39</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Conclusion

- Consumer demands for word processors and spreadsheets are positively correlated
- Johnson & Myatt’s (2006):
  - Niche-market expansion effect: Higher correlation implies increased variance of preferences for suite – and raises profits for pure bundling
- We find that this effect holds not only in ‘niche’ markets
- In the case of mixed bundling, profits increase in correlation because of the interaction of the suite bonus with the market expansion effect
- Changes in correlation affect strategic interaction significantly
- A merger between Lotus and WordPerfect would have been profitable for the merging firms and welfare increasing
158,865 individuals from the 2001 CPS Supplement. The CPS uses weights to produce basic demographic and labor force estimates.

In the case of home (office) use, 61% (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 & complementarity.
The dependent variable is USE, where USE=(2 if the answer to both questions is yes, 1 if the answer to one of the questions is yes and 0 if the answer to both questions is no).

Independent variables are

INCOME - takes on whole numbers between 1-14 that correspond to ranges of yearly family income. For example, 1=less than $5000, 7=$20,000-$24,999, and 14=$75000 or more.

EDUCATION - 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 – 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 – takes on the value one if the individual is in school and zero otherwise.

INTERNET – takes on the value one if the household has Internet service and zero otherwise.

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Home Use</th>
<th>Office Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-Statistic</td>
</tr>
<tr>
<td>Constant</td>
<td>0.08</td>
<td>25.33</td>
</tr>
<tr>
<td>INCOME</td>
<td>0.0043</td>
<td>16.84</td>
</tr>
<tr>
<td>EDUCATION</td>
<td>0.013</td>
<td>160.42</td>
</tr>
<tr>
<td>COMPUTERS</td>
<td>0.18</td>
<td>148.98</td>
</tr>
<tr>
<td>SCHOOL</td>
<td>0.037</td>
<td>22.69</td>
</tr>
<tr>
<td>INTERNET</td>
<td>-0.16</td>
<td>-89.16</td>
</tr>
<tr>
<td>Number of Obs.</td>
<td>158,865</td>
<td>158,865</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.33</td>
<td>0.20</td>
</tr>
</tbody>
</table>
## Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>price</td>
<td>120.48</td>
<td>80.09</td>
<td>20</td>
<td>350</td>
</tr>
<tr>
<td>y94</td>
<td>.1429</td>
<td>.3527</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>y95</td>
<td>.1429</td>
<td>.3527</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>y96</td>
<td>.1429</td>
<td>.3527</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>microsoft2</td>
<td>.4444</td>
<td>.6904</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>k_SS</td>
<td>.6667</td>
<td>.4752</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>K_WP</td>
<td>.6667</td>
<td>.4752</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>suite</td>
<td>.3333</td>
<td>.4752</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>k_SS*rel qual</td>
<td>.6975</td>
<td>.5117</td>
<td>0</td>
<td>1.35</td>
</tr>
<tr>
<td>k_WP*rel qual</td>
<td>.6865</td>
<td>.4925</td>
<td>0</td>
<td>1.22</td>
</tr>
<tr>
<td>sales000</td>
<td>3436</td>
<td>5964</td>
<td>46</td>
<td>3268</td>
</tr>
</tbody>
</table>
The Bivariate Normal Distribution

Positive correlation

Negative correlation

This is Section 4.7 of the 1st edition (2002) of the book Introduction to Probability, by D. P. Bertsekas and J. N. Tsitsiklis. The material in this section was not included in the 2nd edition (2008).
Word Processor Prices

- P-MS-Wproc
- P-LOT-Wproc
- P-WP-Wproc
Significant suite discount after 1995

Figure 8: Microsoft Prices

Year

$
**Estimation Algorithm**

- **Step 1**: Take random draws of \((Y_{1k}, Y_{2k})\) for 100,000 consumers per year. Each consumer makes a single choice.
- **Step 2**: Assume initial values for \(\sigma_1^2, \sigma_2^2, \rho\) and find \(\delta\) using the following contraction mapping until convergence obtained
  \[
  \delta_{j,\text{new}} = \delta_{j,\text{old}} + \ln(\text{actual market shares}) - \ln(\text{simulated market shares})
  \]
- **Step 3**: Run the GMM regression \(\hat{\delta} = X\hat{\beta} + \xi\). 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 the weighting matrix \(W=(Z'Z)^{-1}\)
- **Step 4**: Compute the implied values of the unobservables \(\hat{\xi} = \hat{\delta} - X\hat{\beta}\) and evaluate GMM objective function \(\hat{\xi}'ZWZ'\hat{\xi}\)
- **Step 5**: Update the values of \(\sigma_1^2, \sigma_2^2, \rho\) & return to step 2.