

# Why Are PCs Still Manufactured in the United States?<sup>12</sup>

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In recent years, electronics manufacturing for the U.S. market has moved off shore dramatically. Import penetration for finished electronics rose from 30 percent in 1990 to 64 percent in 2006, far more than for manufactured goods overall. Spurred by trade liberalization, falling shipping costs, and easier communication, companies serving U.S. customers have increased their reliance on foreign assembly hubs, design centers, and parts suppliers, especially the deep base on the far side of the Pacific Rim. In one popular narrative, the pull is inexorable, and U.S. electronics manufacturing is destined to disappear. The evidence presented here suggests the story is more complicated.

At first glance, the personal computer (PC) appears well suited to offshore assembly. The PC is a high-volume product built from standardized parts readily available near Asian re-export zones. Yet according to the author's estimates, from 1994 to 2007 *more than half* of the PCs purchased in the U.S. market were shipped from domestic establishments. This remained true even after the supply chain upheaval that began in the 1990s.

What drives companies to produce in the United States? To answer this question, the author constructed detailed information on the domestic production of PCs shipped to the US market, by company and platform, using responses to U.S. Census Bureau surveys on production, private market data on sales, and company public statements. Tying the variation in domestic intensity to company characteristics sheds light on the factors keeping production near the market. Product mix and sales channel approach play important roles.

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<sup>1</sup> Preliminary and incomplete. Please do not quote without permission. Assistance from Keith McKenzie and Shawn Klimek in acquiring and interpreting the Census data is gratefully acknowledged. Remaining errors are the author's alone.

<sup>2</sup> The research in this paper was conducted while the author was a Special Sworn Status researcher of the U.S. Census Bureau at the Census Bureau Census Research Data Center. Research results and conclusions expressed are those of the author and do not necessarily reflect the views of the Census Bureau. This paper has been screened to ensure that no confidential data are revealed.

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## 1. Overview

In recent decades, electronics manufacturing for the U.S. market has moved off shore dramatically: import penetration in the U.S. market for finished electronics rose from 30 percent in 1990 to 64 percent in 2006, far exceeding the increase for manufactured goods overall. (figure 1a) Spurred by trade liberalization, falling shipping costs, and easier communication, electronics companies serving U.S. customers have increased their reliance on manufacturing abroad through foreign direct investment and contract manufacturing. The most intense effort has been directed toward further exploiting the deep base of inexpensive low-skilled labor, parts suppliers, contract manufacturers and sophisticated design houses on the far side of the Pacific Rim.

Against the backdrop of this seismic shift there is tremendous variation across products. Despite their underlying technical similarities, classes of electronic goods differ markedly in import penetration. (figure 1b) Companies serving the U.S. market for computers and peripherals already relied heavily on offshore production in the 1990s, and imports soared beginning in 2000. For 2006, penetration for computers is second only to consumer electronics, for which domestic production had all but evaporated. In contrast, for other electronics, such as communications equipment, electromedical devices, and industrial electronics, U.S. factories still accounted for over half of the value of production for the U.S. market.

Clearly, careful attention to product detail is critical to understanding global manufacturing patterns. This paper focuses on personal computers (PCs), a bellwether product for the computer industry.<sup>4</sup> Import penetration for PCs is relatively low: The author's estimates are that import penetration was only 37 percent as recently as 2003, the last year for which public data are available.<sup>5</sup> (figure 2) The effect on PC production of the increase in broad computer imports looks surprisingly muted. Evidently, offshore production of electronics is not a foregone conclusion, even for high-volume products.

This paper is an exploratory look at the apparent attraction of domestic production for PCs. A systematic effort is made to use government data, private market

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<sup>4</sup> The computers and peripherals industry (NAICS 3341), shown in figure 1b, is not narrow enough for this analysis. That is, it obscures substantial underlying variation. Import penetration for the peripherals industry (NAICS 334119) and for the storage device industry (NAICS 334112) is far higher than for the narrow computers industry (NAICS 334111). Furthermore, even within the narrow computers industry, import penetration varies markedly by product, being relatively low for servers, moderate for desktops, and high for laptops.

<sup>5</sup> Import penetration calculated as  $1 - (\text{CIR} + \text{WB}) / \text{IDC}$ , where CIR is production reported in the Census Current Industrial Report, WB is small system builder (white box) U.S. sales reported by IDC, and IDC is total U.S. sales. (White boxes, not covered in the CIR, are assumed to be domestic production.) Production data are suppressed in public releases by the Census Bureau starting in 2004 and 2005 respectively for desktops and laptops. Prior to 1997, laptops and desktops were obscured within broader product classes.

data, and company public statements to construct a new measure of the domestic intensity of production by company. Correlation between company characteristics and domestic intensity is then used to consider alternate explanations for location choices. This work complements existing studies based primarily on public information and detailed interviews.<sup>6</sup>

## **2. The Role of Offshore Production**

The PC is designed to exploit the Pacific Rim network of electronic component suppliers. PC companies design systems to use standard parts, which may be sourced from anywhere in the global network, and assemble, configure and test them.<sup>7</sup> (Langlois, 1992) The location of final assembly and shipment, often far from component production, determines the level of import penetration.<sup>8</sup> This global approach has been in place since the outset of high volume production, when IBM exploited the existing supplier network with the first mass-market PC in 1981. (Dedrick and Kraemer, 1998) However, international integration has increased over time, driven by a shift toward a free market orientation in many emerging markets, by easier communication, and by lower transport costs. A wave of trade liberalization driving tariffs down to negligible levels has included most notably the ratification of NAFTA (1994) and the accession of China (2001) to the WTO; U.S. imports surged following these events. (figure 3) International communications costs, on a long downward trend, fell precipitously after massive investment in submarine cables in the late 1990s; and within emerging market locations, the spread of cellular phone networks has made communication far easier. (figure 4) Shipping costs have also come down: Hummels (2007) calculates that quality-adjusted ad valorem prices for trans-Pacific ocean shipping fell from more than 8 percent in the early 1980s to less than 6 percent in 2004. (figure 5).

In response to these falling trade barriers, companies serving the U.S. market have become more footloose, shifting operations abroad to exploit differences in wages, which are substantial. (figure 6) However, the outcome has been far from uniform. Dell

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<sup>6</sup> See especially the body of work produced by Dedrick, Kraemer, and coauthors at Center for Research on Information Technology and Organizations, e.g. Dedrick and Kraemer (1998, 2006, 2007). Also see Angel and Engstrom (1995), Bresnahan and Greenstein (1999), Curry and Kenney (1999).

<sup>7</sup> "Dell's manufacturing process consists of assembly, software installation, functional testing, and quality control. Testing and quality control processes are also applied to components, parts, and subassemblies obtained from third-party suppliers. Quality control is maintained through the testing of components, subassemblies, and systems at various stages in the manufacturing process. Quality control also includes a burn-in period for completed units after assembly, on-going production reliability audits, failure tracking for early identification of production and component problems, and information from Dell's customers obtained through services and support programs." (Dell Annual Report, 2007)

<sup>8</sup> The location of production for components, which embody a substantial share of the value added of PCs, is outside the scope of this paper.

has been relatively slow to move away from domestic production, while Hewlett-Packard, Dell's biggest rival in the U.S. market, has moved off shore more rapidly. (See Appendix A.) This research provides possible explanations for the cross-sectional variation in strategy.

### **3. Factors Affecting Location Decisions**

Companies consider labor, inventory, transportation and coordination costs as they strive to meet consumer demands for the latest technical features, short delivery time, and price. Not surprisingly given the diversity of consumer tastes, companies have situated themselves at different locations in product characteristics space and adopted different business models to manage costs.

Perhaps the most notable distinction among companies is the degree of reliance on direct sales channels, which do not require retail or dealer inventory. Dell and Gateway used a direct sales approach with substantial success in the 1990s and other vendors, such as HP, IBM (later Lenovo), and Apple have increased their reliance on direct sales since then. (figure 7) Direct sales are frequently coupled with a build-to-order approach, which postpones final assembly until the order is in hand. To keep delivery time short, there is a strong incentive to manufacture the PC near the customer. (Curry and Kenney, 1999) In contrast, for retail and other indirect channels, the build-to-forecast approach is more common. Since the product is already in inventory, manufacturing the machine abroad does not entail a delay from the customer's point of view.

However, producers must also consider the extraordinary carrying cost of inventory in this industry.<sup>9</sup> Given the rapid pace of new model introduction, PCs depreciate very rapidly, and the 3-4 week shipping time from Asia may be very costly.<sup>10</sup> At a minimum, producers may wish to wait until the last minute to add the most technically dynamic components, such as the microprocessor. The microprocessor and other logic components account for a substantial share of the difference between

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<sup>9</sup> Many Dell annual financial reports contain a variant of this statement: "The Company's build-to-order manufacturing process is designed to allow the Company to quickly produce customized computer systems and to achieve rapid inventory turnover and reduced inventory levels, which lessens the Company's exposure to the risk of declining inventory values. This flexible manufacturing process also allows the Company to quickly incorporate new technologies or components into its product offerings."

<sup>10</sup> On PC depreciation, see Doms, Dunn, Oliner and Sichel (2004)

premium and basic machines. (table 8) Consequently, higher priced machines are more susceptible to this risk.<sup>11</sup>

Other factors may come into play in the location decision as well:

- (1) Companies focused on large U.S. business and government customers may prefer U.S. manufacturing establishments to deliver large custom orders relatively quickly.<sup>12</sup> Such customers may also wish to monitor supplier operations for critical IT infrastructure. Exposure to the business market varies noticeably across companies. (figure 9)
- (2) Companies may require a certain expected volume of U.S. sales to justify the fixed cost of setting up production in the United States. Entrants may ship from overseas factories until they are established in the market. (The availability of contract manufacturing may mitigate this problem.)
- (3) Companies headquartered in the United States may prefer domestic production, other things equal. Coordinating operations over long distances entails costs, despite the wave of improvements in communication.
- (4) More innovative companies may prefer to produce in the United States. Among the benefits are proximity to innovation clusters and the strong intellectual property protection in the U.S. legal code. However, this is a smaller concern for PCs than for other high tech products, such as semiconductors. PC producers typically spend very little on R&D, with the exception of the more diversified companies such as IBM and HP.
- (5) Incentives offered by local governments matter for location as well, such as tax breaks and infrastructure investment, and differences in regulatory environment. To the degree that ability to exploit these advantages differs across companies, it may explain differences in outcomes.

#### **4. Construction of Domestic Production Intensity by Company**

The key variable in this study is the share of U.S. PC sales shipped from U.S. establishments, referred to in this paper as “domestic intensity.” Because companies do not release this information to the general public, domestic production by company was obtained from the U.S. Census Bureau Current Industrial Reports (CIR). Combining these figures with U.S. PC sales by company from the PC Tracker database published

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<sup>11</sup> In addition to the downward trend in prices, holding inventory is also undesirable because components, particularly memory chips, are prone to wild fluctuations in price. Furthermore, consumer tastes can be unstable.

<sup>12</sup> Dell's *Custom Factory Integration* program is an example.

by IDC Corp. yielded a ratio of production to sales by company and platform for each year from 1994 to 2007.<sup>13</sup>

These raw figures were checked against company public statements, S.E.C. filings, and press reports, and judgmental adjustments were made in some cases.

Most notably, PCs produced domestically by electronics manufacturing services (EMS) firms were allocated to their major customers based on company public statements and other research.<sup>14</sup> EMS companies are an integral part of production for many major vendors. IBM and HP pioneered this approach in the 1990s, selling off plants, which then continued to produce under contract for some time, often with the same management. (Several examples are discussed in Appendix B.)

Only companies accounting for at least 1 percent of U.S. sales were used in the analysis. The scope of the Census CIR survey does not permit consideration of smaller firms, which play an important role—small volume companies, known as “white box” producers, account for perhaps 30 percent of US sales, according to major research consultancies.<sup>15</sup> Excluding their output raises import penetration appreciably. (figure 2b)<sup>16</sup>

Examination of the detailed company-platform series reveals several regularities.<sup>17</sup> First, most companies adopt a strategy of mostly domestic or mostly offshore production. In all but a few cases, domestic intensity is either below 25 percent or above 75 percent. (table 10) Second, changes to domestic intensity were widespread during the period studied. Among companies with domestic intensity above 50 percent for the 1994-1999 period, 46 percent switched to a domestic intensity below 50 percent for the 2002-2007 period. (table 11) The detailed data reveal that most of the notable changes in domestic share occurred rapidly between 1999 and 2002: Domestic intensities were remarkably stable prior to this period, and have been fairly stable since then. Third, exit from the market is significant. Among companies with a high domestic intensity for a platform in the earlier period, 23 percent no longer had a significant share of the US market in the later period. For companies beginning with a low domestic intensity, the exit rate is far higher at 58 percent.

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<sup>13</sup> For 1994 to 1996, desktop PCs and laptops were estimated from broader categories using company-specific splits available from the 1997 survey, when these platforms were first identified in the CIR product structure.

<sup>14</sup> The research produced by Jeffrey Wu of iSuppli is particularly informative on this subject.

<sup>15</sup> Using somewhat different methodologies, IDC and Gartner arrive at similar figures.

<sup>16</sup> Because white box producers tend to focus on specific local markets, their location choices are governed by quite different concerns than major vendors serving the national market, so they are considered in a separate analysis.

<sup>17</sup> To avoid revealing survey responses by individual companies, only summary statistics are shown. The tables show company observations divided into coarse cells, but regressions are run with the detailed, continuous data.

## 5. Empirical Results

The data were aggregated to two periods—1994 to 1999 and 2002 to 2007. The intervening period was not used because the unstable domestic intensity for many companies in this period is in a transition to a new level and transition dynamics are not the focus of this study. As noted earlier, variation within each of the periods used is relatively small.

To accommodate the clustering of domestic intensity near one and zero, a Tobit model was used with both upper and lower censoring.<sup>18</sup> The index of explanatory variables includes direct sales share, PC selling price relative to the year-specific market average, the log of U.S. unit sales, business market share, a U.S. headquarters dummy, and platform and time period dummy variables. Descriptive statistics are shown in table 12.<sup>19</sup> Coefficient estimates are shown in table 13 and the predicted effects of varying company characteristics are shown in table 14.

Direct sales appear to play a critical role in domestic intensity. The regression results suggest a firm with twice the typical emphasis on direct sales would typically have a domestic intensity 33 percentage points higher. Consequently, increasing prevalence of direct sales appears to be closely tied to keeping production in the United States.

Companies selling higher-priced PCs also tend to locate more of their production in the United States. A company whose PC average selling price is one standard deviation higher than the market average is expected to have a domestic intensity 26 percentage points higher.

Firms with higher U.S. sales tend to satisfy a greater share of those sales with domestic production. For a company with typical characteristics, increasing unit sales volume from 1 million a year to 5 million is expected to raise domestic intensity by 35 percentage points. This is consistent with the idea that as companies achieve a certain scale, it becomes optimal to set up shop in the market.

Controlling for the other factors in the model, U.S. headquarters does not increase the domestic intensity among the companies studied. However, without controlling for other characteristics, U.S. headquarters *is* correlated with domestic

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<sup>18</sup> Values were censored at 5% and 95% to avoid disclosing information about individual companies and to accommodate the inherent noisiness of the data. That is, the likelihood contribution of an observation with a domestic intensity of 99% should not differ markedly from an observation with 100%.

<sup>19</sup> To protect the confidentiality of survey responses for specific companies, order statistics are not shown.

intensity, suggesting that U.S. companies tend to have more of the characteristics that encourage domestic production. The share of a company's sales going to business customers also does not appear to play an important role in the location decision.

Surprisingly, controlling for other company characteristics, these data indicate laptop production is more likely to be domestic than desktop production, despite the raw numbers in table 12.<sup>20</sup> Offsetting factors are the lower size of the average laptop producer and the lower emphasis on direct sales in the laptop market. This result is admittedly difficult to swallow. Since the overwhelming perception among the author's industry contacts and other analysts is that, other things equal, companies prefer to have original design manufacturers in Taiwan handle their shipments, this may be an area where data construction or model specification need additional attention. Also, it may be that this trend did not take hold in earnest until late in the period studied.

Finally, once one controls for all of the company characteristics considered, the 2002-2007 period is characterized by a substantially lower overall propensity to locate production in the United States for shipments to the U.S. market. For a fairly typical firm, other things equal, domestic intensity of desktop production is predicted to be 39 percentage points lower in the later period. In other words, holding composition constant for major companies at 1994-1999 levels, import penetration would be substantially higher than seen in the raw data.

Because sales model and product mix are endogenous, these preliminary results are simply a suggestion that those choices and the location choice are closely related. Identifying the parameters of the underlying choice problem is left for more ambitious research.

## **6. Conclusion**

In recent years, falling barriers to trade have had highly varied effects on manufacturing in the electronics sector. Differences in product features and company business models are critical to a full understanding of these trends. As demonstrated here, the micro-data underlying government surveys, in combination with private sector data, can play an important role in uncovering these relationships.

In short, at first glance, PC production appears to be relatively unresponsive to the pull of increasingly global manufacturing. However, once one controls for the

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<sup>20</sup> The "laptops" category in this study also includes machines referred to as "notebooks," "portables," "tablet PCs," and "netbooks," but not "smart phones" or "PDAs."



features of the companies making the location decisions, the increasing attraction of offshore production becomes much more apparent. The composition of major companies with respect to several features explains the persistence of domestic production among PC companies in the U.S. market. First, greater concentration of sales in large-scale companies plays a role, which have a higher tendency to use domestic assembly, in the recent period. Second, a higher emphasis on the direct sales model is important, which is closely tied to a build-to-order approach to assembly and therefore domestic production. Finally, white box companies, which rely on domestic production, boost the overall domestic intensity measure.

Nevertheless, the tenacity of PC manufacturing in the United States is striking given labor cost differences. It is important to keep in mind that assembly and configuration actually forms a relatively small share of the cost of production for PC producers, typically less than 5 percent. (figure 8) Concerns about component inventory carrying costs and time from order to delivery may dominate labor costs. Because a high-end machine will lose its leading edge status within 3-6 months after introduction, the 3-4 week shipping time between Shanghai and Los Angeles makes a huge difference.

What do the estimates imply about domestic intensity in the near future? Several recent trends may lead to changes in the domestic intensity of production. First, if the recent downward trend in direct sales, driven by a change in Dell strategy, continues, domestic intensity may fall. (figure 7) Second, at first glance, the results suggest the ongoing shift toward laptops portends an *increase* in domestic production, but as noted above, this result is very tentative pending additional investigation. Third, if the market share of premium machines declines – one can always find stories lamenting the lack of “killer applications” and PCs becoming a commodity—the share of “bleeding edge” components in the price of machines will fall, and firms may be more inclined to shift production abroad.

What of the factors that have shifted to support globalization? First, while no reversal of the massive liberalization of trade that characterized the 1990s and 2000s seems to be on the horizon, the impetus to offshoring of PC production from these changes is not unbounded and may have played out. Second, a similar dynamic may be in train for communications now that international voice and email communication is nearly costless and communication within offshore locations has vastly improved; however, the effect of advances in videoconferencing on corporate management remain

to be seen. Third, transportation costs seem due for some reversal of their downward trend—higher oil prices imply higher transport costs.<sup>21</sup>

The bottom line is that location decisions, even for assembly of high-volume products, are not well characterized as simply a response to the inexorable pull of low-wage offshore assembly labor. Many other factors come into play.

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<sup>21</sup> Hummel (2007) estimates an elasticity of ocean shipping costs with respect to fuel costs of 0.23; if bunker fuel prices move in tandem with West Texas Intermediate crude oil, which as of 2008 had gone up 150% since 2004, Hummel's model suggests ad valorem shipping costs at levels comparable to the late 1970s.

## Appendix A. Contrasting Dell and HP business models.

Dell and Hewlett-Packard have battled for leadership in the U.S. PC market in recent years, and have taken somewhat different approaches to manufacturing. Dell has focused more narrowly on PCs and tended to keep production in house and close to the market. HP produces a much broader array of products, the company has outsourced manufacturing much more aggressively, and HP appears to have a smaller U.S. PC production footprint. Sketches of the business models are presented here for illustration of the variation in strategies across major players.<sup>22</sup>

### Dell

Over the period studied in this paper, Dell went from a regional to a global manufacturing company. Core manufacturing operations through the early 1990s were in Austin, Texas. Expansion abroad began with Limerick, Ireland in 1993, followed by Penang, Malaysia (1995), Eldorado do Sul, Brazil (1999), and Xiamen, China (1998). Also, new operations in Tennessee began in 1999 (Nashville and Lebanon), and Austin was expanded in 1997. Another wave of overseas operations started in the mid-2000s with a second Xiamen plant (2007), Chennai, India (2007) and Lodz, Poland (2007). Brazilian operations moved to Hortlandia in 2007. U.S. operations expanded with a new plant in Winston-Salem, North Carolina in 2005 and the acquisition of Alienware (Miami, Florida) in 2007. Recent restructuring has including shuttering the Austin and Limerick operations.

Nevertheless, operations overseas have primarily served the needs of expanding sales into new regions, rather than offshoring production for the U.S. market. Dell's 2008 Annual Report states, "In general, our Americas, EMEA, and APJ regions use properties within their geographies," and reports in other years contain statements along those lines.

With regard to outsourcing of manufacturing, Dell has been among the more cautious PC companies. The company's 1994 Annual Report states "the Company manufactures **all** of its desktop and server personal computer systems at its Austin, Texas and Limerick, Ireland manufacturing facilities." Later reports soften this

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<sup>22</sup> All of the information presented here is available in company public statements and reports from consultancies. No alignment of this information with any private company data in Census CIR surveys is implied. In fact, even whether the companies did or did not receive or respond to the CIR surveys is confidential.

statement: From 2002 to 2006 Annual Reports state, "we manufacture **most** of the products we sell," and the 2007 and 2008 Annual Reports state, "we manufacture **many** of the products we sell."

That said, contract manufacturing of subassemblies for laptops has been a key feature of the business model since at least 1993, when the Annual Report states, "The Company contracts with other companies to manufacture unconfigured base notebook personal computers which the Company configures for shipment to customers." Recently, the company appears to have moved toward handing even further control over to contract manufacturers, stating in 2006, "... third-party original equipment manufacturers that build some of our products to our specifications. In addition, we are continuing to expand our use of original design manufacturing partnerships and manufacturing outsourcing relationships ..." Indeed, according to iSuppli, in 2008 essentially all Dell laptops were manufactured by the major Original Design Manufacturers (Quanta, Compal, Wistron, Inventec). Furthermore, iSuppli indicates that these ODM companies have no significant U.S. laptop manufacturing presence. Consequently, if Dell has handed final configuration to ODMs, formerly performed at U.S. facilities, the domestic intensity of Dell laptop production has fallen appreciably.

### Hewlett-Packard

In contrast to Dell, HP operations were already spread around the world by the beginning of the period studied here, and the company produces a broad range of products, not just PCs or even primarily PCs. Since their reports do not detail location of operations by product, and the company downplays any local specialization, it's difficult to know where they were producing PCs from public statements.<sup>23</sup> (A key advantage of the dataset used for this study is access to this missing information.)

However, it is known that beginning in the mid 1990s, a wave of divestitures of manufacturing facilities at HP and IBM spawned the large-scale EMS industry. These facilities typically produced for HP under contract for a period of time afterward. SCL, Celestica, Sanmina handled HP contracts in the late 1990s and Foxconn has produced for Compaq, and subsequently HP, since 2001. Unfortunately, nailing down the magnitude of these EMS operations is not straightforward.

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<sup>23</sup> HP Annual Reports typically contain this statement: "Because of the interrelation of these five segments, substantially all of the properties are used at least in part by each of these segments, and we retain the flexibility to use each of the properties in whole or in part for each of the segments."

HP has also relied for some time on ODMs for its laptops. In 2001 Annual Report, HP states, "In addition, we have engaged manufacturers in Taiwan for the production of notebook computers." According to iSuppli, like Dell, as of 2008, HP outsourced essentially all of their laptop operations to ODMs, which do not have significant operations in the United States.

It is also worth noting that HP relies more on the indirect sales channel than Dell, which has implications for production location choice. The company notes in the 2007 Annual Report, "We utilize two primary methods of fulfilling demand for products: building products to order ("BTO") and configuring products to order ("CTO"). BTO capabilities are employed to maximize manufacturing efficiencies by producing high volumes of basic product configurations. CTO permits configuration of units to the particular hardware and software customization requirements of certain customers. Both BTO and CTO are designed to generate cost efficiencies relating to just-in-time manufacturing, inventory management and distribution practices. Just-in-time manufacturing reduces inventory by manufacturing or taking delivery of the inventory from third-party suppliers immediately prior to the sale or distribution of products to our customers."

## Appendix B. Notes on Electronics Manufacturing Services (EMS) and Original Design Manufacturer (ODM) Production

Contract manufacturers perform stages of the manufacturing process for Original Equipment Manufacturers (OEMs) who are the residual claimant for the product, in the sense that their reputation is on the line, not the contractor's. (figure 13) EMS and ODM companies differ in their business model, with ODMs typically taking responsibility for a wider range of activities, particularly design. ODMs are most commonly contracted for laptop production and EMS companies for desktop production. The major ODMs (currently Wistron, Compal, Inventec, Quanta) have historically been based in Taiwan and play little role in domestic manufacturing in the United States. EMS companies, however, many of whom were started from establishments sold off by IBM and HP, have an extensive U.S. footprint and complicated histories of domestic contract assembly for major OEMs. These notes reflect a distillation of the somewhat patchy set of information found in corporate reports, news stories, and other research.

### Foxconn (aka Hon Hai, Q-Edge)

It seems to be an open secret that HP's major outsourced PC assembly operations for the US market are the Foxconn facility in Plainfield, IN, down the street from a major FedEx terminal, in operation since 2003, and prior to that from 2000-2001 (for Compaq). Strong historical ties to Apple suggest they may be doing some domestic work for Apple PC assembly as well.

### Celestica

The company was clearly involved in US PC manufacturing for HP and IBM in the late 1990s. There has likely been little involvement in PC manufacturing since then. Financial reports show PCs as a share of company revenues dwindled to 5% by 2001, and the descriptions for their North American plants made little mention of computers in 2009.

### Flextronics

Financial reports state company assembled desktop PCs and servers for Dell from 2003 to 2008, but does not specify where. Given Dell's clear statements up until 2007 that they were producing machines for the US market in their own plants in Tennessee and

North Carolina, it seems likely the Flextronics assembly was not taking place in the United States at the time. However, more recently, Dell has been moving toward outsourcing, and some more recent Flextronics production may be in the US for Dell. Note also assembly for Tandem in 1996.

#### Jabil

Longstanding relationship with HP definitely involved PC production in the mid-1990s. However, the location of this production is unclear, as is how long it lasted. The nature of the work for Dell mentioned in company reports is also unknown.

#### Sanmina

Substantial work for IBM beginning in 2002. Perhaps also HP and Dell, but product lines are unclear. More recently, it appears PC production to serve the US market takes place in Apodaca, Mexico.

#### SCI

Definitely doing work for HP (especially), and Compaq, Dell and Apple in the 1990s. Contracts clearly persisted after 2001 acquisition by Sanmina.

#### Benchmark Electronics

Company clearly indicates computer assembly as part of operations in Oregon and Alabama and that large share of business is computers broadly. However, the large customers noted (Sun and EMC) are not in the PC business and the focus of the US locations is evidently on higher value products. Best guess is any PC assembly is insignificant.

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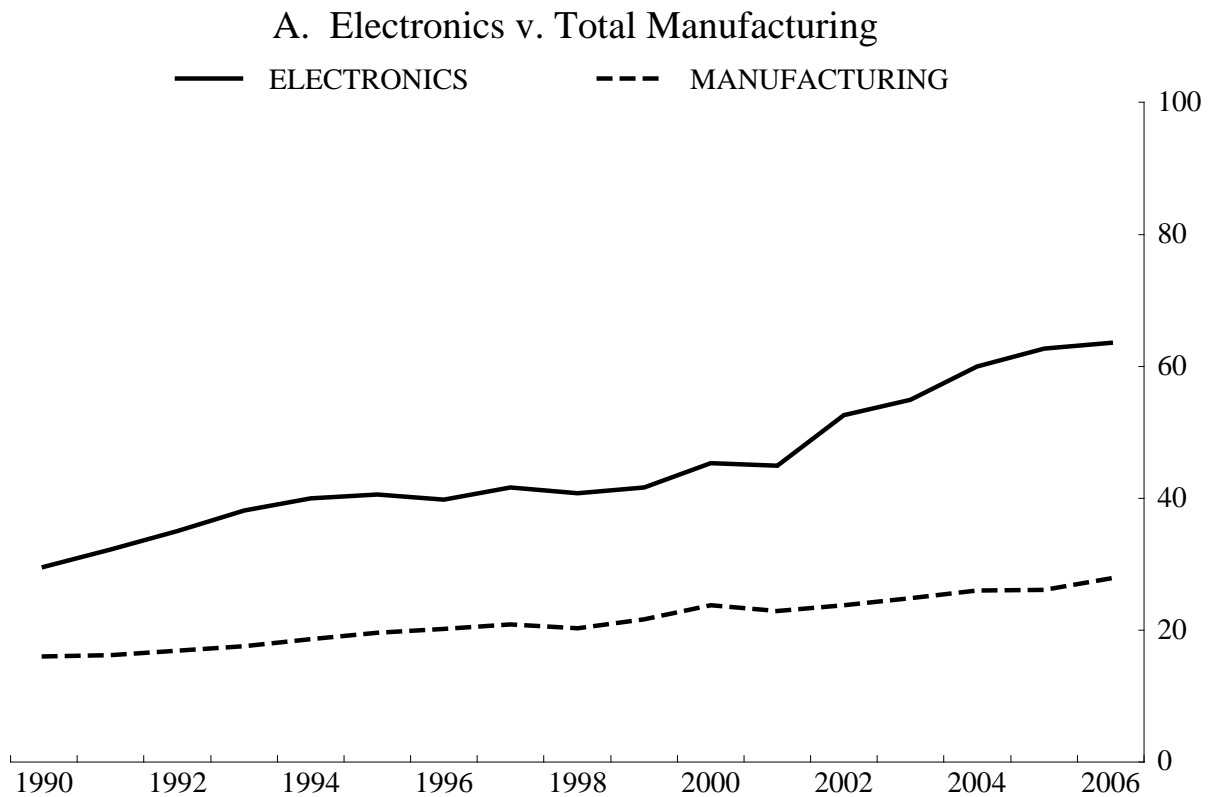
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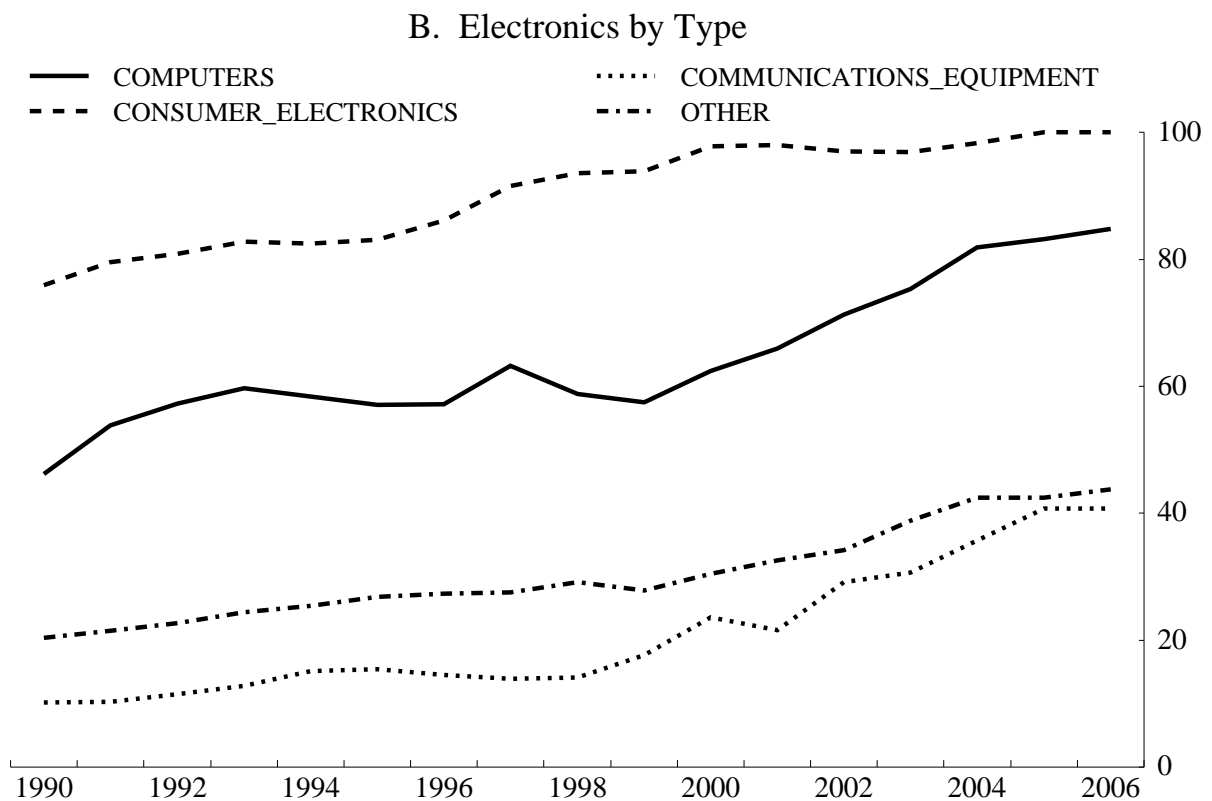
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Figure 1. Nominal Import Penetration, United States



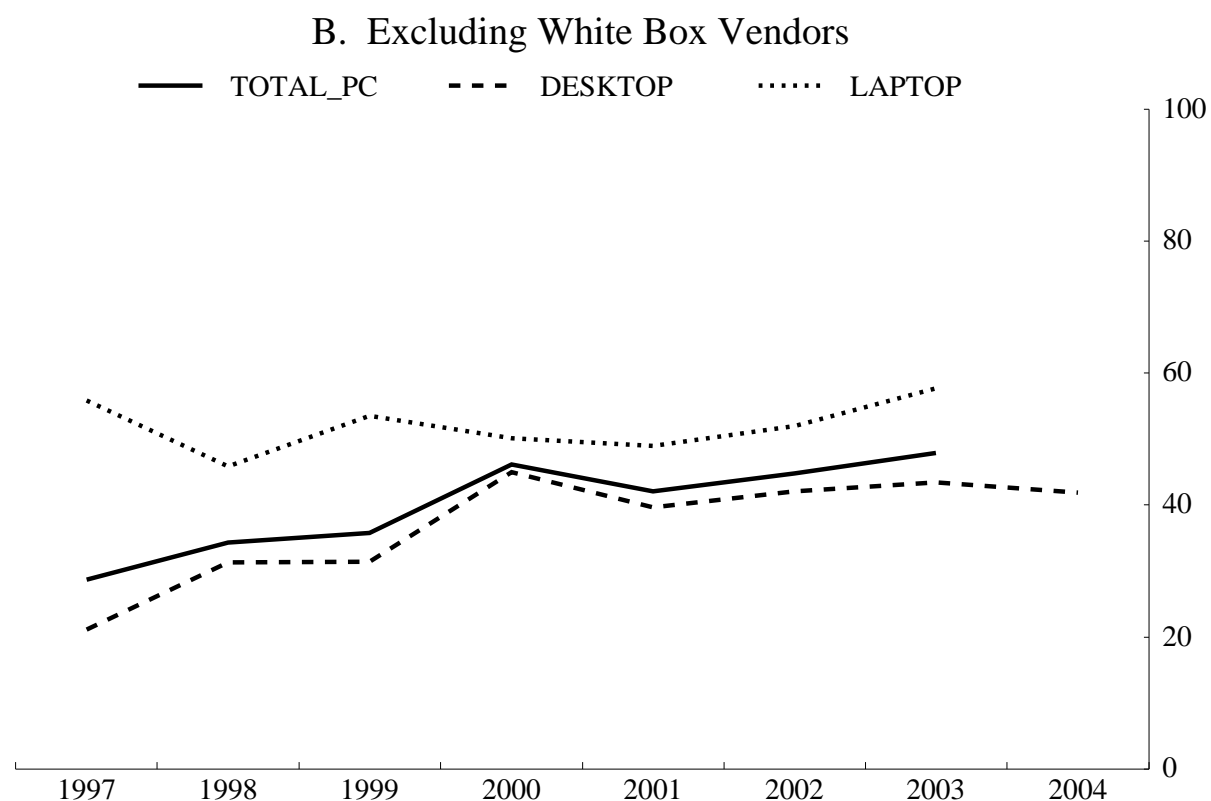
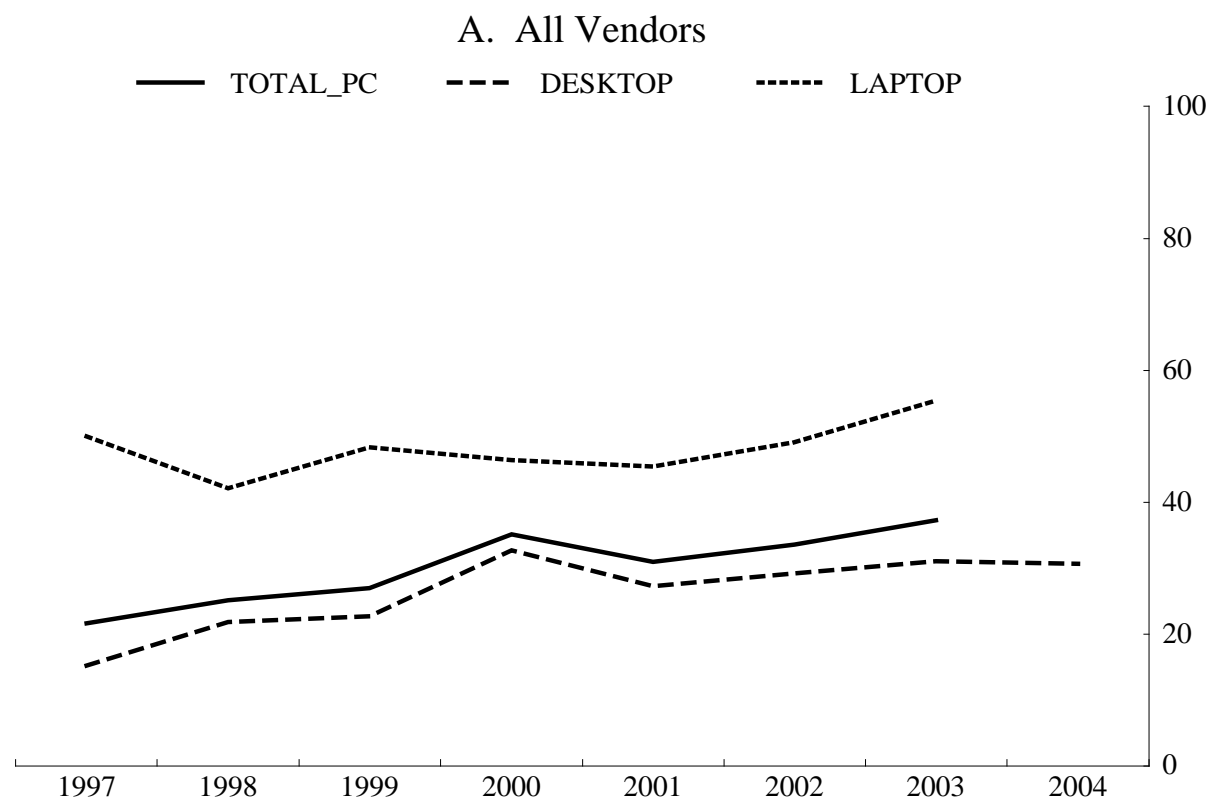
Source. Reed Electronics Research (electronics); U.S. Census Bureau (manufacturing).



Source. Reed Electronics Research.

Note. Other = electronics for control, instrumentation, medical, and industrial applications.

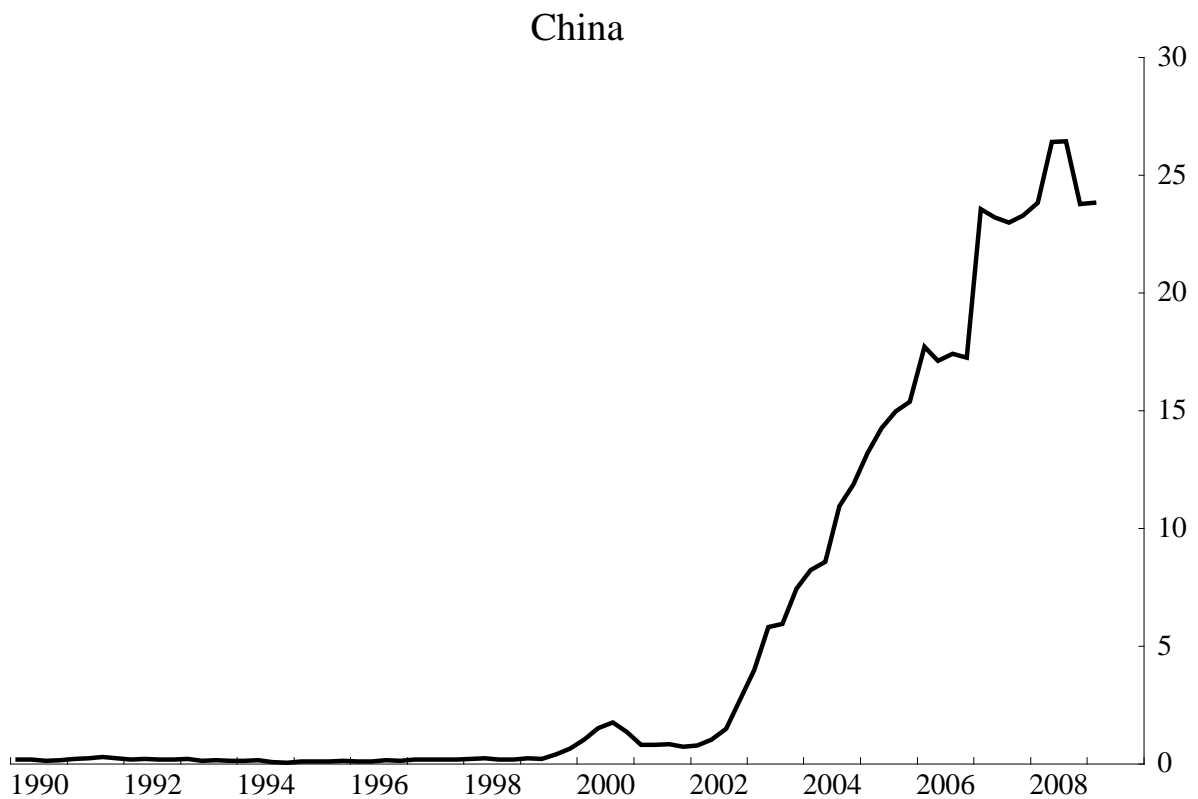
Figure 2. Unit Import Penetration, United States, Personal Computers



Source. Author's calculations.

Note. Census production figures only disclosed for period shown.

Figure 3. U.S. Imports of Computers, \$Billion, Annual Rate



Source. U.S. Bureau of Census.

Figure 4. Indicators of Communication Cost

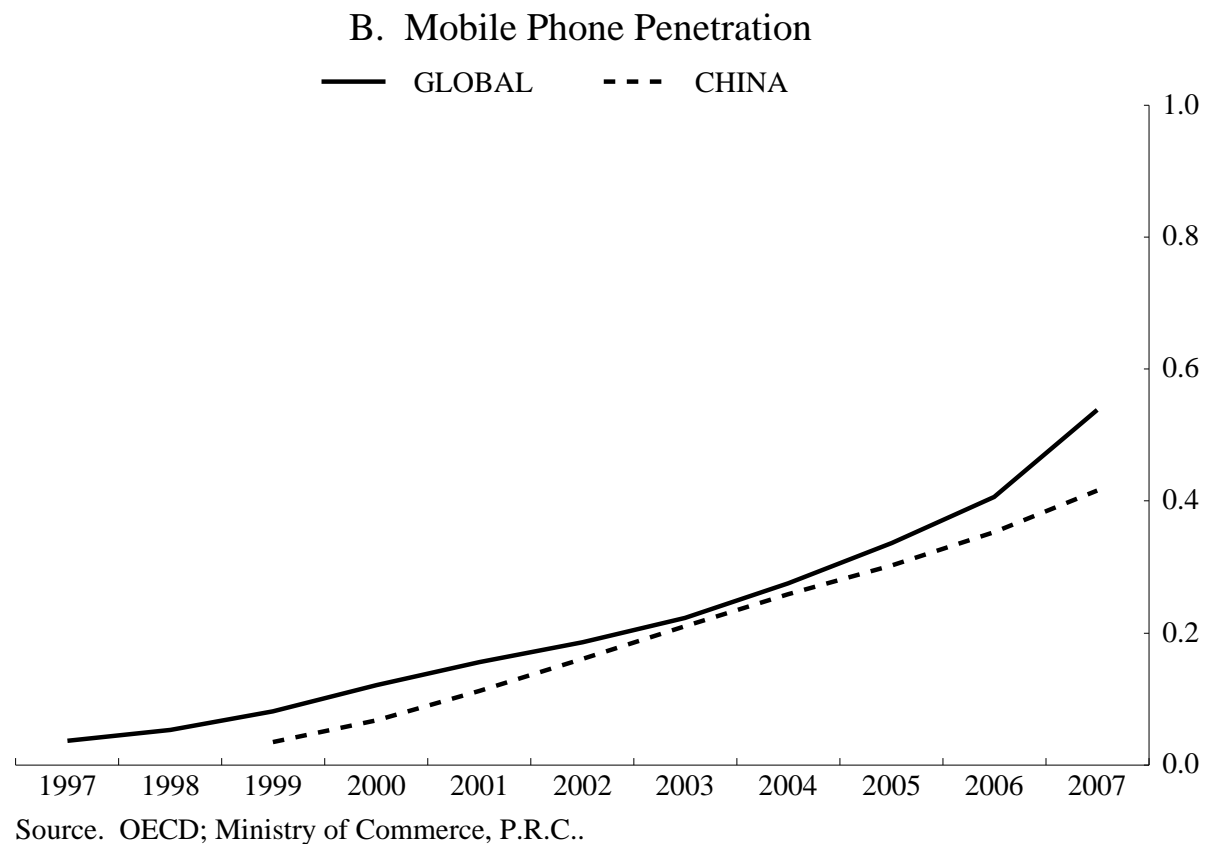
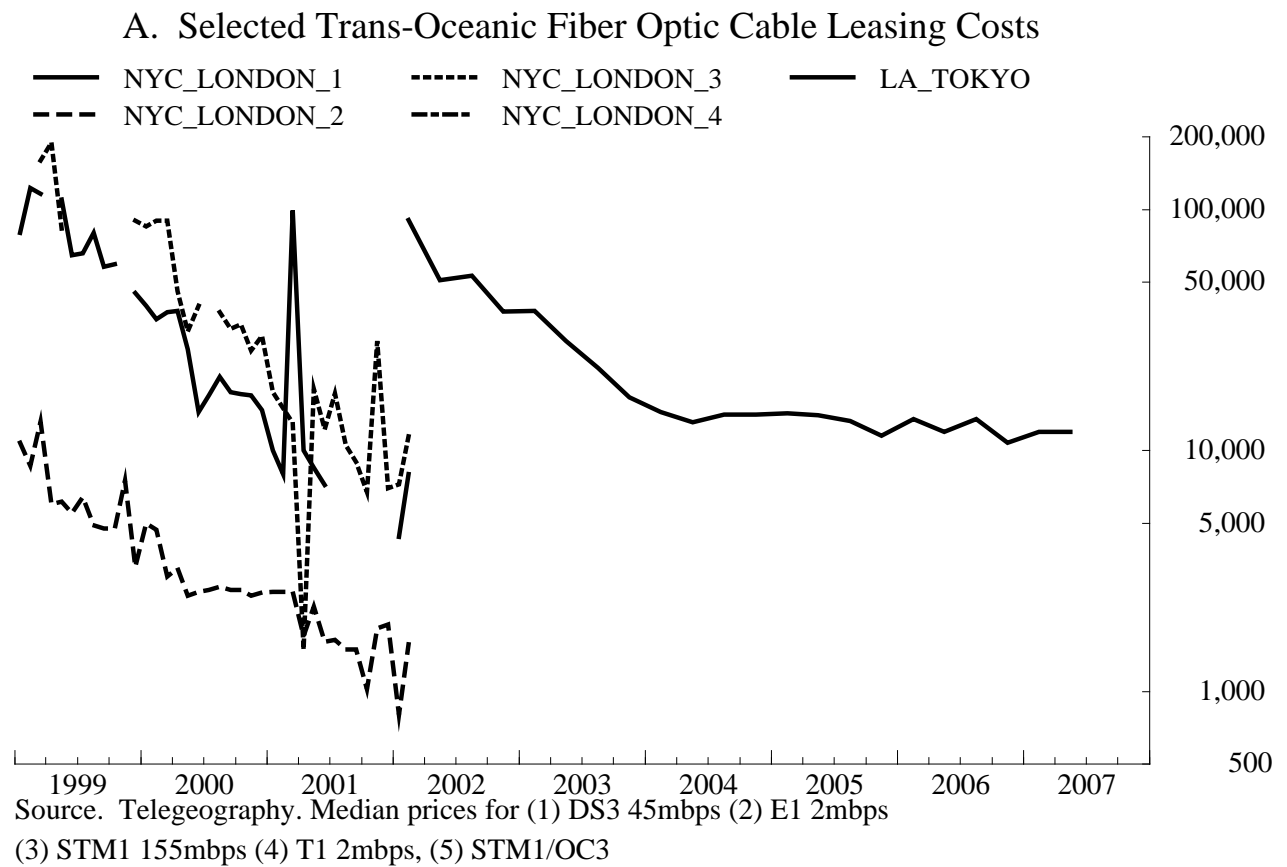
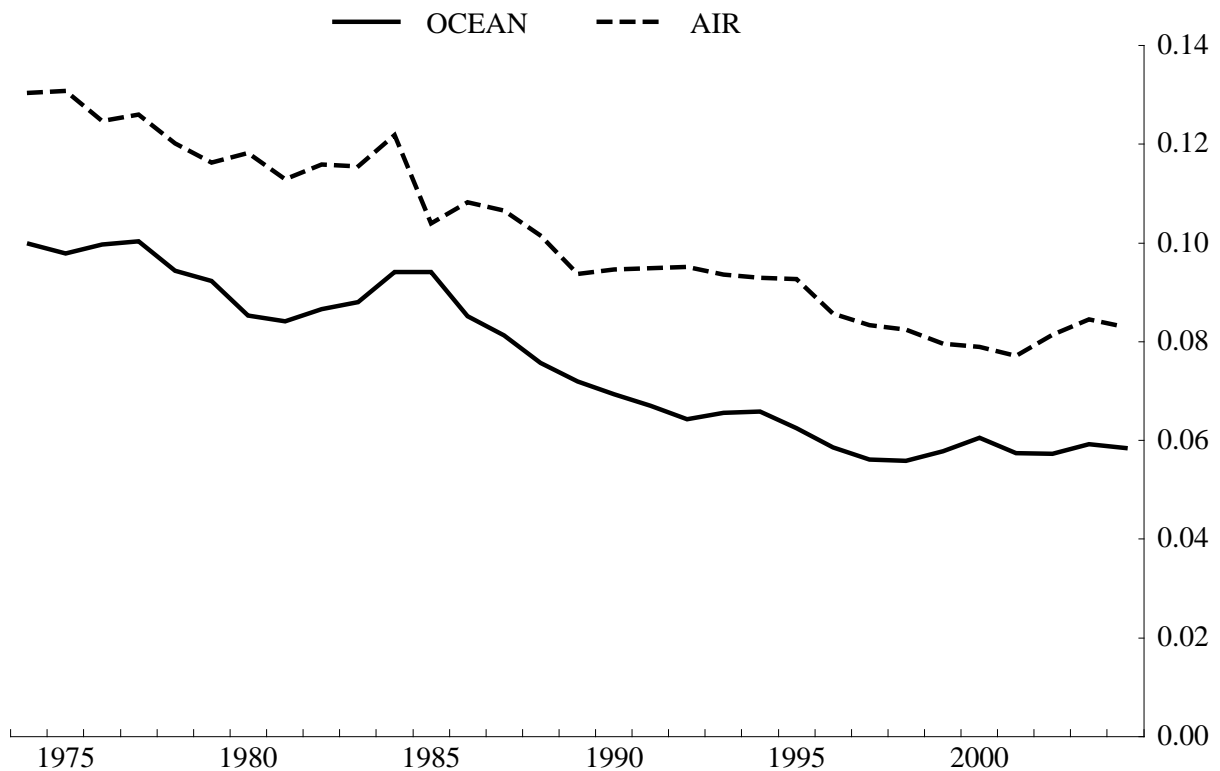
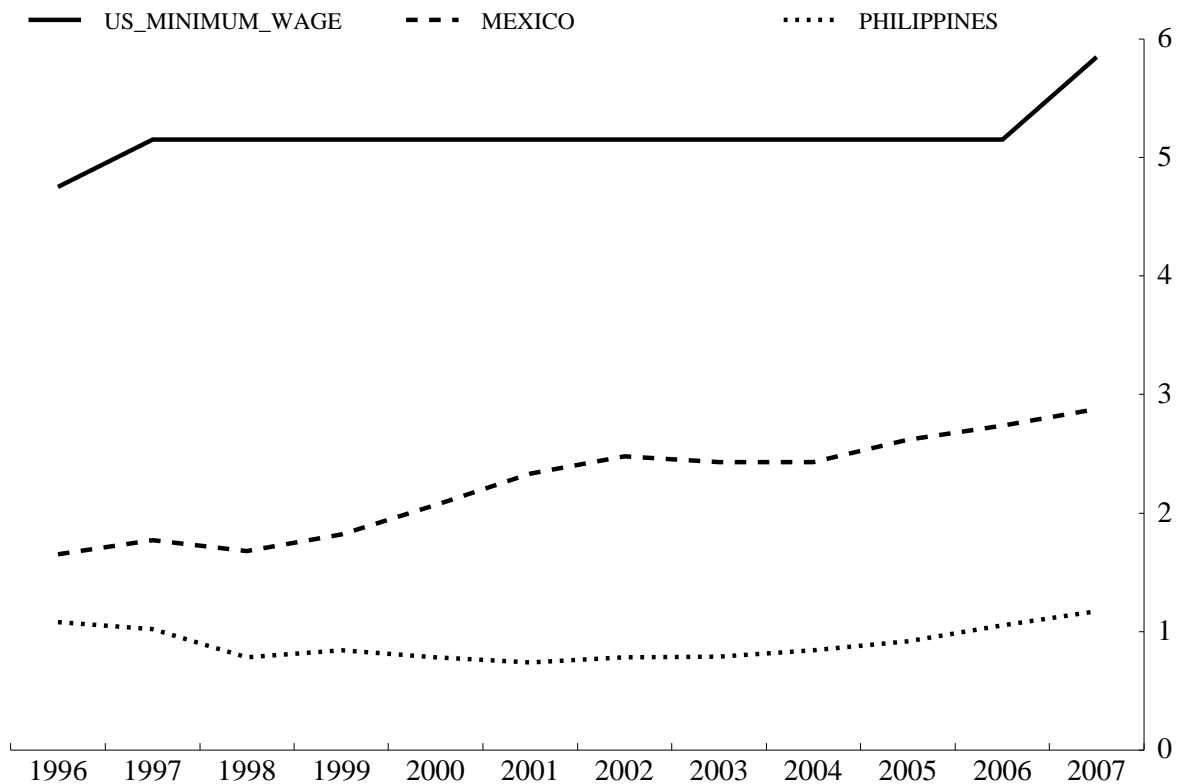


Figure 5. Ad Valorem Freight Costs



Source. Hummels (2007) quality-adjusted indexes.

Figure 6. Hourly Direct Pay in Manufacturing



Source. Bureau of Labor Statistics.

Figure 7. Direct Sales Share, Desktop PCs (Source. IDC.)

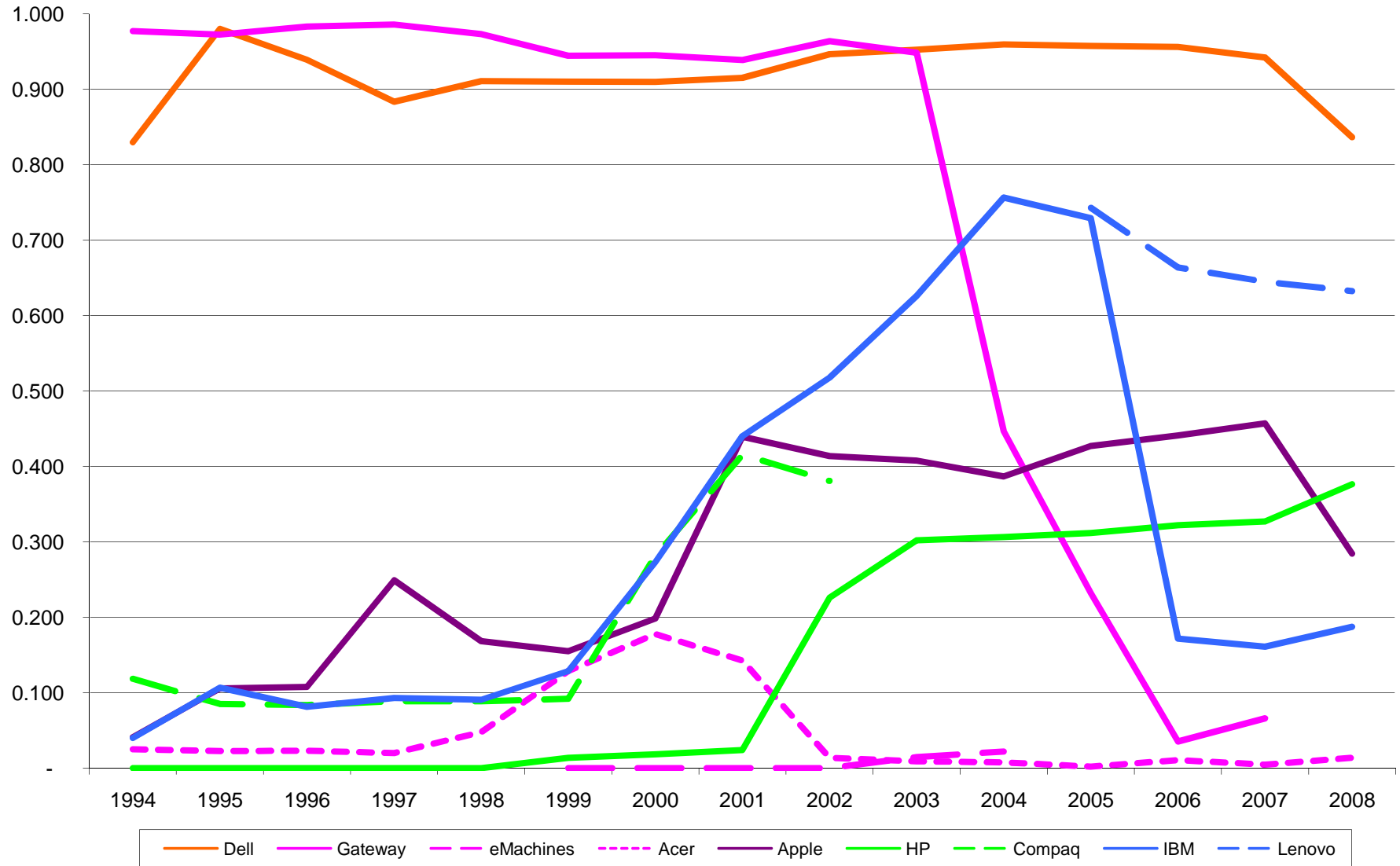


Table 8. PC Cost Decomposition by Platform

Desktop PC	Basic 1998		Premium 1998		Basic 2004		Premium 2004	
	Cost	Share	Cost	Share	Cost	Share	Cost	Share
System Cost	770		1484		579		1460	
MPU & Base Logic	217	28%	500	34%	138	24%	516	35%
Memory & Other Logic	47	6%	138	9%	40	7%	203	14%
Storage	217	28%	367	25%	108	19%	198	14%
Operating System	45	6%	55	4%	55	9%	55	4%
System	209	27%	378	25%	215	37%	457	31%
Assembly	35	5%	46	3%	23	4%	31	2%
Laptop PC	Basic 1998		Premium 1998		Basic 2004		Premium 2004	
	Cost	Share	Cost	Share	Cost	Share	Cost	Share
System Cost	899		2096		836		1393	
MPU	245	27%	687	33%	242	29%	491	35%
Other Logic	122	14%	148	7%	53	6%	186	13%
Storage	196	22%	358	17%	162	19%	268	19%
Operating System	45	5%	45	2%	55	7%	55	4%
System	250	28%	806	38%	291	35%	350	25%
Assembly	41	5%	52	2%	33	4%	43	3%
Source. Gartner.								
US labor cost multiplier	4		4		4		4	
US assembly cost	140		184		92		124	
US system cost	875		1,622		648		1,553	
US total cost multiplier	1.136363636		1.092991914		1.119170984		1.06369863	

**Figure 9. Share of PCs Sold to Business Market, Selected Companies.**  
**Source. IDC.**

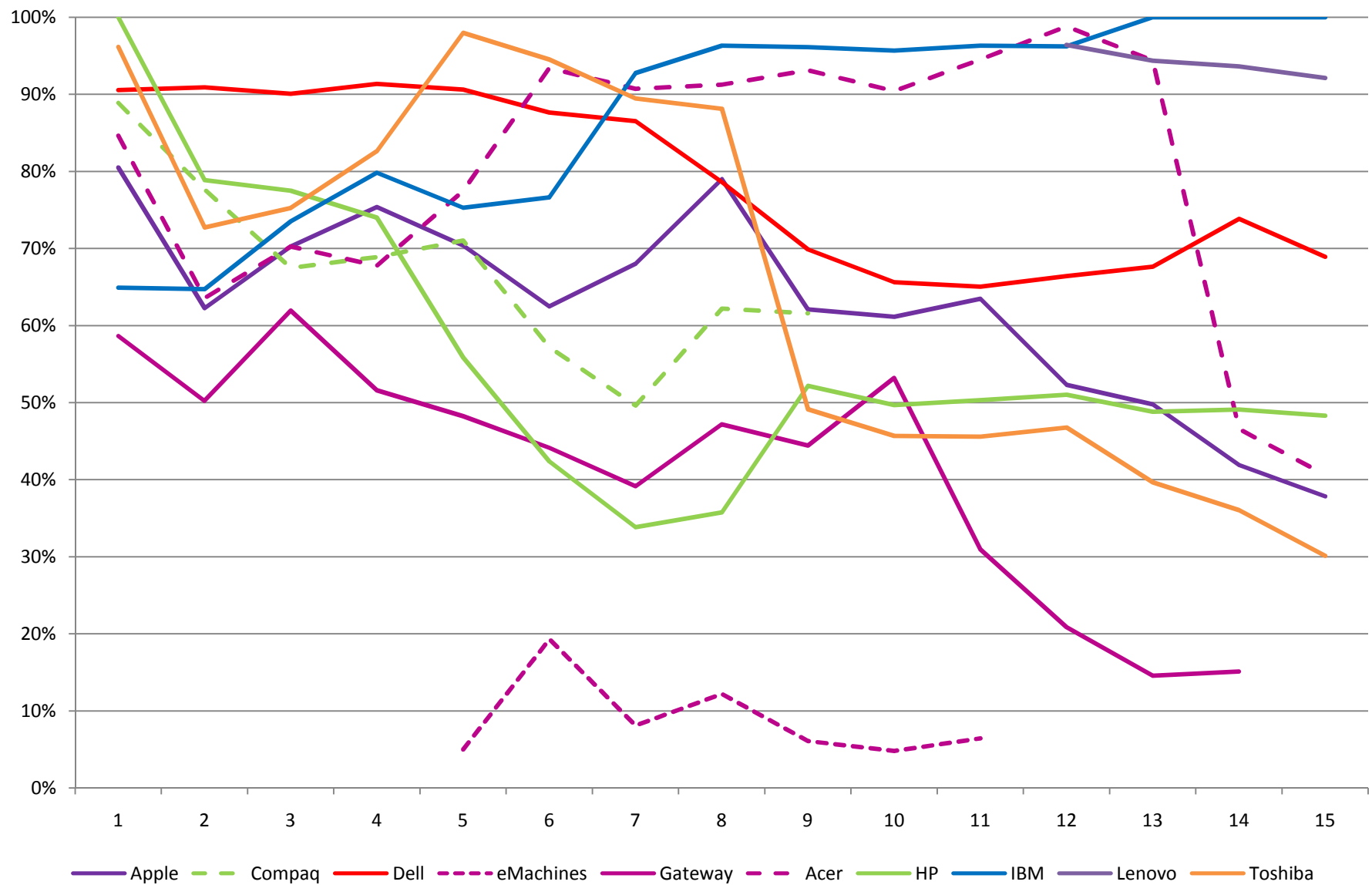




Table 10. PC Company-Platform  
Observations by Domestic Intensity

	1994-1999	2002-20007
> 75 Percent	11	4
25 to 75 Percent	5	4
< 25 Percent	21	15

Table 11. Domestic Intensity Transitions

		2002-2007		
		> 50%	< 50%	Exit
1994-1999	50% or More	0.31	0.46	0.23
	Less Than 50%	0.04	0.38	0.58

## Descriptive Statistics

Desktops						
1994-1999			2002-2007			
	mean	std. Dev.	n	mean	std. Dev.	n
domestic intensity	0.388	0.416	19	0.353	0.407	12
log unit sales	14.778	1.386	19	15.323	1.430	12
relative ASP	1.011	0.163	19	1.263	0.382	12
direct sales share	0.349	0.304	19	0.378	0.410	12
business sales share	0.701	0.288	19	0.610	0.266	12
US headquarters	0.579	0.494	19	0.667	0.492	12

Laptops						
1994-1999			2002-2007			
	mean	std. Dev.	n	mean	std. Dev.	n
domestic intensity	0.327	0.406	18	0.166	0.296	11
log unit sales	12.044	0.877	18	13.870	1.114	11
relative ASP	0.966	0.079	18	1.143	0.184	11
direct sales share	0.219	0.362	18	0.303	0.236	11
business sales share	0.902	0.094	18	0.773	0.239	11
US headquarters	0.500	0.514	18	0.455	0.522	11

Table 13. Tobit Coefficient Estimates

	Coef.	Std. Err.	t
log unit sales	<b>0.293</b>	0.084	3.490
relative ASP	<b>1.065</b>	0.346	3.070
direct sales share	<b>1.310</b>	0.326	4.010
US headquarters	-0.248	0.206	-1.200
business sales share	-0.361	0.389	-0.930
laptop	<b>0.817</b>	0.292	2.790
period 2002-2007	<b>-0.878</b>	0.250	-3.510
_cons	-5.131	1.448	-3.540
sigma	0.509	0.083	0.342

Number of obs = 59

LR chi2(7) = 37.08

Prob > chi2 = 0.0000

Log likelihood = -38.028811

Obs. summary:

27 left-censored observations at lhs<=.05

24 uncensored observations

8 right-censored observations at lhs>=.95

Table 14. Simulated Effects of Changing Characteristics

	baseline		scale increase 1 M to 5 M		higher ave. price 10% increase		higher direct sales 1/3 to 2/3		laptop		2002-2007	
	value	index contrib.	value	index contrib.	value	index contrib.	value	index contrib.	value	index contrib.	value	index contrib.
log unit sales	13.82	4.05	15.42	<b>4.52</b>	13.82	4.05	13.82	4.05	13.82	4.05	13.82	4.05
relative ASP	1.00	1.07	1.00	1.07	1.10	<b>1.17</b>	1.00	1.07	1.00	1.07	1.00	1.07
direct sales share	0.33	0.43	0.33	0.43	0.33	0.43	0.67	<b>0.88</b>	0.33	0.43	0.33	0.43
US headquarters	1.00	-0.25	1.00	-0.25	1.00	-0.25	1.00	-0.25	1.00	-0.25	1.00	-0.25
business sales share	0.75	-0.27	0.75	-0.27	0.75	-0.27	0.75	-0.27	0.75	-0.27	0.75	-0.27
laptop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	<b>0.82</b>	0.00	0.00
period 2002-2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	<b>-0.88</b>
_cons	1.00	-5.13	1.00	-5.13	1.00	-5.13	1.00	-5.13	1.00	-5.13	1.00	-5.13
standardized index		-0.20		0.73		0.01		0.68		1.40		-1.92
predicted intensity		0.42		0.77		0.50		0.75		0.92		0.03
difference v. baseline				<b>0.35</b>		<b>0.08</b>		<b>0.33</b>		<b>0.50</b>		<b>-0.39</b>