**Vertical integration and pricing incentives: evidence from**

**the tablet computer market**

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This paper examines pricing incentives for vertically-integrated manufacturers that retail. We estimate a model of demand and supply in the upstream and downstream markets for tablet computers in the United States and solve the model for the firms’ optimal price conditions. The price conditions are used to recover retail price-cost margins, wholesale price-cost margins and total marginal costs for 176 products supplied by ten manufacturers during the third quarter of 2019. Our results indicate that vertically-integrated firms, specifically Apple and Microsoft have an incentive to increase their wholesale margins to raise rival retailers’ costs. The average increase of $23.80 per model is non-trivial for the dominant firm, Apple, and is equivalent to about $57.85 million per quarter. Some of the benefits from using a direct distribution channel such as The Apple Store or The Microsoft Store to raise rivals’ costs may be offset by an increase in the marginal cost of retailing. The increase in this marginal could be large for Microsoft and may shed some light on why they began closing their physical stores in the late 2010s. (JEL D4, F13, L63).

Key words: dual-channel distribution, price-cost margins, tablet computers, vertical relations

**1. Introduction**

There is a long running debate in economics on the competitive effects of vertical integration. In much of the literature the efficiency gains from the elimination of double marginalization (EDM) are outweighed by raising rivals’ costs (RRCs) and foreclosure effects. Assessment of this tradeoff has informed competition policy, industry regulation and merger outcomes in the United States (Riordan, 2005; Luco and Marshall, 2020). For example, the Department of Justice’s (DOJ’s) challenge to the 2018 AT&T-Time Warner merger emphasized the vertically-integrated firm’s incentive to increase the price or lower the quality of the essential input for downstream firms. The American Innovation and Choice Online Act intends to limit Big Tech platforms, such as the Amazon marketplace, from engaging in discriminatory behavior where they rank their own similar private-label retail products over their rivals in consumer searches. Yelp and TripAdvisor also argue that Google lowers their links in search results in favor of prime placement of Google Maps. A 2020 complaint by the Federal Trade Commission (FTC) accuses Facebook of denying third-party software developers access to its platform to soften competition in the social networking and mobile messaging markets.

In contrast, antitrust concerns over the integrated production and distribution strategies of several well-known brands have been largely ignored by economists and policy makers. Apple, Dell, Samsung and Tesla, for example, are manufacturers that have forward integrated into direct distribution, with the former companies competing head-to-head with independent retailers. While the potential efficiencies from these strategies are well recognized, for example, EDM, quality control, and the internalization of investments in sales promotion, the anti-competitive effects fall outside the mainstream literature and are less understood. This paper contributes to the debate by providing new evidence on the competitive effects from forward integration by Apple and Microsoft in the market for tablet computers. Both of these companies exclusively sell their products in their integrated retail setting, which may add to any RRC effect. In contrast to previous studies, we explicitly focus on the unilateral wholesale pricing incentives for forward-integrated manufacturers to raise their rival retailer’s costs. We also assess welfare by comparing the EDM and RRC effects to increases in the retail costs for integrated manufacturers operating their own stores. Our results also help explain why other manufacturers choose dual-channel distribution. Examples include Dell and Sony in electronics, Adidas, Coach, and Nike in fashion and apparel, and Avenue Supermarts, Budweiser and Coca-Cola in food and beverages.

We begin our analysis with reduced-form regressions of retail prices of tablet computers in the United States market for each quarter from June 2010 to September 2019. The results show, all else held constant, that the vertically-integrated firm can set a higher retail price for the same product sold by the independent retailer. The price premium ranges from two to seven percent during 2012 to 2014. Because these results are descriptive it is not possible to identify the source of market power, so we explore this question further with a structural model of demand and supply with vertical relations. The model employs a commonly used random coefficients logit (RCL) specification of consumer demand and a Bertrand game of oligopoly in both the upstream and downstream markets. Under regular assumptions we show that the unilateral wholesale pricing incentive for the forward-integrated manufacturer to raise rivals’ costs depends on displacement ratios and the wholesale to retail price pass-through rates. In the language of Shapiro (2021), this result describes the integrated firm’s incentive to increase wholesale prices upstream and to increase profits from the diverted sales from the upstream to the downstream market. We use our estimated demand parameters, observed retail prices and the firm’s optimal price conditions to recover price-cost margins for 176 products during the third quarter of 2019. The results show incentives for Apple and Microsoft to increase their wholesale margins to rivals. The average increase of $23.80 per model is non-trivial for the dominant firm, Apple, and accounts for almost 26 percent of their estimated wholesale price-cost margin. It also appears that some of the benefits from using direct distribution to raise rivals’ costs may be offset by an increase in the retail costs from operating physical stores.

Most papers on vertical relations use structural models to recover the margins for popular consumption goods. Sudhir (2001) tests how alternative demand functions impact wholesale to retail price pass-through for yogurt and peanut butter. His supply-side only considers the direct effect of the wholesale price on the retail price through the retailer’s input cost. Manuszak (2001) studies the effect of upstream mergers on gasoline retailers and models the indirect effect of the wholesale price through its impact on the choice of the downstream retail margin. Villa-Boas and Zhao (2005) consider direct and indirect wholesale price effects in their study of ketchup and find that price endogeneity in consumer utility can bias the wholesale price below that observed in the data. Richards et al. (2011) find that organic growers earn a larger share of the total margin than non-organic growers, but this vertical market power is eroding over time as supply adjusts. Like Sudhir and Villa-Boas and Zhao, they also assume a single retailer. Bonnet and Dubois (2010) suggest that manufacturers use two-part tariffs with resale price maintenance in the market for bottled water. Haucap et al. (2021) find that upstream market size increases with the higher cost pass-through rates from resale price maintenance than from linear pricing.

None of these studies permit vertical integration between upstream and downstream firms or allow multiple retailers. In contrast, Chipty (2001) finds that integrated television producers and distributors exclude rival networks from their packages but have lower prices for basic cable. Since the model is reduced form, it is not possible to separate the efficiency from the foreclosure effects.[[2]](#footnote-2) Villa-Boas (2007) estimates a structural model of vertical relations in the supermarket industry when wholesale prices are not observed. She computes price-cost margins under different supply specifications to identify the vertical contract that best fits the data for yogurt sales. Crawford et al. (2018) estimate a structural model of bargaining over the fee paid by distributors to producers in multichannel television markets. They permit integration between producers of regional sports networks and distributors but compute their model by assuming that firm decisions on affiliate fees and retail prices happen simultaneously. The typical assumption is that affiliate fees are first negotiated, and then the distributors choose the packages and prices they supply to consumers. Miravete et al. (2020) evaluate liquor taxation where a control board applies the same markup to all retail products. This regulation simplifies computation because the matrix of derivatives of retail prices with respect to wholesale prices has common diagonal elements that reflect the uniform markup and tax.

We study tablet computers because we have good quality data on their product characteristics, retail prices, sales and distribution channels. The analysis of vertical relations in consumer electronics can also offer additional insights to a literature primarily focused on groceries. For example, Villa-Boas (2007) shows that producers of national yogurt brands lower their wholesale prices when competing with vertically-integrated supermarkets producing their own private labels.[[3]](#footnote-3) We show that a forward-integrated manufacturer of tablets has incentive to increase their wholesale prices to independent retailers and present empirical estimates of these RRC effects. Other interesting features of our study are that upstream firms set wholesale prices first and account for their expected indirect impacts on retail prices when considering their first-order conditions for profit maximization, and that vertically-integrated firms only sell their own products in their retail stores. This contrasts with subscription television where AT&T, for example, have offered the independent Altitude Sports channel and the integrated AT&T Sports Net Rocky Mountain channel in their satellite television plans for Colorado.

The paper is organized as follows. The next section describes United States tablet computer markets. Section 3 describes the empirical model used to identify the RRC effects, including the additional unilateral wholesale pricing incentives for vertically-integrated firms. Estimates of consumer demand are presented in section 4. Section 5 uses the demand estimates to recover retail and wholesale price-cost margins and performs a robustness check of our linear pricing assumption. The EDM and RRC effects, as well as the additional integrated pricing incentives, are also backed out and discussed in this section. Section 6 concludes.

**2. United States tablet computer markets**

2.1 Production and distribution

Tablet computers are portable personal computers that run on mobile operating systems such as Android, iOS, or Windows, and provide many applications. While they have existed since the release of the GRiDPad in 1989, Apple introduced the modern tablet to consumers with the iPad in April 2010.[[4]](#footnote-4) Consumers typically use tablets for web browsing, and composing, editing and viewing music, photos and videos. IDC (2019) data show that about 18 million tablets shipped to children, consumer and commercial customers in the United States during 2010, with Apple and Samsung selling the most. Sales peaked in 2014 with about 57 **million units sold, and more recently, about 28 million units were sold during the first three quarters of 2019.** Figure 1 plots total sales and sales to consumers and shows that the pattern for the consumer market segment is similar to total sales. The share of consumer sales declined during the latter part of the sample period, which is not surprising as this market segment likely has a longer replacement cycle than the children and commercial segments. Apple dominates the consumer market with quarterly market shares consistently around 60 percent or more.

The value chain for tablet computers is comprised of original equipment manufacturers (OEMs), name-brand manufacturers (“manufacturers”) and retailers. OEMs such as Foxconn and Quanta Computer design and assemble products according to the specifications of the manufacturer. The manufacturer then sells these products to consumers in the United States indirectly through independent retailers and/or directly through their own retail operations. Comparative advantage in the design and assembly of tablets, and manufacturer market power, drive the gains from trade and the independence of the OEM and manufacturing stages of production. Absent Hewlett Packard (HP), most of the name-brand tablets in our sample are assembled by OEMs in mainland China, India, South Korea, and Taiwan. HP mainly focus on the supply of customized, high-value computers to commercial customers, and they make these in the United States to address customers preferences more effectively and for quicker delivery (US Trade Commission, 2014).

Eight of the 15 manufacturers in our data are headquartered in the United States, two are in China, South Korea, and Taiwan, respectively, and one is in France. During our sample period, these manufacturers regularly sold their products in United States consumer markets with total retail sales of about $112.2 billion. ASUS, E Fun, LG Electronics and Pandigital are independent manufacturers that sell their products to independent retailers. Acer Group, Amazon, Lenovo, HP, Nabi, RCA, Samsung, and Verizon are integrated manufacturers and retailers that sell their products to independent retailers and to consumers through their own online stores. Apple, Barnes & Noble, and Microsoft are also integrated manufacturers and retailers that sell their products to independent retailers and to consumers through their own online and physical stores. The three most popular tablet brands in the market during the sample period were Apple with 68.9 percent of total retail sales revenue at an average price of $496, Samsung with 12.4 percent of retail revenue and an average price of $292, and Amazon with 4.13 percent of retail revenue and an average price of $215.

Other than quarterly sales and retail prices we have limited information about the downstream market structure. IDC (2020) classify retail sales into five distribution channels. An online store refers to sales made directly by the manufacturer to consumers through their website. A physical store refers to sales made directly by the manufacturer to consumers through storefront businesses that are owned and supplied directly by the manufacturer. The “storefront businesses” or retailers exclusively sell products from their integrated manufacturers, which is a distinct supply-side characteristic from other papers on this topic. An indirect online store refers to sales made indirectly by the manufacturer to consumers through an independent retailer’s website. An indirect physical store refers to sales made indirectly by the manufacturer to consumers through storefront businesses that are owned by independent retailers. An indirect “Telco” store refers to sales made indirectly by the manufacturer to consumers through telecommunications companies that operate cellular services, such as the Verizon Store, and includes online and storefront sales.

About 66 percent of the retail revenue from our sample products is from indirect sales through online and physical retailers such as Best Buy, Costco, Staples, Target, and Walmart. Although we cannot identify the individual product sales through these retailers, aggregate data from Dealerscope (2019) shows that Best Buy and Walmart were two of the leading consumer electronics retailers from 2010 to 2018. Best Buy’s (2018) biggest selling products in 2018 were mobile phones and computers, comprising about 45 percent of their total revenue, and 55 percent of their sales were Apple, HP, and Samsung products. The Amazon Nextbook and the Apple iPad tablets were also often top sellers for Walmart from 2010 to 2016 (Cain, 2019). The remaining 34 percent of retail sales revenue from our sample products is from direct sales to consumers through the vertically-integrated manufacturer’s own retail operations. About one-half of these direct sales revenue were through the manufacturer’s online stores such as [www.apple.com](http://www.apple.com) and [www.samsumg.com](http://www.samsumg.com), and the rest were through physical stores such as the Apple Store, Barnes & Noble, and the Microsoft Store.

Apple and Microsoft are computer and electronic device manufacturers that forward integrated into retail during the early part of the twentieth century. The first two Apple Stores opened in 2001 and by 2017 there were 272 locations throughout the United States. The first two Microsoft Stores opened in 2009 and there were 49 in 2017. However, on June 26, 2020, Microsoft announced it would close all of its retail stores in favor of online distribution.[[5]](#footnote-5) [[6]](#footnote-6) In contrast, Barnes & Noble, which operated over 600 retail stores across the United States in 2020, backward integrated into tablet production and released the Nook in 2010. Between 2013 and 2017 they subcontracted with Samsung for production, and in 2018, they subcontracted with Netronix, a company that makes e-reader tablets. Figure 2 shows the share of direct sales from all manufacturers between 2010 and 2019, as well as Apple’s direct sales share. On average, the direct sales share was about 0.340 over the sample period, ranging from 0.165 to about 0.533. Since the fourth quarter of 2013, most of the direct sales of tablet computers are by Apple.

2.2 Sample data

We analyze the consumer market for tablets in the United States with quarterly data on sales, prices, and product characteristics from IDC (2019). The sales data are aggregated to the product model level across 38 quarterly markets from June 2010 to September 2019. The initial dataset is comprised of over 21,000 product-market observations on quarterly sales in children’s toy markets, commercial and consumer markets. We do not study children and commercial sales because they are derived demands and represent different optimization problems, for example, household utility maximization and firm cost minimization, respectively.

To ensure we are studying the important players in consumer markets, we first omitted individual tablet models with sales of fifty units or fewer per quarter, as these sales should have no strategic effects on the overall market. We then omitted all firms that appeared briefly in the sample and had individual cumulative market shares of one-half percent or fewer over the entire sample period. We measure the tablet price with the average end-user retail price paid by consumers for the product in a given quarter. We adjust the average end-user price with the consumer price index and use this normalized price (*pjt*) to approximate the retail price of product *j* = 1, … , *J* at time period *t* = 1, … , *T*. Because low-price models have limited functionality and are typically marketed to children, and high-price models are marketed to commercial customers, we limited our sample to models with a price between $150 and $900. The final sample for empirical analysis comprises 8,620 product-market observations.

Because tablets are not customized to individual consumers and are typically not bundled with a phone plan, we assume all consumers face the same product characteristics and price for a given tablet product. The measured product characteristics are similar to those described on mobile device company and tablet-comparison web sites. *STORAGE* is the storage capacity of the tablet in gigabytes (GB), *SCREEN* is the diagonal measure of the tablet’s display area in inches, *CPU* is the speed in gigahertz (GHz) of the central processing unit (CPU), *CORE* is the number of processors in the CPU, *MEGAPIXELS* is the number of megapixels in the tablet’s camera, *PIXEL DENSITY* is the number of pixels per square inch of screen size, *BATTERY* is the number of hours of usage time supported by the battery, *CELLULAR* equals one when the tablet has third- or fourth-generation cellular network compatibility and zero otherwise, *DETACHABLE* equals one when the tablet has a detachable keyboard and zero otherwise, *ANDROID* equals one when the tablet runs on the Android mobile operating system and zero otherwise, and *AGE* is the number of quarters since the product’s release into the market.

Consumer utility from tablets, net of prices and observed physical characteristics, may also depend on the retail sales distribution channel. For example, some consumers may be in the market for electronics and prefer to shop at a consumer electronics store such as Best Buy. Others may be in the market for experience, image, and lifestyle, etc. and prefer to shop directly at the vertically-integrated manufacturer’s store. Vertically-integrated stores may also provide better product information and service to consumers from trained sales assistants. For example, the “geniuses” at Apple Stores are trained and certified by Apple to provide personal, concierge-style service to customers. Integrated stores may also have lower waiting times for products due to bottlenecks, etc., and are more likely to let consumers return purchases when they are unhappy with their product, or when a new version comes out after the initial sale. We measure the relationship between sales distribution channel and consumer utility with *INDIRECT*, which equals one when the tablet is sold indirectly to consumers through an independent retailer’s online and/or physical store and zero otherwise.

The sample for demand estimation includes 649 unique tablet products from 15 manufacturing firms over 38 quarters. Table 1 presents summary statistics. Quarterly sales are 91,570 for each product with a mean retail price of about $451. On average, storage capacity was 58.8 GB, screen size was 9.52 inches and CPU speed was 1.66 GHz. About 93 percent of tablets have a camera. The average number of camera megapixels was 5.31, the number of pixels per square inch of screen size was about 221, the number of hours of viewing time supported by the battery was 9.26, and the number of processors in the CPU was 2.5. About 30 percent of tablets have third- or fourth-generation cellular capability, 42.3 percent run on the Android operating system, and 69.9 percent are sold to consumers indirectly through retailers. The average number of quarters since the release date of a new product in our sample was 3.57. Columns two through four show substantial variation in prices and characteristics across tablets with nominal prices ranging from $150 to $899, storage from one to 512GB, screen size from seven to 13.3 inches, and CPU speed from one to 2.6 GHz.

**2.3 Market power**

Due to confidentiality agreements little is publicly known about the determination of prices and profit margins at each stage of the tablet value chain. Industry reports indicate that most OEMs have limited market power and earn profit margins of about one to three percent.[[7]](#footnote-7) Our sample data also show that tablet manufacturers with dual distribution of sales accounted for over 90 percent of retail sales during the 2010s, and this corresponds to relatively low retail market power and margins during the same period (Firdaus, 2011; Tabini, 2013; Best Buy, 2018). For example, Apple iPads are regularly sold to retailers at three percent below their minimum advertised price, and rivals such as Samsung typically set a five to 15 percent discount from the retail price. Retailers accept these terms because they have few viable outside options. Apple, for example, and Microsoft to some extent, can credibly threaten to sell their own products if the retailer does not like the wholesale price, and contracting with an OEM to produce a retail store brand tablet, and promoting that brand, is cost prohibitive. Microsoft and Samsung also have “experience stores” that could be transformed into conventional stores.

Retailers may trade off lower profit margins for increased store traffic and sales of accessories and warranties. However, price reductions will be limited when large manufacturers such as Apple and Samsung offer incentives for retailers listing their products at suggested minimum advertised retail prices. Because computers are complex products, these incentives help ensure the benefits from sales effort accrue to the retailer who makes the appropriate investment.[[8]](#footnote-8) While a retailer can inform consumers about tablet functionalities at the point of sale, this investment in sales effort is costly and can externally benefit competing retailers. This externality lowers incentives for investment in retailer service quality and the final consumer demand for tablets (Mathewson and Winter, 1984).

Figure 3 compares the average revenue per unit (ARPU) for products sold directly to consumers by vertically-integrated firms to products sold by independent retailers. These data show that retail prices for direct and indirect sales trended down from 2010 and stabilized around 2014. This initial period coincides with the introduction of the iPad and the entry of Amazon, Barnes & Nobel and Microsoft into the tablet market. Retail prices for indirect sales then increased relative to the retail prices for indirect sales, with the difference in prices peaking in 2016. By the third quarter of 2019, the retail prices for direct and indirect sales, respectively, had converged. We investigate these trends further with reduced-form regressions that control for brand- and model-specific fixed effects and time and estimate the difference in the conditional mean prices for direct and indirect sales. The baseline regression specifies the log of the retail price of product *j* = 1, …, *J* in time period *t* = 1, …, *T* as:

*ln pjt* = *µ1m(j)* + *µ2f(j)* + *xjt'µ3* + *µ4VIjt* + *µ5TRENDt* + *µ6VIjt*×*TRENDt* + *ujt* (1)

where *µ1m(j)* is a vector of model fixed effects with *m(j)* indicating model *m* and product *j*, *µ2f(j)* is a vector of brand fixed effects with *f(j)* indicating firm *f* and product *j*, *xjt* is the vector of product characteristics *k* for product *j* in period *t* and a cost shifter *X86jt*, *X86jt* equals one when the manufacturer uses a high-end x86 processor in product *j* in period *t* and zero otherwise, *VIjt* equals one when tablet product *j* is sold directly to consumers through a vertically-integrated manufacturer’s physical or online retail store in period *t* and zero otherwise, *TRENDt* is a linear time trend, *µ3* through *µ6* are parameters to be estimated, and *ujt* is a random error term.

Columns one and two of Table 2 present ordinary least squares (OLS) estimates of equation (1). An *F* statistic (F(2, 8,393) = 10.27; prob = 0.00) rejects the null that the estimated coefficients on *VIjt* and *VIjt*×*TRENDt* are jointly equal to zero. The estimated coefficient on *VIjt* shows that, all else held constant, the expected price for a tablet sold directly to consumers by the manufacturer is about five percent higher than a similar tablet sold by retailers. The estimated negative coefficient on *VIjt*×*TRENDt* shows that the premium declines during the sample period. Columns three and four present estimates of an alternative specification that relaces *VIjt* and *VIjt*×*TRENDt* with interactions between *VIjt* and 38 quarter fixed effects from June 2010 to September 2019; *VI×QUARTER1*, …, *VI×QUARTER38*. An *F* statistic (F(8, 8321) = 5.14; prob = 0.00) rejects the null that the eight interactions from the December quarter 2012 (*VI×QUARTER11*) to the September quarter 2014 (*VI×QUARTER18*) are jointly equal to zero and the price premium ranges from two to seven percent during this period. Interestingly, the estimated coefficient on the cost-shifter, *X86*, is also positive and statistically different from zero. This is consistent with high-end processors from the x86 instruction set architecture being more complex and typically more valuable to consumers than the common ARM processor.

Previous studies have used the retail price premium to make inferences about upstream market power under the assumption that retail and wholesale incentives are similar (Luco and Marshall, 2020). This assumption seems unlikely in tablet markets where anecdotal evidence suggests market power in manufacturing and relatively lower markups for independent retailers. Our alternative structural approach recovers wholesale price-cost margins from estimated demand elasticities and a specification of oligopoly supply in the upstream and downstream markets. This approach is computationally burdensome but allows the margins to be decomposed into the Lerner index, the unilateral pricing incentive from multi-product supply and the incentive to raise rivals’ costs to divert sales from the upstream to the downstream market. The wholesale margins and total marginal costs from indirect sales can also be compared to the margins and costs from direct sales to assess any potential increase in the retail costs from the direct distribution of tablets by the vertically-integrated firm.

**3. Empirical model**

**3.1 Consumer demand**

The analysis of wholesale pricing incentives for vertically-integrated firms begins with the specification of an RCL model of consumer demand. In each market and time period, consumers choose to purchase either one tablet or the outside option of no purchase. Demand is static with consumers not considering future prices and product characteristics when making current choices.[[9]](#footnote-9) Consumers maximize utility given their preferences and the equilibrium retail prices and characteristics of the products supplied. The indirect utility consumer *n* = 1, …, *N* obtains from purchasing tablet computer product *j* = 1, …, *J* or the outside option of no tablet purchase in time period *t* = 1, …, *T* is:

*Vnjt = Xjt'β – αnpjt + λf(j) + γt + ξjt + enjt*  (2)

where the *K* × 1 vector *Xjt* includes the product characteristics described in Section 2.2 (*xjt*), *BATTERYjt*×*SCREENjt*, *BATTERYjt*×*CPUjt* and *INDIRECTjt*×*TRENDt*, *λf(j)* is a time-invariant brand fixed effect that measures preferences for a brand with *f(j)* indicating firm *f* and product *j*, *γt* is a product-invariant time fixed effect that controls for changes in tablet quality over time such as reliability and durability, *ξjt* is a structural error term for product *j* in period *t* that captures the mean utility from unobserved product characteristics, *β* is a *K* × 1 vector of marginal utilities for the *k* product characteristics, *αn* is the marginal utility of income that varies across consumers, and *enjt* is an unobserved random error term assumed to be independently and identically distributed type I extreme value. The interactions *BATTERYjt*×*SCREENjt* and *BATTERYjt*×*CPUjt* are included in utility to examine whether consumer preferences for hours of usage time supported by the tablet’s battery are related to screen size and the speed of the CPU. The interaction *INDIRECTjt*×*TRENDt* examines whether consumer preferences for their sales distribution channel change during the sample period.

We assume that the marginal utility of income varies across the population according to the normal distribution *αn* ~ *Φ*(*α*, *Σ*). The mean utility for product *j* at time *t* is described by *δjt = Xjt'β – αpjt + λf(j) + γt + ξjt* and the mean utility from the outside good *j* = 0 is normalized to zero. Since the random error term *enjt* is distributed type I extreme value, the market shares for all products and the outside good for a given set of estimated demand parameters are consumers are:

 (3)

which is the weighted sum of the individual consumer choice probabilities across the whole population, with the weights given by the density function *ϕ(αn)*. The variance parameter *Σ* and the *J* × 1 vector of mean utilities for each period can be found and solved for the consumer demand parameters using the contraction mapping suggested by Berry, Levinsohn and Pakes (1995). The identifying assumption for the generalized method of moments (GMM) estimator of the demand parameters is *E*[*ξjt* | *zjt*] = 0, where *zjt* is a *L* × 1 vector of instruments with *L* – *K* > 0 excluded instruments correlated with price but uncorrelated with the structural error.

**3.2 Supply**

The supply of products from manufacturers to retailers to consumers is described by a multi-stage static Bertrand pricing game between three different types of firms: manufacturers; retailers; and vertically-integrated manufacturers and retailers. For easier notation, we assume a given time period for supply and omit the time subscript from the subsequent description of the model. We also define a product manufactured by the same firm but distributed to consumers through different retailers as separate products. This allows different wholesale prices to be chosen by manufacturers for the same physical product sold to different retailers. Similar to Bonnet and Dubois (2010), we also define the *J* differentiated products in the supply side to be comprised of *J'* products sold by independent retailers to consumers and *J* – *J'* products sold by vertically-integrated manufacturers and retailers to consumers.

There are *fu* = 1, …, *Nu* independent upstream firms that manufacture and sell their products to retailers. There are *fd* = 1, …, *Nd* independent downstream firms that retail the full variety of products produced by independent and vertically-integrated manufacturers to consumers. There are *fv* = 1, …, *Nv* vertically-integrated firms that manufacture their own products and sells these products indirectly to consumers through the independent retailers, and directly through their own retail operations, for example, the Apple Store, the Microsoft Store, and [www.samsung.com](http://www.samsung.com). In any given time period, there are *Nu* + *Nd* + *Nv* total firms in the market and each sells a subset of the *j* = 1, …, *J* total products in the market to retailers and consumers. The set of products produced by independent manufacturing firm *fu* and sold to retailers are . The set of products sold by independent retailing firm *fd* to consumers are . The set of products produced by vertically-integrated firm *fv* and sold to independent retailers are  and the set of products manufactured by vertically-integrated firm *fv* and sold directly to consumers through their own retail operations are .

The profit function for independent upstream manufacturer *fu* in a given time period is:

 (3)

where *wj* is the wholesale price charged to independent retailers for product *j*, *cj* is the manufacturer’s constant marginal cost of production for product *j*, *s(p(w))* is the market share of product *j*, *p* is the vector of retail prices for all the retail products in the market, *w* is the vector of wholesale prices for all the wholesale products in the market, *M* is market size or the number of potential customers in the market including those that buy the outside good, *qj* = *s(p(w))M* is the quantity of product *j* demanded and sold in the retail market, and *Fu* is the fixed cost of production for firm *fu*. The profit function for independent downstream retailer *fd* is:

 (4)

where *pj* is the retail price of product *j*, *rcj* is the retailer’s constant marginal cost of selling product *j* to consumers, and *Fd* is the fixed cost of production for firm *fd*. The retailer’s marginal cost represents all the selling costs not determined by the upstream manufacturer. The profit function for the vertically-integrated manufacturer and retailer *fv* is:

 (5)

where the term for retail revenue shows that *wj* = *cj* is the transfer price charged to vertically-integrated retailers for all products , and *Fv* is the fixed cost of production for firm *fv*.

Firm decision-making is described in three stages. In the first stage, firms choose their type and the set of products they will manufacture or sell directly to consumers. This stage, along with firm entry and exit decisions, is taken as given. In the second stage, manufacturing firms *fu* and *fv* observe firm types and the set of products available from each firm and choose the wholesale prices *wj* to be charged to the retailers. As first movers, firms *fu* and *fv* anticipate that the third-stage equilibrium in retail prices depends on their second-stage choices of wholesale prices. Furthermore, because they set retail prices for a subset of their products in the third stage, the vertically-integrated firms *fv* commit to wholesale prices in the second stage by writing enforceable contracts with their independent retailers. In the third stage, retail firms *fd* and *fv* observe firm types, the set of products available from each firm and their wholesale prices and choose the retail price *pj* for all products to be charged to consumers.[[10]](#footnote-10) We solve these stages in reverse order and assume that each firm chooses prices to maximize profits given the demand and characteristics of its own products and the prices, demand and characteristics for competing products. We also assume that the overall solution for the game is the subgame-perfect Bertrand-Nash equilibrium set of wholesale and retail prices that satisfy the firm’s first-order conditions.

Given a pure-strategy equilibrium in prices, the retail price of product *j* sold by independent firm *fd* in the third stage of the game must satisfy the first-order condition:

 (6)

for all . During the same stage, the retail price of product *j* sold by vertically-integrated firm *fv* must satisfy the first-order condition:

 (7)

for all . In the second stage, independent and vertically-integrated manufacturers maximize their profits by choosing the wholesale price of product *j* sold to independent retailers, given the retail price responses in equations (6) and (7), respectively. The wholesale price must satisfy the first-order condition:

 (8)

for all  products sold by the independent manufacturing firm *fu*. The wholesale price must also satisfy the first-order condition:

 (9)

for all  products sold by the vertically-integrated firm *fv* to independent retailers.

For easier interpretation, Appendix A re-writes equations (6) through (9) as the percentage price-cost markup over price and expresses these markups as functions of demand substitution effects. The price-cost markup equations (6') through (9') describe three pricing incentives facing firms in the upstream and downstream markets. For retail prices, the first term on the right-hand side of equations (6') and (7') is the Lerner index of market power for product *j*. The second term is the standard unilateral pricing incentive that shows how the multi-product firm can set a higher retail price for product *j* than a single-product firm because it internalizes the substitution effects from all of the retail products in its joint profit function. The third term in equation (7') highlights the vertically-integrated firm’s incentive to soften wholesale price competition in the upstream market because it internalizes the substitution effects from the wholesale products in its joint profit function. This incentive shows that the vertically-integrated retailer can set a higher retail price for product *j* than the independent retailer. Moresi and Schwartz (2021) describe a similar retail pricing effect in their theory of vertical mergers with a monopolized and a competitively supplied input as the Chen (2001) incentive.

The wholesale price equations (8) and (9) have similar effects to retail prices albeit with one key difference; the wholesale price indirectly impacts firm incentives through retail prices. The effect from the third term in equation (9*'*) in Appendix A depends on own- and cross price elasticities of demand, displacement ratios, and the extent of cost past-through, and has policy interest because of potential anti-trust concerns. Both Shapiro (2021) and the 2020 Vertical Merger Guidelines note that this type of effect describes the vertically-integrated firm’s incentive to increase input prices in the upstream market and increase profits from the diverted sales from the upstream to the downstream market. This effect is not identified in the empirical framework employed by Villa-Boas (2007) and Bonnet and Dubois (2010).

**3.3 Computing price-cost margins**

The *J* × 1 vector of first-order conditions for wholesale prices is:

 (10)

where w – c is the *J* × 1 vector of wholesale price-cost margins, Iu is the *J* × *J* ownership matrix for upstream firms with elements equal to one when products *j* and *k* are produced by the same manufacturer and sold to independent retailers and zero otherwise, Sw = Sp×Pw is the *J* × *J* matrix of the derivatives of retail market shares with respect to all wholesale prices, Sp is the *J* × *J* matrix of derivatives of retail market shares with respect to all retail prices, Pw is the *J* × *J* matrix of derivatives of retail prices with respect to all wholesale prices, s(p(w)) is the *J* × 1 vector of market shares, and 0 is the *J* × 1 vector of zeros. The additional integrated unilateral wholesale pricing incentive (the “WPI”) for the vertically-integrated firm is measured by the *J* × 1 vector:



where Γv is *J* × *J* ownership matrix for vertically-integrated manufacturers with elements equal to one when products *j* and *k* are manufactured and sold directly to consumers by the vertically integrated manufacturer and zero otherwise, p – mc is the *J* × 1 vector of retail price-cost margins, p is the *J* × 1 vector of retail prices, mc is the *J* × 1 vector of retail costs, mc = w + rc for independent retailers, and mc = c + rc for vertically integrated retailers. The last *J* – *J'* lines of matrices ,  and  are zeros since they represent products with no wholesale prices. Similarly, the last *J* – *J'* lines of vectors w – c and s(p(w)), and matrices Iu and , are also zeros because they represent products that are sold by vertically-integrated retailers and, as such, have no wholesale prices. Note that absent h, equation (10) describes the standard first-order conditions for wholesale prices with independent upstream and downstream firms.

The *J* × 1 vector of first-order conditions for retail prices is:

 (11)

where Id is the *J* × *J* ownership matrix for downstream firms with elements equal to one when products *j* and *k* are sold to consumers by the same retailer and zero otherwise. The additional integrated unilateral retail pricing incentive for the vertically-integrated firm (the “RPI”) is measured by the *J* × 1 vector:



where the last *J* – *J'* lines of matrix  and vector w – c are zeros because they represent products with no wholesale prices. Absent g, equation (11) describes is the standard first-order conditions for retail prices with independent upstream and downstream firms.

Because manufacturers choose wholesale prices first, the derivatives of retail market shares with respect all wholesale prices in equation (10):

Sw = Sp×Pw = 

must account for the strategic interactions between manufacturers and retailers. The elements of Pw are computed from the total differentiation of the retailer’s first-order conditions with respect to wholesale prices and are presented in Appendix B. In matrix form:

 (12)

where  is the *J* × *J* augmented ownership matrix for downstream firms with elements equal to one when products *j* and *k* are sold to consumers by the same independent retailer, negative one when the vertically-integrated firm sells product *j* through its own retail operation and product *k* through an independent retailer, and zero otherwise. The individual elements djk of the *J* × *J* matrix D are equal to:

 (13)

where Γp(j, l) is a scalar that equals one when products *j* and *l* are sold to consumers by the same independent retailer and zero otherwise, and Γp(j, k) is a scalar that equals one when products *j* and *k* are sold to consumers by the same independent retailer and zero otherwise. The individual elements dvjk of the *J* × *J* matrix Dv are equal to:

 (14)

where is (j, m) is a scalar that equals one when the integrated firm sells product *j* through its own retail operation and product *m* through an independent retailer, and zero otherwise.

Equations (10) and (11) can be stacked into the *2J* × 1 vector of non-linear first-order conditions Ω(w – c, p – mc) that relate wholesale and retail price-cost margins to the estimated demand parameters, observed retail prices and product characteristics:

 (15)

Given observed retail prices p and market shares s(p(w)) from the sample data, the system of *2J* first-order conditions in equation (15) can be solved for the *2J* unknown retail and wholesale price-cost margins. The numerical solution method chooses values for w – c and p – mc to minimize Ω(w – c, p – mc)T×I× Ω(w – c, p – mc), where I is the *2J* × *2J* identity matrix.

**4. Demand estimates**

**4.1 Estimation and instrumental variables**

We estimate consumer demand by applying BLP’s GMM estimator to the sample moment condition *E*[*ξjt* | *zjt*] = 0, where *zjt* is assumed to be mean independent of the unobserved error term *ξjt*. We control for price endogeneity with the cost shifter interacted with cellular capability, *X86jt*×*CELLULARjt*, and with BLP-type product characteristics of the other tablets from the same firm and rivals as the instruments for price. Identification of the demand parameters in consumer utility comes from variation in consumer choices across the different tablet products supplied by firms within each market. The key assumptions are that conditional on controls and *PRICEjt* the cost shifter does not have direct effect on consumer utility, and the product characteristics within choice sets are not correlated with the unobserved demand shocks.

Section 2.3 suggests that *X86jt*×*CELLULARjt* should be positively correlated with price but not correlated with utility in equation (2), after controlling the demand-side for improved tablet functionality with *COREjt*, *CPUjt* and *CELLULARjt*. In equilibrium, the price of a tablet depends on its location in the product characteristics space relative to other product models and the extent to which substitute models are produced by the same firm or by rival firms. Our BLP demand-side instruments are the deviation from the average of the characteristics for all other products produced by the firm in a given market (Gandhi and Houde, 2016). When a particular tablet is in a market with other models with superior characteristics, more competition will force the price of that tablet to be low conditional on its own characteristics. The BLP instruments are therefore expected to be negatively correlated with tablet prices through the price-cost markups but not correlated with unobserved consumer utility.

We initially estimated demand with the full set of BLP type instruments corresponding to the nine non-price product characteristics described in Section 2.2, and the cost shifter, *X86jt*×*CELLULARjt*. We then estimated various specifications with alternative sub-sets of instruments and tested the exclusion restrictions with difference-in-Sargan statistics to arrive at our final specification. The final specification employs three BLP type instruments, *PIXEL DENSITY DIFFjt*, *BATTERY DIFFjt* and *CELLULAR 4G DIFFjt*, where “*DIFF*” indicates deviation from the average of the characteristics for all other products, and *CELLULAR 4Gjt* equals one when the tablet has fourth-generation cellular network compatibility and zero otherwise, and *X86jt*×*CELLULARjt*. This specification also provided the most plausible estimates of consumer demand. The *F* statistics for the joint significance of the excluded instrumental variables in the first-stage regression of price on all the exogenous variables are reported in columns three and five of Table 3. They show that the excluded instruments are relevant in the fixed-coefficients logit (F = 18.06; prob = 0.010) and the RCL (F = 102.8; prob = 0.000) specifications of demand. The Hansen J statistic (χ2 = 2.945; prob = 0.400) is reported in column three of Table 3 and cannot reject the null that the overidentification restrictions in the fixed-coefficients logit specification are appropriate.

**4.2 Demand estimates**

Table 3 presents estimates of consumer demand. Columns one and two report OLS estimates with fixed coefficients (“FCL–OLS”), columns three and four report GMM estimates with fixed coefficients (“FCL–GMM”), and columns five and six report BLP estimates with random coefficients on price and battery time (“RCL–BLP”).[[11]](#footnote-11) The data fit the demand specifications reasonably well as judged by the signs and significance of the estimated marginal utility coefficients. The instrumental-variable estimators report positive marginal utilities for most non-price characteristics and a negative marginal utility for price. The estimated coefficient on *pjt* in the FCL–OLS specification in column one is relatively small in absolute terms and becomes larger as the potential endogeneity of price is controlled for with instrumental variables in columns three and five. This finding is consistent with previous studies where smartphone and tablet prices are found to be positively correlated with unobserved demand shocks.

The RCL-BLP estimates in columns five and six of Table 3 show that the mean and standard deviation of the price coefficient are precisely estimated. The standard deviation is about 37 percent of the mean and suggests that tastes for prices vary in the consumer population. There is also large, estimated variation in consumer tastes for hours of usage time supported by the tablet’s battery. The mean willingness-to-pay (WTP) for most of the non-price product characteristics conform to expectations. All else held constant, the representative consumer is willing to pay $0.11 (s.e. = 0.02) for an additional GB of storage, $33.18 (s.e. = 23.43) for an additional inch of screen size, $1.75 (s.e. = 0.94) for an additional processor in the CPU, $0.30 (s.e. = 0.03) for an additional pixel per square inch of screen size, $4.72 (s.e. = 1.11) for an additional megapixel in the tablet’s camera, $31.16 (s.e. = 3.39) for 3G or 4G cellular capability, and $7.12 (s.e. = 3.92) for a detachable screen. There is a premium for the dominant firm with the representative consumer willing to pay about $62 (s.e. = 5.63) for an Apple iPad. These estimates are consistent with received studies on smartphones, tablets and televisions (Moulton et al., 1998; Sun, 2012; Fan and Yang, 2016, Hiller et al., 2018; Hiller and Savage, 2021).

The estimated negative coefficient on *BATTERYjt*×*SCREENjt* indicates that the representative consumer’s preferences for hours of usage time supported by the tablet’s battery decrease with screen size. Large screens have more surface area and require more power to light up. Because larger devices usually have a larger battery to support their additional power consumption, consumers with these devices may have lower marginal valuations for battery capacity. The estimated positive coefficient on *BATTERYjt*×*CPUjt* indicates that the representative consumer’s preferences for hours of usage time increase with CPU speed. Because flagship CPUs consumer more power than low- and mid-range CPUs, consumers with these devices may have higher marginal valuations for battery capacity. The estimated positive coefficient *INDIRECTjt*×*TRENDt* indicates that consumer preferences for the sales distribution channel change dramatically during the sample period. For example, during the second quarter of 2010, the representative consumer does not value a tablet that is that is indirectly sold to them by an independent retailer. During the third quarter of 2019, the representative consumer is willing to pay $45.38 (s.e. = 4.16) for a tablet that is indirectly sold to them by an independent retailer.

We use the estimated demand parameters and observed prices and sales to calculate own- and cross-price elasticities of demand for the 176 products in the last quarter of our sample. Brand-level price elasticities of demand are reported in Table 4 and are similar to previous studies. The own-price elasticities range from –3.82 to –6.33 and the cross-price elasticities range from small positive values to 0.203. Tables C1 and C2 in Appendix C also show that the brand-level own-price elasticities are similar for indirect and direct tablet sales. The own-price elasticities for direct sales for the vertically-integrated firms Amazon, Lenovo, RCA, and Samsung are, on average, about three percent lower in absolute value than their elasticities for indirect sales. The own-price elasticities for direct sales for Apple, HP, and Microsoft are, on average, about eleven percent higher than for indirect sales. Microsoft is an outlier with an average own-price elasticity of demand for direct sales of -5.20 that is substantially bigger than their average own-price elasticity of demand for indirect sales of -3.78.[[12]](#footnote-12)

We also use equations (12) through (14) to calculate the *J* × *J* matrix of derivatives of retail prices with respect to all wholesale prices, Pw, or the pass-through effects. The elements of Pw are first obtained by total differentiation of the retailer’s first-order conditions with respect to wholesale prices. Equations (13) and (14) show that the elements of Pw are described by the *J* × *J* × *J* array of second-order derivatives of retail market shares with respect to all retail prices. This array includes the partial effects for firms supplying products in upstream and downstream markets and their calculation becomes very complicated and time consuming with multiple, manufacturers, retailers, and products.

**5. Price-cost margins**

**5.1 Supply-side simulation**

Our supply-side simulation assumes there are ten upstream manufacturers that supply 176 tablet products to retailers during the third quarter of 2019. ASUS, Acer Group and E Fun are independent manufacturers that sell their products to independent retailers. Amazon, Apple, Lenovo, HP, Microsoft, RCA, and Samsung are vertically-integrated manufacturers that sell their own products to independent retailers and to consumers directly through their own online stores. Apple and Microsoft also sell their own products to consumers through their own physical stores. Because IDC provide no data on individual product retail sales by physical and online retailer, we assume the independent retailers are a single representative online retailer and a single representative physical retailer that do not manufacture tablets.[[13]](#footnote-13) The starting assumption is that all manufacturers and retailers practice linear pricing when setting retail and wholesale prices. This implies double marginalization for independent retailers and rules out quantity discounts. Preliminary simulations yielded indirect retail margins that seemed high given the level of competition in the marketplace, and that did not differ substantially between direct and indirect sales channels. We calibrated the ratio of price elasticities of demand for indirect to direct sales so that the estimated retail margins and retail costs have behaviorally interpretable values during the simulations. We tested various percentage increases of the baseline price elasticities of demand for indirect sales and settled on 50 percent as the most plausible increase. The calibrated brand-level price elasticities of demand are reported in Table 5 in Appendix C. When optimizing the firm’s objective function, we increased the diagonal elements of Sp by 50 percent for all products that are sold indirectly to consumers.

**5.2 Linear pricing**

We solve equation (15) for equilibrium wholesale and retail wholesale price-cost margins with the numerical solution method presented in Appendix D. The complete set of simulation results for all of the 176 individual model versions are available on request from the authors. Brand-level summaries of wholesale price-cost margins, costs and WPIs for tablets that vertically-integrated manufacturers indirectly sell to consumers are reported in Table 5. There are seven manufacturer brands supplying 58 unique product versions at an average price per product of $356.24. The sales-weighted total (production plus retail) marginal costs of all products is $227.81 and the sales-weighted wholesale margin is $83.19. The sales-weighted WPI is $16.54 and comprises about 18 percent of the wholesale margin. At the brand level, Apple benefits from an economically significant WPI of about $23.80 per model and Microsoft also benefits, albeit to a lesser extent, from a WPI of about $2.79 per model. Both of these estimates indicate non-trivial revenues from raising wholesale margins to rivals of $57.85 million per quarter for Apple and $0.60 million per quarter for Microsoft. In contrast, the benefits to Samsung are about $0.04 million per quarter. Although Apple is the dominant firm in the market, both Apple and Microsoft share several supply-side characteristics. They both market high-end iPad and Surface tablets with relatively high wholesale price-cost margins of about $100. They also have large totals of indirect sales and sell similar shares of indirect sales through the representative online retailer. Perhaps, most importantly, both firms have dual-channel retail distributions with their own stores also selling their exclusive products directly to consumers.

The retail price-cost margins and simulated costs for direct tablet sales by vertically-integrated manufacturers are reported in Table 6. Altogether, seven brands supply 34 unique product versions at an average price of $333.43. The sales-weighted total marginal cost of all these products is $241.19 and their sales-weighted retail margin is $92.24. The observations from Table 6 are reasonably consistent with Table 5 although Samsung’s retail price and cost indicate that they mainly sell low-end tablets directly online in our data. Just like indirect sales, Apple dominate direct physical and online sales. Except for Samsung, all of the brand-level marginal costs increase when comparing indirect to direct sales, which plausibly reflects the additional marginal costs from retail operations. Apple’s marginal costs increase from $220.14 to $232.60. The difference of $12.46 is less than their WPI of $23.80 and suggests that some of the benefits from using direct distribution for Apple to raise rivals’ costs may be offset by an increase in retail costs. Microsoft shares a similar but more dramatic experience with marginal costs increasing from $421.75 to $466.01. The difference dominates their WPI of $2.79 and may help explain why they began closing physical stores in the late 2010s.

Although not the main focus of this paper, our RPI estimates provide additional insights into the sources of profitability for vertically-integrated firms. The last two columns of Table 6 present the sales-weighted average RPI and the ratio of the RPI to the retail price-cost margin for seven brands with direct sales. The average RPI for all products is $33.05 per model and comprises about 35.22 percent of the retail margin. At the brand level, Apple gains from an economically significant RPI of about $35.21 per model and Microsoft also gains from a RPI of about $11.63 per model. These estimates indicate benefits from raising retail margins of $42.3 million per quarter for Apple and $0.773 million per quarter for Microsoft. In contrast, Samsung has relatively fewer direct sales (like Microsoft) and fewer benefits from the RPI of about $0.054 million per quarter. Overall, these results provide some additional evidence to support Microsoft’s decision to operate its own retail stores despite having a relatively low WPI. It appears, however, that the WPI and RPI are insufficient to offset the increase in marginal costs when indirect and direct sales are considered together.[[14]](#footnote-14)

**5.2 No vertical integration**

Our results show an incentive for vertically-integrated firms to use their wholesale prices, and their own retail operations, to raise rival costs. This type of behavior is consistent with Big Tech companies using their own marketplace or platform to favor their products over downstream rivals in, for example, consumer searches and social networking. One possible, albeit somewhat extreme, implication from this behavior is regulatory intervention that prohibits vertical integration. We now use our model to inform policy makers on this form of intervention with a simple counterfactual of no vertical integration. Absent data on wholesale prices, we cannot isolate the marginal costs of production and distribution in the simulation and let the retail prices re-equilibrate. Instead, we assume constant retail prices and measure the changes in consumer demand and firm profits from the vertical integration case in Section 5.1. Specifically, we use equation (15) to calculate combined wholesale and retail marginal costs, remove any product sold through a direct channel from the product offering, and then re-calculate market share using equation (3) based only on indirect channels for sales. See Appendix F for a description of the solution method.

Table 7 presents changes in brand-level market shares, wholesale price-cost margins, and variable profits when moving from the vertically-integrated market described in Section 3.3 to the counterfactual no-integration market.[[15]](#footnote-15) The seven brands supply 58 unique product versions at an average price per product of $359.12 and the sales-weighted wholesale margin is $81.94. The average increase in indirect sales across all brands is 23.7 percent. However, the 9.8 percent of all sales are lost to the outside option of no purchase, indicating that some brands lose consumers and profits when denied the ability to sell products from their own stores. Those manufacturers without substantial direct sales benefitted from this restriction as some consumers shift purchases in response to a lack of direct sales, however no new consumers joined the market as prices were unchanged and no value was added to any product offering. Since brand-level wholesale and retail price-cost margins do not change, the 69.7 percent decline in Amazon variable profit is attributed to the inability to retail its own product. Apple, as the market leader with large incentives from vertical integration, loses 19.2 percent of variable profit. This occurs because direct sales had accounted for a large share of total sales in the vertically-integrated market and while some of the sales were shifted to indirect sales, 16.8 percent of sales were moved to other firms or the outside option. Not all firms are hurt by the removal of vertical integration with Lenovo, RCA, and Samsung experiencing relatively large increases in profit. These firms gain as they do not have substantial direct sales, and are no longer subject to the anticompetitive effects from vertical integration by larger firms. There is no significant impact on Microsoft. This scenario would reduce consumer welfare, although any reduction in welfare may be attenuated if prices were allowed to adjust to the market change.

**5.3 Alternative pricing assumptions**

For robustness, we compare several other pricing assumptions to our baseline of linear pricing. The pricing models are detailed in Appendix G and include: (1) linear pricing; (2) nonlinear pricing with zero WPI and RPI incentives; (3) nonlinear pricing with zero wholesale margins; (4) nonlinear pricing with zero retail margins; and (5) and nonlinear pricing with a combination of (3) and (4).[[16]](#footnote-16) We follow Villa-Boas (2007) and Bonnet and Dubois (2010) by indirectly testing the pricing models by comparing the goodness of fit of their underlying marginal costs, conditional on observed cost shifters. This approach is appropriate because the cost shifters are product *j* characteristics, which are exogenous to the pricing assumptions. We implement the tests by computing the price-cost margins for each pricing model and recovering their accompanying marginal costs. The marginal cost function:

*ln Cj* = *Xj'ω* + *φINDIRECTj* + *θ(X86j*×*CELLULARj)* + *ζf(j)* + *ln ηj* (16)

is then estimated for each pricing model, where *Cj* is the marginal cost of production and distribution, *ζf* are brand fixed effects, and *ηj* are unobserved random cost shocks. The cost estimates are then used to form the residual sum of squares (RSS) for each marginal cost function and Vuong’s (1989) procedure tests their goodness of fits. For example, when model 2 is compared to model 1, the null hypothesis is that the two nonnested models are asymptotically equivalent when the difference in their RSS approaches zero.

The marginal cost estimates are presented in Table G1 of Appendix G. We observe that the estimated cost coefficients have plausible signs and magnitudes across all five pricing models.[[17]](#footnote-17) They generally show that higher quality products have higher costs of production. An interesting contrast are the negative coefficients on *CPUj* and *X86j*×*CELLULARj*, respectively, which indicate that tablets with high-quality processers may have the same or even lower costs than tablets with low-quality processors. These estimates may be capturing a production process where chip makers build a fully functional, high-quality processing unit and then systematically disable components of the unit to degrade its quality, but at a higher cost of production.

The tests for comparing nonnested pricing models 2 through 5 to pricing model 1 are presented in Table 8. The test statistics are relatively small and generally indicate no significant difference in the explanatory power of the marginal cost of tablet production for the nonlinear pricing models 3 through 5 relative to the baseline linear pricing model.[[18]](#footnote-18) The nonlinear pricing model with zero WPI and RPI incentives is the exception and appears to outperform the linear pricing model at conventional levels of significance. This result is consistent with vertically-integrated manufacturers forgoing some of the variable revenue from their WPI and RPI incentives and extracting fixed fee revenue from the retailers of their products. Because they have their own retail operations, vertically-integrated manufacturers may use their bargaining power to charge fixed fees to retailers for, for example, returned products and E-Cyle programs.

**6 Conclusions**

Vertical integration can enable firms to raise rivals’ costs through a previously unexplored wholesale pricing incentive. In this study, we present a model where a vertically-integrated firm sells its products directly through its store and indirectly through an independent retailer. Using the tablet computer market in the United States we test the magnitude of any WPI effect. We find that Apple, the dominant firm in the industry, derives 25.8 percent of wholesale margins from such an incentive. Microsoft, another vertically integrated firm in this market, derives a smaller 2.6 percent of margin from the WPI.

Our findings reveal previously unexamined anticompetitive effects of vertical integration. A vertically-integrated firm with significant market share, competing both directly and indirectly, can raise rivals' costs and increase its margins through integration. This paper outlines a method of estimating those effects. We find that tablet prices in the United States are likely elevated because of vertical integration. We perform a simulation that eliminates integration, generating a shift in market share to smaller firms, decreasing the profits of the market leaders. Further research could leverage market data with better access to wholesale costs to simulate equilibrium price and welfare changes from such a change.

While convenient, our assumption of two independent firms in the retail sector likely contributes to more market power in our model estimates. Future work should consider a more explicit retail market structure. Finally, the focus of our empirical analysis is on tablet sales due to data availability, but placing tablet sales in context of these vertically-integrated firms may be useful. None of the major vendors in our data sell tablets exclusively, instead offering a more extensive electronics product line. Apple sells a complete consumer electronics line through Apple stores, including the extremely popular iPhone and a computer line. In contrast, Microsoft has a more limited consumer electronic line that has lacked a cellular phone since 2015. Apple’s scale and scope may create a benefit in cost structure and WPI, whereas Microsoft struggled to achieve a WPI that matched additional costs with a less successful consumer electronics product line. Apple provides a clear example of a company able to pressure competitors with significant market share along an extensive product line in dual channels, but there are other applications to explore. For example, Nike offers an extensive apparel line in both retail and direct distribution. The pricing incentives obtained from this dual distribution could provide an advantage of apparel competitors. Exploring these potential benefits is an area for future research.

**References**

Berry, S., J. Levinsohn, and A. Pakes. 1995. “Automobile Prices in Market Equilibrium.” *Econometrica*, 63(4), 841-90.

Best Buy. 2018. Best Buy Fiscal Annual Report 2018. <https://s2.q4cdn.com/785564492/files/doc_financials/2018/annual/Annual-Report.pdf>.

Bonnet, C., and P. Dubois. 2010. “Inference on Vertical Contracts between Manufacturers and Retailers Allowing for Nonlinear Pricing and Resale Price Maintenance.” *The Rand Journal of Economics*, 41(1), 139-164.

Cain, A. 2019. “Walmart Reveals Its Best-Selling Tech Products of Every Year Since 2010.” Macworld, December 19, <https://www.businessinsider.com/walmart-best-selling-tech-products-ipods-iphones-led-tvs-2019-12>.

Chamberlain, G. 1987. “Asymptotic Efficiency in Estimation with Conditional Moment Restrictions.” *Journal of Econometrics*, 34(3), 305-334.

Chen, Y. 2001. “On Vertical Mergers and Competitive Effects.” *Rand Journal of Economics*, 32, 667-685.

Chipty, T. 2001. “Vertical Integration, Market Foreclosure, and Consumer Welfare in the Cable Television Industry.” *American Economic Review*, 91(3), 428-453.

Conlon, C., and J. Holland Mortimer. 2021. “Empirical Properties of Diversion Ratios.” *Rand Journal of Economics*, 52(4), 693-726.

Crawford, G., R. Lee, M. Whinston, and A. Yurukoglu. 2018. “The Welfare Effects of Vertical Integration in Television Markets.” *Econometrica*, 86(3), 891-954.

Dealerscope. 2019. Sales of the Leading 10 Consumer Electronics Retailers in North America 2010-2018, April, 2019, Dealerscope.com.

Decarolis, F., M. Polyakova, and S. Ryan. 2020. “Subsidy Design in Privately-Provided Social Insurance: Lessons from Medicare Part D.” *Journal of Political Economy*, 128(5), 1712-1752.

DOJ and FTC, 2020. *The 2020 Vertical Merger Guidelines*, June 30, 2020, <https://www.justice.gov/atr/page/file/1290686/download>.

Fan, Y., and C. Yang. 2020. “Competition, Product Proliferation and Welfare: A Study of the U.S. Smartphone Market.” *AEJ Microeconomics*, 12(2), 99-134.

Farrell, J., and C. Shapiro. 2010. “Antitrust Evaluation of Horizontal Mergers: An Economic Alternative to Market Definition.” *The B.E. Journal of Theoretical Economics (Policies perspectives)*, 10(1), Article 9. Available at: <http://www.bepress.com/bejte/vol10/iss1/art9>.

Firdaus. 2011. “Production Cost of Amazon’s Kindle Fire Tablet More Than the Retail Price? <https://socialbarrel.com/production-cost-of-amazon%E2%80%99s-kindle-fire-tablet-more-than-the-retail-price/22012/>.

Gandhi, A., and J. Houde. 2016. “Measuring Substitution Patterns in Differentiated Products Industries.” Working paper, January 26.

Haucap, J., U. Heimeshoff, G. Klein, D. Rickert and C. Wey. 2021. “Vertical Relations, Pass-Through, and Market Definition: Evidence from Grocery Retailing.” *International Journal of Industrial Organization*, 74, 1-25.

Hiller, R., and S. Savage. 2021. “Tariff Pass-Through and Welfare in the Tablet Computer Market.” *Journal of Industrial Economics*, 69(2), 369-409.

Hiller, R., S. Savage, and D. Waldman. 2018. “Using Aggregate Market Data to Estimate Patent Value: An Application to United States Smartphones 2010 to 2015.” *International Journal of Industrial Organization*, 60, 1-31.

IDC, 2019. *Quarterly Personal Computing Device Tracker: 2019Q3 Historical Release*, August 8, Framingham, MA.

Lou, W., D. Prentice, and X. Yin. 2011. “What Difference Does Dynamics Make? The Case of Digital Cameras.” *International Journal of Industrial Organization*, 30, 30-40.

Luco, F., and G. Marshall. 2020. “The Competitive Impact of Vertical Integration by Multiproduct Firms.” *American Economic Review*, 110(7), 2041-2064.

Manuszak, M., R. Goettler, C., Moul, and A. Cohen. 2001. “The Impact of Upstream Mergers on Retail Gasoline Markets.” <https://www.researchgate.net/publication/277296498_The_Impact_of_Upstream_Mergers_on_Retail_Gasoline_Markets>.

Mathewson, F., and F. Winter. 1984. “An Economic Theory of Vertical Restraints.” *Rand Journal of Economics*, 15, 27-38.

Miravete, E., K. Seim, and J. Thurk. 2020. “One Markup to Rule Them All: Taxation by Liquor Pricing Regulation.” *AEJ Microeconomics*, 12(1), 1-41.

Moresi, S., and M. Schwartz. 2021. “Vertical Mergers with Input Substitution: Double Marginalization, Foreclosure and Welfare.” *Economics Letters*, 10(1), Article 9. Available at: <http://www.bepress.com/bejte/vol10/iss1/art9>.

Moulton, B., T. LaFleur, and K. Moses. 1998. “Research on Improved Quality Adjustment in the CPI: The Case of Smartphones.” Bureau of Labor Statistics U.S. Department of Labor, Washington, D.C.

Richards, T., R. Acharya, and I. Molina. 2011. “Retail and Wholesale Market Power in Organic Apples.” *Agribusiness*, 27(1), 62.81.

Riordan, M. 2005. “Competitive Effects of Vertical Integration.” Discussion Paper No. 0506-11, Department of Economics, Columbia University.

Shapiro, C. 2021. “Vertical Mergers and Input Foreclosure: Lessons from the AT&T/Time Warner Case.” *Review of Industrial Organization*, 59, 303-341.

Sudhir, K. 2001. “Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer.” *Marketing Science*, 20(3), 244-264.

Sun, Y. 2012. “The Value of Branding in Two-Sided Platforms.” Working paper, November 27.U.S. Patent and Trademark Office. 2017. *35 U.S.C. 101: Inventions Patentable*. Ninth Edition of the MPEP. <https://www.bitlaw.com/source/35usc/101.html>*.*

Tabini, M. 2013. “How Apple Sets Its Prices.” Macworld, January 13, <https://www.macworld.com/article/220085/how-apple-sets-its-prices.html>.

Train, K., 1986. *Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand*. The MIT Press, Cambridge.

United States Trade Commission. 2014. *Post-Recession Onshoring: An Examination of the U.S. Computer and Electronics Sector*. Office of Industries Working Paper No. ID-038, Washington, DC.

Villas-Boas, S. 2007. “Vertical Relationships Between Manufacturers and Retailers: Inference with Limited Data.” *The Review of Economic Studies*, 74(2), 625-652.

Villas-Boas, J., and Y. Zhao. 2005. “Retailer, Manufacturers and Individual Consumers: Modeling the Supply Side in the Ketchup Market Place.” *Journal of Marketing Research*, 42, 83-95.

Vuong, Q. H. 1989. “Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses.” *Econometrica*, 58, 307-333.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 1. Summary statistics** | | | | |
|  | Mean | S.D. | Min | Max |
| *M* | 2.01e+07 | 6,341,194 | 6,568,836 | 3.58e+07 |
| *SALES* | 32,272 | 100,338 | 50 | 3,981,776 |
| *p (nominal)* | 451.6 | 195.8 | 150.9 | 899 |
| *STORAGE* | 45.37 | 44.39 | 1 | 512 |
| *SCREEN* | 9.174 | 1.534 | 7 | 13 |
| *CPU* | 1.623 | 0.426 | 1 | 2.6 |
| *CORE* | 2.596 | 1.089 | 1 | 6 |
| *MEGAPIXELS* | 4.923 | 2.910 | 0 | 13 |
| *PIXEL DENSITY* | 214.0 | 72.58 | 103.7 | 289.4 |
| *BATTERY* | 9.355 | 2.793 | 3.150 | 25 |
| *CELLULAR* | 0.296 | 0.457 | 0 | 1 |
| *DETACHABLE* | 0.284 | 0.451 | 0 | 1 |
| *ANDROID* | 0.423 | 0.494 | 0 | 1 |
| *AGE* | 4.052 | 3.979 | 0 | 21 |
| *X86* | 0.285 | 0.451 | 0 | 1 |
| *CELLULAR 4G* | 0.263 | 0.440 | 0 | 1 |
| *VI* | 0.301 | 0.459 | 0 | 1 |
| *M* | 2.10e+07 | 5,876,603 | 6,568,836 | 3.58e+07 |
| *Notes*. S.D. is standard deviation. 8,620 observations, except market size (*M*) where the statistics are calculated from 38 quarters. *M* is total mini, traditional and ultra-slim notebook sales plus total tablet computer sales. *SALES* is total tablet sales for each vendor during each quarter. Some of the data on battery life, pixel density, processors, and number of quarters since the product’s release are not reported by IDC and were obtained from third-party websites.  Source. IDC (2019) | | | | |

| **Table 2. Reduced-form retail price regressions** | | | | |
| --- | --- | --- | --- | --- |
|  | With *VI* interacted with  the time trend | | With *VI* interacted with the  quarter fixed effects | |
|  | Coefficient | s.e. | Coefficient | s.e. |
| *CONSTANT* | 10.359\*\*\* | 0.5172 | 8.3051\*\*\* | 0.5753 |
| *STORAGE* | 0.0007\*\*\* | 0.0001 | 0.0007\*\*\* | 0.0001 |
| *SCREEN* | -0.3646\*\*\* | 0.0444 | -0.3926\*\*\* | 0.0517 |
| *CPU* | 0.1703\* | 0.0972 | 0.6983\*\*\* | 0.1106 |
| *CORE* | -0.0248\*\*\* | 0.0055 | -0.0046 | 0.0059 |
| *MEGAPIXELS* | 0.0455\* | 0.0279 | 0.1453\*\*\* | 0.0333 |
| *PIXEL DENSITY* | -0.0002 | 0.0004 | 0.0024\*\*\* | 0.0005 |
| *BATTERY* | -0.6045\*\*\* | 0.0522 | -0.4830\*\*\* | 0.0581 |
| *CELLULAR* | 0.2201\*\*\* | 0.0054 | 0.2230\*\*\* | 0.0051 |
| *DETACHABLE* | 0.1129\*\*\* | 0.0481 | -0.0244 | 0.0503 |
| *ANDROID* | -0.3951\*\*\* | 0.0406 | -0.3957\*\*\* | 0.0440 |
| *AGE* | -0.0023 | 0.0015 | -0.0007 | 0.0019 |
| *X86* | 0.0600\*\*\* | 0.0274 | 0.0610\*\*\* | 0.0274 |
| *VI* | 0.0510\*\*\* | 0.0115 |  |  |
| *VI×TREND* | -0.0021\*\*\* | 0.0005 |  |  |
| *VI×QUARTER1* |  |  | -0.0054 | 0.0429 |
| *VI×QUARTER2* |  |  | -0.0054 | 0.0429 |
| *VI×QUARTER3* |  |  | 0.0063 | 0.0361 |
| *VI×QUARTER4* |  |  | 0.0124 | 0.0274 |
| *VI×QUARTER5* |  |  | -0.0012 | 0.0333 |
| *VI×QUARTER6* |  |  | 0.0274 | 0.0392 |
| *VI×QUARTER7* |  |  | 0.0075 | 0.0268 |
| *VI×QUARTER8* |  |  | -0.0148 | 0.0287 |
| *VI×QUARTER9* |  |  | -0.0430 | 0.0276 |
| *VI×QUARTER10* |  |  | -0.0105 | 0.0241 |
| *VI×QUARTER11* |  |  | 0.0347\* | 0.0200 |
| *VI×QUARTER12* |  |  | 0.0264 | 0.0221 |
| *VI×QUARTER13* |  |  | 0.0161 | 0.0253 |
| *VI×QUARTER15* |  |  | 0.0665\*\*\* | 0.0219 |
| *VI×QUARTER16* |  |  | 0.0534\*\*\* | 0.0203 |
| *VI×QUARTER17* |  |  | 0.0696\*\*\* | 0.0197 |
| *VI×QUARTER18* |  |  | 0.0660\*\*\* | 0.0209 |
| *VI×QUARTER19* |  |  | -0.0155 | 0.0226 |
| *VI×QUARTER20* |  |  | -0.0176 | 0.0184 |
| *VI×QUARTER21* |  |  | -0.0113 | 0.0188 |
| *VI×QUARTER22* |  |  | -0.0126 | 0.0183 |
| *VI×QUARTER23* |  |  | -0.0205 | 0.0170 |
| *VI×QUARTER24* |  |  | -0.0214 | 0.0189 |
| *VI×QUARTER25* |  |  | -0.0160 | 0.0179 |
| *VI×QUARTER26* |  |  | -0.0140 | 0.0190 |
| *VI×QUARTER27* |  |  | 0.0231 | 0.0215 |
| *VI×QUARTER28* |  |  | 0.0130 | 0.0218 |
| *VI×QUARTER29* |  |  | 0.0152 | 0.0169 |
| *VI×QUARTER30* |  |  | -0.0368 | 0.0277 |
| *VI×QUARTER31* |  |  | -0.0249 | 0.0266 |
| *VI×QUARTER32* |  |  | -0.0320 | 0.0280 |
| *VI×QUARTER33* |  |  | -0.0372 | 0.0197 |
| *VI×QUARTER34* |  |  | -0.0184 | 0.0182 |
| *VI×QUARTER35* |  |  | -0.0221 | 0.0181 |
| *VI×QUARTER36* |  |  | -0.0314 | 0.0232 |
| *VI×QUARTER37* |  |  | -0.0051 | 0.0246 |
| *VI×QUARTER38* |  |  | -0.0072 | 0.0192 |
| Joint test of trend | 10.27\*\*\* |  |  |  |
| Joint test of interactions |  |  | 5.14\*\*\* |  |
| Brand fixed effects | Yes |  | Yes |  |
| Model fixed effects | Yes |  | Yes |  |
| Quarter fixed effects | No |  | Yes |  |
| Adjusted R2 | 0.8860 |  | 0.8988 |  |
| *Notes*. Dependent variable is *ln(pjt)*. 8,620 observations. s.e. is robust standard error. \*significant at ten percent. \*\*significant at five percent. \*\*\*significant at one percent. Joint test of trend tests the null that estimated coefficients on *VIjt* and *VIjt×TRENDt* are jointly equal to zero. Joint test of interactions tests the null that the estimated coefficients on the interactions *VIjt×QUARTER11* through *VIjt×QUARTER18* are jointly equal to zero. | | | | |

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| **Table 3. Estimates of consumer demand** | | | | | | |
|  | (i) FCL-OLS | | (ii) FCL-GMM | | (iii) RCL-BLP | |
|  | MU | s.e. | MU | s.e. | MU | s.e. |
| *CONSTANT* | -8.0303\*\*\* | 0.5918 | -10.569\*\*\* | 1.0020 | -4.2851\*\*\* | 0.7847 |
| *STORAGE* | -0.0009\*\*\* | 0.0003 | 0.0066\*\*\* | 0.0013 | 0.0033\*\*\* | 0.0006 |
| *SCREEN* | 0.1155\*\* | 0.0531 | 1.5186\*\*\* | 0.2235 | 1.0911\*\*\* | 0.1057 |
| *CPU* | 0.4774\*\* | 0.2089 | 0.4675 | 0.3707 | -0.0044 | 0.3012 |
| *CORE* | 0.0138 | 0.0221 | 0.1135 | 0.0340 | 0.0542\* | 0.0296 |
| *MEGAPIXELS* | 0.0244\*\* | 0.0291 | 0.0779 | 0.0475 | 0.1469\*\*\* | 0.0400 |
| *MEGAPIXELS2* | -0.0049\*\* | 0.0023 | 0.0102\*\* | 0.0041 | -0.0006 | 0.0033 |
| *PIXEL DENSITY* | -0.0040\*\*\* | 0.0005 | 0.0116\*\*\* | 0.0025 | 0.0094\*\*\* | 0.0012 |
| *CELLULAR* | -0.7787\*\*\* | 0.0539 | 1.3492\*\*\* | 0.3319 | 0.9624\*\*\* | 0.1393 |
| *DETACHABLE* | -0.3727\*\*\* | 0.0835 | 0.7046\*\*\* | 0.2011 | 0.2198\* | 0.1253 |
| *ANDROID* | -0.0446 | 0.0916 | -2.8804\*\*\* | 0.4474 | -2.7494\*\*\* | 0.2034 |
| *AGE* | -0.0598\*\*\* | 0.0074 | -0.0829\*\*\* | 0.0139 | -0.0642\*\*\* | 0.0115 |
| *BATTERY×SCREEN* | -0.0242\*\*\* | 0.0052 | -0.0416\*\*\* | 0.0083 | -0.0197\*\*\* | 0.0070 |
| *BATTERY×CPU* | -0.0086 | 0.0227 | 0.0262 | 0.0388 | 0.0986\*\*\* | 0.0329 |
| *INDIRECT* | -0.0688 | 0.1322 | -0.9019\*\*\* | 0.2272 | -0.7786\*\*\* | 0.1761 |
| *INDIRECT×TREND* | 0.0284\*\*\* | 0.0053 | 0.0589\*\*\* | 0.0088 | 0.0559\*\*\* | 0.0069 |
| *PRICE (p)* |  |  |  |  |  |  |
| Mean | -0.0001 | 0.0002 | -0.0231\*\*\* | 0.0034 | -0.0309\*\*\* | 0.0013 |
| S.D. |  |  |  |  | 0.0114\*\*\* | 0.0013 |
| *BATTERY* |  |  |  |  |  |  |
| Mean | 0.3088\*\*\* | 0.0561 | 0.4221\*\*\* | 0.0868 | -0.0072 | 0.0725 |
| S.D. |  |  |  |  | 0.1869\*\*\* | 0.0305 |
| Relevance |  |  | 18.06\*\*\* |  | 102.8\*\*\* |  |
| Validity |  |  | 2.945 |  |  |  |
| *Notes*. MU is marginal utility. 8,620 observations. s.e. is robust standard error. \*significant at ten percent. \*\*significant at five percent. \*\*\*significant at one percent. S.D. is standard deviation. Brand and quarter fixed effects are not reported. RCL-BLP specification is estimated with optimal instruments. Relevance is an *F* test of the significance of first-stage excluded instruments. Validity is the Hansen *J* test of the null that the overidentification restrictions are appropriate. | | | | | | |

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| **Table 4 Brand-level price elasticities of demand** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS | -5.9972 | 0.0001 | 0.0099 | 0.2034 | 0.0002 | 0.0001 | 0.0010 | 0.0039 | 0.0002 | 0.0313 |
| Acer | 0.0000 | -6.2133 | 0.0006 | 0.1310 | 0.0000 | 0.0001 | 0.0007 | 0.0360 | 0.0000 | 0.0201 |
| Amazon | 0.0002 | 0.0000 | -4.1644 | 0.1629 | 0.0003 | 0.0001 | 0.0009 | 0.0013 | 0.0003 | 0.0301 |
| Apple | 0.0001 | 0.0004 | 0.0041 | -6.2847 | 0.0001 | 0.0001 | 0.0010 | 0.0164 | 0.0001 | 0.0281 |
| E Fun | 0.0001 | 0.0000 | 0.0099 | 0.1656 | -4.7386 | 0.0001 | 0.0008 | 0.0023 | 0.0002 | 0.0242 |
| HP | 0.0001 | 0.0002 | 0.0055 | 0.1837 | 0.0001 | -5.6947 | 0.0009 | 0.0109 | 0.0001 | 0.0261 |
| Lenovo | 0.0001 | 0.0003 | 0.0097 | 0.1989 | 0.0002 | 0.0001 | -6.3275 | 0.0114 | 0.0002 | 0.0353 |
| Microsoft | 0.0001 | 0.0007 | 0.0019 | 0.1506 | 0.0001 | 0.0001 | 0.0008 | -3.8176 | 0.0001 | 0.0219 |
| RCA | 0.0001 | 0.0000 | 0.0117 | 0.1663 | 0.0002 | 0.0001 | 0.0008 | 0.0019 | -4.5732 | 0.0264 |
| Samsung | 0.0001 | 0.0001 | 0.0108 | 0.1994 | 0.0002 | 0.0001 | 0.0010 | 0.0073 | 0.0002 | -5.4794 |
| *Notes*. Brand-level elasticities are sales-weighted calculations for all models sold in the consumer market by brand *f(j)* during the third quarter of 2019. | | | | | | | | | | |

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| **Table 5. Simulated tablet wholesale margins and costs for indirect sales by integrated manufacturers** | | | | | | | | | |
| Vendor | Models  (versions)+ | Indirect  sales+ | Indirect  online  sales+ | Indirect  online  share | Price+  ($) | Marginal  cost ($) | Wholesale  Margin  ($) | WPI  ($) | WPI /  wholesale margin++ |
| All | 35 (58) | 3,535,044 | 1,013,937 | 0.2868 | 356.24 | 227.81 | 83.19 | 16.54 | 0.1797 |
| Amazon | 1 (1) | 9,474 | 852 | 0.0899 | 136.00 | 75.98 | 33.85 | 0.08 | 0.0024 |
| Apple | 6 (15) | 2,430,565 | 726,820 | 0.2990 | 357.24 | 220.14 | 92.36 | 23.80 | 0.2589 |
| HP | 5 (5) | 803 | 493 | 0.6140 | 275.91 | 193.86 | 47.17 | 0.00 | 0.0000 |
| Lenovo | 9 (12) | 26,951 | 5,728 | 0.2125 | 291.22 | 206.61 | 46.40 | 0.00 | 0.0001 |
| Microsoft | 2 (4) | 214,187 | 82,122 | 0.3834 | 604.15 | 421.75 | 106.23 | 2.79 | 0.0240 |
| RCA | 1 (1) | 33,932 | 31,993 | 0.9429 | 161.00 | 99.26 | 36.23 | 0.00 | 0.0000 |
| Samsung | 11 (20) | 819,132 | 165,929 | 0.2026 | 301.27 | 207.64 | 53.73 | 0.05 | 0.0010 |
| *Notes*. Third quarter of 2019. All is all seven vertically integrated manufacturers combined. Models is the number of unique tablet models for each manufacturer and versions is the number of model versions. Marginal cost is the sum of production and retail costs. Price, marginal cost, wholesale margin, WPI, and WPI/wholesale margin++ are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019. WPI is the wholesale pricing incentive of a vertically integrated firm. Indirect sales are wholesale sales to physical and online retailers. Indirect online sales are wholesale sales to online retailers.  Source. +IDC (2019) | | | | | | | | | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 6. Simulated retail margins and costs for direct sales by integrated manufacturers** | | | | | | | | | |
| Vendor | Models  (versions)+ | Direct  sales+ | Direct  online  sales+ | Direct  online  share | Price+  ($) | Marginal  cost  ($) | Retail margin  ($) | RPI  ($) | RPI/  Retail margin |
| All | 21 (34) | 1,305,728 | 586,762 | 0.4494 | 333.43 | 241.19 | 92.24 | 33.05 | 0.3522 |
| Amazon | 1 (1) | 26,228 | 26,228 | 1 | 136.00 | 103.27 | 32.73 | 0.06 | 0.0017 |
| Apple | 3 (10) | 1,202,099 | 506,573 | 0.4214 | 326.07 | 232.60 | 93.46 | 35.21 | 0.3758 |
| HP | 3 (3) | 249 | 249 | 1 | 315.10 | 263.84 | 51.26 | 0.00 | 0.0001 |
| Lenovo | 6 (7) | 972 | 972 | 1 | 278.26 | 233.77 | 44.49 | 0.19 | 0.0049 |
| Microsoft | 1 (2) | 66,441 | 43,001 | 0.6472 | 568.13 | 466.01 | 102.12 | 11.63 | 0.1011 |
| RCA | 1 (1) | 183 | 183 | 1 | 161.00 | 125.67 | 35.33 | 0.15 | 0.0042 |
| Samsung | 6 (10) | 9,556 | 9,556 | 1 | 179.85 | 139.91 | 39.94 | 5.62 | 0.1412 |
| *Notes*. Third quarter of 2019. All is all seven vertically integrated manufacturers combined. Models is the number of unique tablet models for each manufacturer and versions is the number of model versions. Marginal cost is the sum of production and retail costs. Price, retail margin, marginal cost, RPI, and RPI/retail margin are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019.RPI is the Retail Pricing Incentive of a vertically integrated firm. Direct sales are direct physical and online sales to customers. Direct online sales are direct online sales to consumers.  Source. +IDC (2019) | | | | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 7. Simulation with no vertical integration** | | | | | | |
| Vendor | Total Share Change  (%) | Indirect Change  (%) | Price+  ($) | Wholesale Margin  ($) | Wholesale Margin Change (%) | Variable Profit Change  (%) |
| All | -9.8 | 23.7 | 359.12 | 81.94 | -1.5 | -13.6 |
| Amazon | -70.0 | 13.1 | 136.00 | 33.36 | -1.4 | -69.7 |
| Apple | -16.8 | 24.4 | 358.73 | 90.00 | -2.6 | -19.2 |
| HP | -8.9 | 19.4 | 281.53 | 47.77 | 1.3 | -9.6 |
| Lenovo | 17.5 | 21.7 | 294.63 | 46.81 | 0.9 | 18.7 |
| Microsoft | -5.4 | 27.4 | 620.23 | 108.20 | 1.9 | -2.7 |
| RCA | 13.4 | 14.0 | 161.00 | 36.26 | 0.1 | 13.5 |
| Samsung | 20.1 | 21.5 | 308.51 | 54.49 | 1.4 | 22.2 |
| *Notes*. Third quarter of 2019. All is all seven vendors combined. Total share change, indirect change, and wholesale margin change are the percentage change of sales from the baseline scenario of vertical integration to the no vertical integration scenario. Price and wholesale margin are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019. Variable profit change considers the difference in share and wholesale margin, as well as the loss of direct sales with retail margin to calculate the difference in profit from the foreclosed direct channel scenario, excluding fixed costs. All dollar changes are due to shifts in demand and market share resulting from the removal of vertical integration without any changes in equilibrium prices.  Source. +IDC (2019) | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 8. Non-nested comparisons** | | | |
| Null | Difference | t | P > | t | |
| 1. Linear pricing | - | - | - |
| 2. Nonlinear pricing with zero WPI and RPI incentives | 0.0006 | 2.36 | 0.043 |
| 3. Nonlinear pricing with zero wholesale margins | 0.0036 | 1.82 | 0.107 |
| 4. Nonlinear pricing with zero retail margins | 0.0036 | 1.84 | 0.101 |
| 5. Nonlinear pricing with a combination of 3 and 4 | -0.0008 | -1.13 | 0.287 |
| *Notes*. Null compares model’s 2 through 5 to model 1. Difference is the residual sum of squares from model 1 less the residual sum of squares from models 2 through 5, respectively. t is the (uncorrected) t-statistic where the underlying standard errors and clustered by brand. P > | t | is the probability of rejecting the null hypothesis. | | | |

**Figure 1. Quarterly tablet sales 2010 to 2019 (m)**

Source. IDC (2019)

**Figure 2. Direct sales by manufacturers 2010 to 2019**

Source. IDC (2019)

**Figure 3. Average revenue per unit 2010 to 2019**

Source. IDC (2019)

**Appendix A Price-cost markups**

Equation (6) can be rearranged into the retail price markup equation for the multi-product retail firm *fd*:

 (6*'*)

where  is the own-price elasticity of demand for product *j* with respect to the retail price and  is the diversion ratio between products *j* and *k* for all . The diversion ratio measures the fraction of sales lost on product *j* that are diverted to product *k* ≠ *j* following an increase in the price of product *j* (Farrell and Shapiro, 2010; Conlon and Mortimer, 2021; Shapiro, 2021). Given the positive retail margin, , earned from sales that are diverted from product *j* to *k* ≠ *j*, the firm only loses a fraction, 1 – *Djk*, of its overall net-revenue when increasing the price of product *j*. As such, firm *fd* can set a higher retail price for product *j* than a single-product firm because it internalizes the substitution effects from all products in its joint profit function.

Equation (7) can be rearranged into the retail price markup equation for the vertically-integrated multi-product firm *fv*:

 (7*'*)

Equation (8) can be rearranged into the wholesale price markup equation for the multi-product manufacturing firm *fu*:

 (8*'*)

where  is the own-price elasticity of demand for product *j* with respect to the wholesale price,  is the total derivative of product *j* with respect to the wholesale price and measures the strategic effects of the second stage choices of wholesale prices on retail prices,  is the diversion ratio between products *j* and *k* for all , and  is the total derivative of product *k* with respect to the wholesale price.

Equation (9) can be rearranged into the wholesale price markup equation for the vertically-integrated multi-product firm *fv*:

 (9*'*)

where  is the elasticity of the retail price for product *m* with respect to the wholesale price for product *k* for all ,  is the diversion ratio between products *k* and *m* for all , and  is the total derivative of product *m* with respect to the wholesale price.

**Appendix B Total differentiation of optimal retail prices**

Total differentiation of equation (6) with respect to wholesale price  is:

 (13*'*)

where  equals one when *j* = *k* and zero otherwise.

Total differentiation of equation (7) with respect to wholesale price  is:

 (14*'*)

where  equals one when *j* = *k* and zero otherwise.

**Appendix C Elasticities**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table C1 Brand-level price elasticities of demand for indirect sales** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS | -5.9981 | 0.0001 | 0.0037 | 0.1958 | 0.0002 | 0.0001 | 0.0010 | 0.0037 | 0.0001 | 0.0312 |
| Acer | 0.0000 | -6.1944 | 0.0002 | 0.1422 | 0.0000 | 0.0001 | 0.0007 | 0.0355 | 0.0000 | 0.0202 |
| Amazon | 0.0002 | 0.0000 | -4.1749 | 0.1512 | 0.0003 | 0.0001 | 0.0008 | 0.0013 | 0.0002 | 0.0298 |
| Apple | 0.0001 | 0.0004 | 0.0015 | -6.2584 | 0.0001 | 0.0001 | 0.0010 | 0.0160 | 0.0001 | 0.0282 |
| E Fun | 0.0001 | 0.0000 | 0.0037 | 0.1563 | -4.7394 | 0.0001 | 0.0008 | 0.0022 | 0.0001 | 0.0241 |
| HP | 0.0001 | 0.0002 | 0.0021 | 0.1834 | 0.0001 | -5.6876 | 0.0009 | 0.0106 | 0.0001 | 0.0261 |
| Lenovo | 0.0001 | 0.0003 | 0.0036 | 0.1966 | 0.0002 | 0.0001 | -6.3364 | 0.0111 | 0.0001 | 0.0352 |
| Microsoft | 0.0001 | 0.0007 | 0.0007 | 0.1594 | 0.0001 | 0.0001 | 0.0008 | -3.4911 | 0.0000 | 0.0221 |
| RCA | 0.0001 | 0.0000 | 0.0043 | 0.1560 | 0.0002 | 0.0001 | 0.0008 | 0.0018 | -4.5740 | 0.0262 |
| Samsung | 0.0001 | 0.0001 | 0.0040 | 0.1950 | 0.0002 | 0.0001 | 0.0010 | 0.0070 | 0.0001 | -5.4821 |
| *Notes*. Brand-level elasticities are sales-weighted calculations for all models sold directly in the consumer market by brand *f(j)* during the third quarter of 2019. | | | | | | | | | | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table C2 Brand-level price elasticities of demand for direct sales** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS |  |  | 0.0121 | 0.2196 |  | 0.0001 | 0.0014 | 0.0047 | 0.0156 | 0.0395 |
| Acer |  |  | 0.0007 | 0.1070 |  | 0.0001 | 0.0004 | 0.0374 | 0.0017 | 0.0029 |
| Amazon |  |  | -4.1615 | 0.1879 |  | 0.0001 | 0.0018 | 0.0015 | 0.0208 | 0.0589 |
| Apple |  |  | 0.0050 | -6.3543 |  | 0.0001 | 0.0009 | 0.0180 | 0.0077 | 0.0173 |
| E Fun |  |  | 0.0121 | 0.1854 |  | 0.0001 | 0.0011 | 0.0027 | 0.0157 | 0.0365 |
| HP |  |  | 0.0068 | 0.1842 |  | -5.7116 | 0.0010 | 0.0123 | 0.0098 | 0.0215 |
| Lenovo |  |  | 0.0119 | 0.2036 |  | 0.0001 | -6.0755 | 0.0124 | 0.0135 | 0.0417 |
| Microsoft |  |  | 0.0024 | 0.1355 |  | 0.0001 | 0.0006 | -5.1674 | 0.0041 | 0.0078 |
| RCA |  |  | 0.0144 | 0.1881 |  | 0.0001 | 0.0013 | 0.0023 | -4.5567 | 0.0438 |
| Samsung |  |  | 0.0132 | 0.2087 |  | 0.0001 | 0.0016 | 0.0082 | 0.0153 | -5.1351 |
| *Notes*. Brand-level elasticities are sales-weighted calculations for all models sold indirectly in the consumer market by brand *f(j)* during the third quarter of 2019. ASUS, Acer, and E Fun do not have elasticity results because they do not have any direct tablet offerings. | | | | | | | | | | |

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| **Table C3 Brand-level price elasticities of demand for online sales** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS | -6.1314 | 0.0003 | 0.0101 | 0.2122 | 0.0003 | 0.0001 | 0.0012 | 0.0027 | 0.0022 | 0.0353 |
| Acer | 0.0001 | -6.3380 | 0.0006 | 0.1548 | 0.0000 | 0.0000 | 0.0009 | 0.0197 | 0.0002 | 0.0244 |
| Amazon | 0.0002 | 0.0001 | -4.1632 | 0.1637 | 0.0004 | 0.0001 | 0.0010 | 0.0011 | 0.0029 | 0.0324 |
| Apple | 0.0002 | 0.0021 | 0.0042 | -6.2315 | 0.0002 | 0.0000 | 0.0012 | 0.0095 | 0.0011 | 0.0331 |
| E Fun | 0.0002 | 0.0002 | 0.0101 | 0.1692 | -4.7378 | 0.0000 | 0.0010 | 0.0017 | 0.0022 | 0.0269 |
| HP | 0.0002 | 0.0013 | 0.0057 | 0.1991 | 0.0002 | -5.0044 | 0.0011 | 0.0065 | 0.0014 | 0.0304 |
| Lenovo | 0.0002 | 0.0015 | 0.0100 | 0.2134 | 0.0003 | 0.0001 | -6.4668 | 0.0067 | 0.0019 | 0.0402 |
| Microsoft | 0.0001 | 0.0038 | 0.0020 | 0.1720 | 0.0001 | 0.0000 | 0.0010 | -3.8648 | 0.0006 | 0.0262 |
| RCA | 0.0002 | 0.0001 | 0.0120 | 0.1690 | 0.0003 | 0.0001 | 0.0010 | 0.0015 | -4.5701 | 0.0290 |
| Samsung | 0.0002 | 0.0008 | 0.0109 | 0.2113 | 0.0003 | 0.0001 | 0.0012 | 0.0046 | 0.0022 | -5.4105 |
| *Notes*. Brand-level elasticities are sales-weighted calculations for all models sold online in the consumer market by brand *f(j)* during the third quarter of 2019. | | | | | | | | | | |

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| **Table C4 Brand-level price elasticities of demand for physical sales** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS | -5.9371 | 0.0000 | 0.0004 | 0.1904 | 0.0002 | 0.0002 | 0.0001 | 0.0057 | 0.0001 | 0.0123 |
| Acer | 0.0000 | -6.2100 | 0.0000 | 0.0929 | 0.0000 | 0.0001 | 0.0000 | 0.0590 | 0.0000 | 0.0016 |
| Amazon | 0.0001 | 0.0000 | -4.1785 | 0.1629 | 0.0002 | 0.0002 | 0.0002 | 0.0016 | 0.0001 | 0.0180 |
| Apple | 0.0001 | 0.0002 | 0.0002 | -6.3864 | 0.0001 | 0.0002 | 0.0001 | 0.0262 | 0.0000 | 0.0059 |
| E Fun | 0.0001 | 0.0000 | 0.0004 | 0.1606 | -4.7379 | 0.0002 | 0.0001 | 0.0031 | 0.0001 | 0.0114 |
| HP | 0.0001 | 0.0001 | 0.0002 | 0.1597 | 0.0001 | -6.4782 | 0.0001 | 0.0173 | 0.0001 | 0.0072 |
| Lenovo | 0.0001 | 0.0001 | 0.0004 | 0.1766 | 0.0001 | 0.0002 | -5.7887 | 0.0181 | 0.0001 | 0.0129 |
| Microsoft | 0.0000 | 0.0004 | 0.0001 | 0.1165 | 0.0001 | 0.0001 | 0.0000 | -3.7674 | 0.0000 | 0.0031 |
| RCA | 0.0001 | 0.0000 | 0.0005 | 0.1630 | 0.0002 | 0.0002 | 0.0001 | 0.0025 | -4.5725 | 0.0136 |
| Samsung | 0.0001 | 0.0001 | 0.0004 | 0.1802 | 0.0001 | 0.0002 | 0.0001 | 0.0116 | 0.0001 | -5.3442 |
| *Notes*. Brand-level elasticities are sales-weighted calculations for all models sold physically in the consumer market by brand *f(j)* during the third quarter of 2019. | | | | | | | | | | |

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| **Table C5 Calibrated brand-level price elasticities of demand** | | | | | | | | | | |
|  | ASUS | Acer | Amazon | Apple | E Fun | HP | Lenovo | Microsoft | RCA | Samsung |
| ASUS | -8.9937 | 0.0001 | 0.0099 | 0.2038 | 0.0002 | 0.0001 | 0.0010 | 0.0039 | 0.0002 | 0.0313 |
| Acer | 0.0000 | -9.3207 | 0.0006 | 0.1312 | 0.0000 | 0.0001 | 0.0007 | 0.0361 | 0.0000 | 0.0204 |
| Amazon | 0.0002 | 0.0000 | -4.7168 | 0.1633 | 0.0003 | 0.0001 | 0.0009 | 0.0013 | 0.0003 | 0.0299 |
| Apple | 0.0001 | 0.0004 | 0.0041 | -8.3798 | 0.0001 | 0.0001 | 0.0010 | 0.0164 | 0.0001 | 0.0284 |
| E Fun | 0.0001 | 0.0000 | 0.0099 | 0.1659 | -7.1060 | 0.0001 | 0.0008 | 0.0023 | 0.0002 | 0.0242 |
| HP | 0.0001 | 0.0002 | 0.0056 | 0.1840 | 0.0001 | -7.6017 | 0.0009 | 0.0109 | 0.0001 | 0.0263 |
| Lenovo | 0.0001 | 0.0003 | 0.0097 | 0.1993 | 0.0002 | 0.0001 | -7.9965 | 0.0114 | 0.0002 | 0.0355 |
| Microsoft | 0.0001 | 0.0007 | 0.0019 | 0.1502 | 0.0001 | 0.0001 | 0.0008 | -4.4927 | 0.0001 | 0.0221 |
| RCA | 0.0001 | 0.0000 | 0.0117 | 0.1666 | 0.0002 | 0.0001 | 0.0008 | 0.0019 | -4.7140 | 0.0263 |
| Samsung | 0.0001 | 0.0001 | 0.0107 | 0.1994 | 0.0002 | 0.0001 | 0.0010 | 0.0075 | 0.0002 | -7.2833 |
| *Notes*. Calibrated brand-level elasticities are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019. When optimizing the firm’s objective function, we increased the diagonal elements of Sp by 50 percent for all products that are sold indirectly to consumers. | | | | | | | | | | |

**Appendix D Numerical solution method for vertical integration**

We solve equation (15) for equilibrium wholesale and retail price cost margins with an iterative algorithm that determines the values of w – c and p – mc to minimize Ω(w – c, p – mc). For easier explanation, let θt = [(w – c)t, (p – mc)t] be a *2J* ×1 vector of the current values of the parameters for the objective function Ω(θt), where the current values in θt are t steps from the starting values in θ0. The solution method proceeds as follows:

(i) Construct the observed ownership matrices, Iu, Id, , Γv,  and Γp, the vector of observed market shares, s, and the vector of observed retail prices, p, directly from the data.

(ii) Use the estimated means and standard deviations from the RCL model results in Table 3 to draw the marginal utilities of price and battery, respectively, for 1,000 consumers from the normal distribution. Use the observed retail prices and product characteristics, the full set of estimated demand parameters, and the distributions of the marginal utilities of price and battery from (i) above to calculate the vector of the expected values of product market shares, , to approximate equation (3).

(iii) Use Train’s (1986) algorithm to recalibrate the estimated brand-specific fixed effects according to *λ1* = *λ0* + ln(s/), where *λ1* is the vector of adjusted estimates of *λf(j)* after one iteration, and *λ0* is the vector of initial estimates from the RCL model.[[19]](#footnote-19)

(iv) Use the consumer draws of the marginal utility of price and the estimated market shares to calculate the expected value of the *J* × *J* matrix of first-order derivatives of retail market shares with respect to all retail prices, Sp, and the expected value of the *J* × *J* × *J* array of second-order derivatives of retail market shares with respect to all retail prices, Spp. Use Sp, Spp and equations (12) through (14) to calculate the *J* × *J* matrix of derivatives of retail prices with respect to all wholesale prices, Pw. Form Sw = Sp × Pw.[[20]](#footnote-20)

(v) Form the objective function Ω(θt+1) and take a second-order Taylor’s approximation of Ω(θt+1) around Ω(θt). Use the first-order condition = 0 to find the value of θt+1 that maximizes this approximation to Ω(θt+1). The first-order condition can be arranged into θt+1 = θt + (–Ht-1)gt, where θt=0 are the starting values, H is the Hessian matrix of second derivatives, and g is the gradient vector of first derivatives.

(vi) Use θt+1 = θt + (–Ht-1)gt to find the steps from θt to θt+1 and continue until the convergence criteria are met and Ω(θt+1) is sufficiently close to its optimal value.[[21]](#footnote-21)

**Appendix E Supply-side simulation for the first quarter of 2016**

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| **Table E1. Simulated tablet wholesale margins and costs for indirect sales by integrated manufacturers** | | | | | | | | | |
| Vendor | Models  (versions)+ | Indirect  sales+ | Indirect  online  sales+ | Indirect  online  share | Price+  ($) | Marginal  cost ($) | Wholesale  Margin  ($) | WPI  ($) | WPI /  wholesale margin++ |
| All | 51 (162) | 2,752,269 | 1,457,840 | 0.5297 | 406.11 | 295.31 | 74.29 | 19.97 | 0.2015 |
| Acer | 5 (18) | 106,619 | 29,237 | 0.2742 | 276.25 | 208.78 | 38.40 | 0.00 | 0.0001 |
| Apple | 5 (45) | 1,603,890 | 775,095 | 0.4833 | 487.71 | 351.25 | 96.24 | 34.22 | 0.3449 |
| HP | 14 (35) | 35,024 | 9,521 | 0.2718 | 501.09 | 406.75 | 52.90 | 0.04 | 0.0008 |
| Lenovo | 10 (27) | 53,611 | 24,126 | 0.4500 | 296.42 | 229.96 | 37.17 | 0.01 | 0.0002 |
| Microsoft | 3 (10) | 96,791 | 40,334 | 0.4167 | 621.03 | 507.98 | 63.90 | 0.26 | 0.0037 |
| Nabi | 3 (6) | 67,918 | 21,621 | 0.3183 | 197.40 | 136.25 | 34.83 | 0.00 | 0.0001 |
| RCA | 2 (3) | 124,927 | 93,301 | 0.7468 | 165.52 | 107.28 | 33.55 | 0.00 | 0.0000 |
| Samsung | 9 (18) | 663,488 | 464,604 | 0.7002 | 268.89 | 194.03 | 44.36 | 0.08 | 0.0017 |
| *Notes*. First quarter of 2016. All is all eight vertically integrated manufacturers combined. Models is the number of unique tablet models for each manufacturer and versions is the number of model versions. Marginal cost is the sum of production and retail costs. Price, marginal cost, wholesale margin, WPI, and WPI/wholesale margin++ are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019. WPI is the wholesale pricing incentive of a vertically integrated firm. Indirect sales are wholesale sales to physical and online retailers. Indirect online sales are wholesale sales to online retailers.  Source. +IDC (2019) | | | | | | | | | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table E2. Simulated retail margins and costs for direct sales by integrated manufacturers** | | | | | | | | | |
| Vendor | Models  (versions)+ | Direct  sales+ | Direct  online  sales+ | Direct  online  share | Price+  ($) | Marginal  cost  ($) | Retail margin  ($) | RPI  ($) | RPI/  Retail margin |
| All | 33 (89) | 772,899 | 416,680 | 0.5391 | 531.27 | 417.09 | 114.18 | 49.84 | 0.4197 |
| Acer | 4 (8) | 1,278 | 981 | 0.7679 | 245.51 | 210.27 | 35.25 | 0.66 | 0.0189 |
| Apple | 6 (34) | 717,502 | 389,884 | 0.5434 | 530.35 | 411.75 | 118.60 | 53.47 | 0.4482 |
| HP | 10 (18) | 10,889 | 2,241 | 0.2058 | 489.92 | 441.04 | 48.87 | 0.48 | 0.0093 |
| Lenovo | 8 (11) | 2,656 | 1,630 | 0.6137 | 527.92 | 470.32 | 57.60 | 0.42 | 0.0112 |
| Microsoft | 3 (10) | 27,162 | 16,841 | 0.6200 | 633.00 | 568.47 | 64.52 | 2.62 | 0.0390 |
| Nabi | 1 (2) | 1,180 | 671 | 0.5682 | 190.64 | 157.52 | 33.12 | 0.37 | 0.0111 |
| Samsung | 5 (6) | 12,233 | 4,432 | 0.3623 | 459.81 | 407.78 | 52.03 | 6.35 | 0.1301 |
| *Notes*. First quarter of 2016. All is all seven vertically integrated manufacturers combined. Models is the number of unique tablet models for each manufacturer and versions is the number of model versions. Marginal cost is the sum of production and retail costs. Price, retail margin, marginal cost, RPI, and RPI/retail margin are sales-weighted calculations for all models sold in the consumer market during the third quarter of 2019.RPI is the Retail Pricing Incentive of a vertically integrated firm. Direct sales are direct physical and online sales to customers. Direct online sales are direct online sales to consumers.  Source. +IDC (2019) | | | | | | | | | |

**Appendix F Solution method for no vertical integration**

We begin by using the same steps as outlined in Appendix D to recover the marginal costs of production and distribution. Given marginal costs, the solution method proceeds as follows:

(i) Remove any product characteristics with positive utility from all directly sold products in vector *Xjt* in order to ensure the predicted market share of those products will be zero. Adjust ownership matrices Iu, Id, , Γv,  and Γp such that all products sold directly are no longer considered in the optimization process for those firms.

(ii) Use the existing marginal utilities estimates of price and battery, respectively, combined with existing retail prices and product characteristics, the full set of estimated demand parameters, and the distributions of the marginal utilities of price and battery from Appendix D to re-calculate the vector of the expected values of product market shares, , to approximate equation (3) with the directly sold products excluded.

(iii) Given marginal costs and market shares, calculate firm sales and profits.

**Appendix G Alternative pricing assumptions**

In the linear pricing model (a) described in Section 3.2.3, the *J* × 1 vector of first-order conditions for retail prices is:

 (11)

The sum of the marginal cost of production and distribution, C = c + rc, under this scenario is:

 (17)

For robustness, we now consider several possible nonlinear pricing models. In nonlinear pricing model (b), the vertically-integrated manufacturers forgo the variable profits from their WPI and RPI incentives and set g = h = 0 in equations (11) and (17). They then extract some of their lost surplus with fixed fees that the retailers must pay to the vertically-integrated manufacturers. The *J* × 1 vector of first-order conditions for retail prices is:

 (18)

Rearranging equation (18), the marginal cost of production and distribution in this model is:

 (19)

Following Villa-Boas (2007) and Bonnet and Dubois (2010), we also consider nonlinear pricing model (c) where the manufacturing firms let the retailing firms be the residual claimants on profits by eliminating the wholesale price-cost margin. The retailers will maximize their profits given that the wholesale prices are equal to the marginal costs of production. The manufacturer extracts part of the surplus with a fixed fee that the retailers must pay. When w = c,  = 0, and the *J* × 1 vector of first-order conditions for retail prices is:

 (20)

Rearranging equation (20), the marginal cost of production and distribution in this model is:

 (21)

In nonlinear pricing model (d), retailing firms let the manufacturing firms be the residual claimants on profits by eliminating the retail price-cost margin. The manufacturers will maximize their profits given that the retail prices are equal to the marginal costs of production and distribution. Retailers set franchise fees to extract the manufacturer’s profits. When p = mc, , and the *J* × 1 vector of first-order conditions for wholesale prices is:

 (22)

Since the retail prices equal marginal costs, Pw is now a diagonal matrix and Sw = Sp×Pw = Sp. Rearranging equation (22), the marginal cost of production and distribution in this model is:

 (23)

When there are no vertically integrated manufacturers, Γv becomes a zero matrix and equations (21) and (23) resemble the implied price-cost margins presented in Villa-Boas (2007: p. 635). Equation (23) is different to equation (21) because the retail ownership matrix Id is different from the manufacturer’s ownership matrix Id. As explained by Villa-Boas, the manufacturers and retailers are maximizing their profits over a different set of products.

Nonlinear pricing model (e) combines (c) and (d). The independent retailing firms let the manufacturing firms be the residual claimants on profits by eliminating the retail price-cost margin. The manufacturers will maximize their profits given that the retail prices for products distributed by the independent retailers are equal to the marginal costs of production and distribution. The vertically-integrated retailers will maximize their profits given that the wholesale price is a transfer price equal to the marginal costs of production. Given equations (21) and (23), the sum of the marginal cost of production and distribution in this scenario is:

 (21)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table F1 Estimated marginal costs** | | | | | | | | | | |
|  | Model (1) | | Model (2) | | Model (3) | | Model (4) | | Model (5) | |
|  | Coefficient | s.e. | Coefficient | s.e. | Coefficient | s.e. | Coefficient | s.e. | Coefficient | s.e. |
| *CONSTANT* | 0.9343 | 1.1538 | 0.9122 | 1.1473 | 0.7873 | 1.1127 | 0.7936 | 1.1122 | 0.6880 | 1.1622 |
| *STORAGE* | 0.0009 | 0.0003 | 0.0009 | 0.0003 | 0.0009 | 0.0003 | 0.0009 | 0.0003 | 0.0009 | 0.0003 |
| *SCREEN* | 0.2769 | 0.0949 | 0.2860 | 0.0943 | 0.2981 | 0.0915 | 0.2975 | 0.0915 | 0.3099 | 0.0956 |
| *CPU* | -0.1328 | 0.2208 | -0.1193 | 0.2196 | -0.1347 | 0.2130 | -0.1350 | 0.2129 | -0.1219 | 0.2224 |
| *CORE* | 0.0518 | 0.0198 | 0.0495 | 0.0197 | 0.0615 | 0.0191 | 0.0611 | 0.0191 | 0.0522 | 0.0200 |
| *MEGAPIXELS* | 0.4398 | 0.0942 | 0.4311 | 0.0937 | 0.4303 | 0.0909 | 0.4293 | 0.0909 | 0.4284 | 0.0949 |
| *MEGAPIXELS2* | -0.0190 | 0.0052 | -0.0185 | 0.0052 | -0.0188 | 0.0051 | -0.0187 | 0.0050 | -0.0182 | 0.0053 |
| *PIXEL DENSITY* | 0.0017 | 0.0010 | 0.0018 | 0.0010 | 0.0018 | 0.0009 | 0.0018 | 0.0009 | 0.0017 | 0.0010 |
| *CELLULAR* | 0.1796 | 0.0474 | 0.1770 | 0.0471 | 0.1803 | 0.0457 | 0.1796 | 0.0457 | 0.1817 | 0.0477 |
| *DETACHABLE* | 0.0593 | 0.1221 | 0.0426 | 0.1214 | 0.0652 | 0.1178 | 0.0661 | 0.1177 | 0.0152 | 0.1230 |
| *ANDROID* | -0.5586 | 0.2309 | -0.5535 | 0.2296 | -0.5169 | 0.2227 | -0.5161 | 0.2226 | -0.5685 | 0.2326 |
| *AGE* | 0.0383 | 0.0103 | 0.0383 | 0.0102 | 0.0384 | 0.0099 | 0.0384 | 0.0099 | 0.0387 | 0.0104 |
| *BATTERY* | 0.0375 | 0.0813 | 0.0452 | 0.0809 | 0.0458 | 0.0785 | 0.0455 | 0.0784 | 0.0482 | 0.0819 |
| *BATTERY×SCREEN* | -0.0168 | 0.0084 | -0.0174 | 0.0083 | -0.0180 | 0.0081 | -0.0179 | 0.0081 | -0.0187 | 0.0084 |
| *BATTERY×CPU* | 0.0305 | 0.0228 | 0.0291 | 0.0227 | 0.0286 | 0.0220 | 0.0286 | 0.0220 | 0.0293 | 0.0230 |
| *INDIRECT* | -0.1655 | 0.0424 | -0.1959 | 0.0421 | 0.0085 | 0.0408 | 0.0085 | 0.0408 | -0.0601 | 0.0427 |
| *X86×CELLULAR* | -0.0845 | 0.2849 | -0.0602 | 0.2832 | -0.1225 | 0.2747 | -0.1218 | 0.2746 | -0.0770 | 0.2869 |
| Adjusted R2 | 0.7314 |  | 0.7332 |  | 0.7429 |  | 0.7433 |  | 0.7360 |  |
| *Notes*. Dependent variable is the natural logarithm of the marginal cost of production and distribution for pricing models (1) through (5). 176 observations. s.e. is (uncorrected) standard error. | | | | | | | | | | |

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2. For example, lower carriage of rival programming could be due to foreclosure or more efficient carriage of integrated programming (due to lower transaction costs from bargaining over inputs and better coordination of marketing efforts in upstream and downstream markets) that substitutes for rival’s programming. [↑](#footnote-ref-2)
3. Villa-Boas (2007), Bonnet and Dubois (2010) and Haucap et al. (2021) permit retail competition and the integration of retailers and private labels. However, private labels are not sold by a rival retailer. [↑](#footnote-ref-3)
4. The GRiDPad weighed 4.5 pounds, had a tethered pen resistive screen, and ran on MS-DOS. [↑](#footnote-ref-4)
5. Between 2013 and 2019, Microsoft had another 58 mall kiosk locations focusing on the Surface product line. [↑](#footnote-ref-5)
6. Samsung also forward integrated into retail by opening five “experience stores” in 2019 and 2020. They also have similar “pop-up” and “mini-shops” in retail stores, such as Best Buy, that are staffed by Samsung employees. The direct sales from these “stores” are not in our data because of low volume or because they are counted as sales by the larger retail stores. [↑](#footnote-ref-6)
7. Chu (2017) and Tao (2019) note that China’s OEMs earn low processing fees and gross profit margins of about three to six percent. The margins for Taiwanese OEMS are similar. Clover (2020) reports that Foxconn, Apples’s largest supplier, has single-digit gross margins. The Wall Street Journal shows gross (net) margins of 6.24 (2.98) and 3.23 (1.02) percent in 2021 for Quanta Computer Inc. and Compal Electronics Inc., respectively. See:

   <https://hkmb.hktdc.com/en/1X0ABKC0/hktdc-research/Evolving-Role-of-%E2%80%9CMade-in-China%E2%80%9D#:~:text=In%202015%2C%20the%20revenue%20of,margin%20of%20a%20mere%206%25>;

   <https://www.seetao.com/details/6653.html>; <https://www.macrumors.com/2020/10/27/apple-foxconn-profit-margin-tensions/> and <https://www.wsj.com/market-data/quotes/company-list>. [↑](#footnote-ref-7)
8. Mini-Apple shops with trained consultants present Apple’s full product line in many Best Buy and Target stores. Unlike retail grocery stores, we have found no evidence that retailers such as Best Buy and Target charge slotting allowances to Apple for this space and shopping experience. [↑](#footnote-ref-8)
9. We follow Lou et al. (2011) and Decarolis et al. (2020) by including age since initial product release date (*AGE*) in our demand specification to help control for dynamic effects that might bias *αn* towards zero. [↑](#footnote-ref-9)
10. In this stage, upstream firms choose retail prices for their integrated retail stores given the upstream costs, and independent retailers choose retail prices independently of the upstream firms and of each other. [↑](#footnote-ref-10)
11. The marginal utility of battery time varies across the population according to the normal distribution. We use one thousand consumer draws to approximate the market share integrals. We start with values of 0.5 on the random coefficients in the non-linear optimization of the difference between actual and predicted shares. We also tried alternative starting values from 0.05 to 0.95 to check that the objective function was globally concave. [↑](#footnote-ref-11)
12. For completeness, we report brand-level elasticities of demand for physical and online store sales in Tables C4 and C5 in Appendix C. Overall, they show relatively more elastic demand in the online market although most of the differences are small, except for Lenovo. In contrast, HP have relatively less elastic demand in the online market. [↑](#footnote-ref-12)
13. We tried alternative market structures but found them too arbitrary and computationally difficult to solve. [↑](#footnote-ref-13)
14. We checked the sensitivity of our results to time with a simulation on ten upstream manufacturers that supply 264 tablet products to retailers during the first quarter of 2016, the quarter with the greatest volume of sales in our data. The results, reported in Appendix E, are qualitatively similar to those in Tables 5 and 6. We note that the share of online sales and both the WPI/Wholesale margin and the RPI/Retail margin are relatively higher during the first quarter of 2016. It also appears that Samsung directly supplied more higher-end tablets during the first quarter of 2016. [↑](#footnote-ref-14)
15. Given the constant retail price assumption, the profit change reflects the change in demand from consumers moving from direct to indirect sales, and the reallocation of indirect sales among brands with indirect distribution channels only, all else held constant. [↑](#footnote-ref-15)
16. We do not consider retail price discrimination because it is typically not observed in consumer tablet markets. Back-to-school and holiday promotions reduce prices for some consumer types, but these are relatively sparse compared to phones where retailers discount locked phones upfront to sort by consumer’s time preferences. [↑](#footnote-ref-16)
17. We do not comment on the precision of the estimated cost coefficients because their standard errors are not corrected for the additional variance from the marginal costs that are recovered from the demand estimates. Time constraints prevent us from obtaining the empirical distribution of the standard errors (and the test statistics in Table 8) by bootstrapping the demand model and calculating price-cost margins and marginal costs for each pricing model, and for each bootstrap replication. [↑](#footnote-ref-17)
18. Vuong’s test statistic (1989) is consistent under the assumptions that the observed cost shifters are exogenous, the unobserved cost shocks are log-normally distributed, and the exponential functional form is the correct specification. [↑](#footnote-ref-18)
19. The brand-specific fixed effects *λf(j)* are included in the demand specification to account for the average market demand from unobserved factors among the different manufacturers. Because they are estimated for the entire sample period and our simulation is for the most recent period in the data, these fixed effects require recalibration to the September quarter of 2019. We find that 20 iterations is sufficient to remove any significant difference between the calibrated and actual market shares. [↑](#footnote-ref-19)
20. The Sp and Spp matrices are predetermined in that they do not change when the optimization routine updates it values for θt = [(w – c)t, (p – mc)t]. We employ starting values for w – c that were twenty percent of the observed retail prices to calculate Pw and θt in (v) when t = 0. The values for p – mc in θt are automatically calculated from w – c in equation (11). The values for Pw and θt are simultaneously updated at each step. Note that a standard desktop computer takes about four weeks to simulate the Spp array with 1,000 consumer draws. [↑](#footnote-ref-20)
21. We experimented with different tolerance levels and decided on a relative difference of 1e-08 for θt, Ω(θt) and gt'(–Ht-1)gt, respectively. We used the Davidon-Fletcher-Powell method to calculate an arc Hession over various steps of the iteration process and found that this method minimized the objective function after ten iterations. [↑](#footnote-ref-21)