The Effects of Vertical Integration on Tablet Computer Prices

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November 22, 2024

Abstract

We analyze pricing dynamics in the tablet computer market using a vertical relations model across 176 tablet models in 2019. For vertically-integrated firms, raising rivals' costs (RRC) accounts for 9% of wholesale prices, while the incentive to soften price competition (SPC) comprises 10.6% of retail prices. Apple primarily drives both effects. In a vertical-disintegration scenario, high-end model prices increase due to RRC and SPC effects, while low-end prices decrease from eliminated double margins. Overall, vertical integration reduces average retail prices by 8.5%, increases sales by 13%, and improves welfare by 18.4% of baseline profits. JEL classification: D4, F13, L63

Key words: retail prices, tablet computers, vertical relations, welfare, wholesale prices

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1. Introduction

There is a long-running debate on the welfare effects from vertical integration. One of the most important questions is whether the efficiency gains from the elimination of double margins (EDM) outweigh the anticompetitive incentive to raise rivals' costs (RRC). We contribute to the literature by presenting empirical evidence from a vertical-relations model with oligopoly firms in the upstream and downstream markets for tablet computers. Using counterfactual analysis, we quantify the three main mechanisms through which the integration of manufacturers, such as Apple, into direct retail distribution affects wholesale and retail prices. Our comparison of the vertically-integrated and disintegrated equilibria shows heterogenous price changes across all models and brands. The RRC effect and the incentive to soften price competition (SPC) increase retail prices for high-end models, while the EDM effect decreases prices for low-end models, and the overall sales, consumer surplus and welfare in the market increase. The policy implication is that vertical integration can be efficient in markets where there is sufficient consumer heterogeneity and product differentiation.

Theoretical and empirical studies of the on vertical integration's efficiency inform competition policy, industry regulation and merger outcomes (Salinger, 1991; 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 of 2021 intends to limit "Big Tech" platforms, such as Amazon, from engaging in discriminatory behavior where they rank their own similar private-label retail products over their rivals in consumer searches. Yelp and TripAdvisor argue that Google lowers their search links in favor of prime placement of Google Maps. In 2020, the

Federal Trade Commission accused Facebook of denying third-party software developers access to its platform to soften competition in the social networking and mobile messaging markets. In 2024, the DOJ claimed that Apple used anticompetitive strategies, such as degrading the appearance of Android messages on iPhones, to maintain monopoly power over smartphones.

Despite policymaker's interest in RRC and other anticompetitive incentives, there is little empirical research identifying the size of these effects relative to the potential efficiency gains from the EDM effect. We fill this gap by investigating the effects of vertical integration on tablet computer prices. We study tablets because we have good quality data on their product characteristics, retail prices, sales and distribution channels and because their branded manufacturers produce and sell a nontrivial quantity through their own retail stores, both physical and online. For example, Apple and Microsoft had about 270 and 50 physical retail stores, respectively in 2017, and the direct sales from all vertically-integrated manufacturers accounted for about one-third of retail sales between 2010 and 2019. Manufacturers also supplied their tablets to retailers such as Best Buy, Walmart, and Amazon that competed with their own retail stores. State and federal policymakers have also raised antitrust concerns that some Big Tech firms are harming independent downstream firms. While we focus on the impact of vertical integration on the pricing incentives for firms in the tablet industry, any changes in these incentives are also likely to follow those of similar products in the larger computer, smartphone, and consumer electronics markets.

We begin our analysis with reduced-form regressions of the retail prices of tablet computers in the United States for each quarter from June 2010 to September 2019. The results suggest that vertically-integrated firms have higher retail price-cost margins during the former part of our sample, but this relationship reverses toward the latter quarters. Because these results are descriptive, it is not possible to confirm the specific source(s) of market power, and so we explore this question further with a structural model of supply-and-demand. Our model employs the random-coefficients logit (RCL) specification of demand and a Bertrand game of oligopoly in the upstream and downstream markets with constant marginal costs. Under these assumptions, we identify two key anticompetitive effects from vertical integration in the tablet market. The first is the standard RRC effect, where vertically-integrated firms increase their wholesale prices to independent retailers. The second is the SPC effect, where vertically-integrated firms increase their retail prices to divert sales to products with higher wholesale margins (Chen, 2001; Moresi and Schwartz, 2021). From a theoretical point of view, these mechanisms are not new. Our contribution is to quantify these individual effects in a market that is more general than a monopoly and to assess whether they are economically relevant in explaining equilibrium retail and wholesale prices.

We use our demand estimates, observed retail prices and market shares, and the firm's optimal-price conditions to infer the marginal costs and wholesale prices for 176 product models during the third quarter of 2019. These baseline vertical-integration results show that the RRC effect comprises nine percent of wholesale prices for vertically-integrated firms and the SPC effect comprises 10.6 percent of retail prices. Both effects are largely driven by the dominant firm, Apple. We conduct a counterfactual vertical-disintegration scenario, where vertical integration is not permitted for all firms, and compare the market outcomes to those from the baseline market structure with vertical integration. This analysis shows that the anticompetitive RRC and SPC effects increase prices for high-end models, but the EDM effect decreases prices for low-end models. Overall, when the market is vertically integrated, the average sales-weighted retail price decreases by 8.52 percent, total sales increase by 13 percent, and welfare increases by an amount equivalent to 18.4 percent of total firm variable profits in the baseline scenario. These results are robust to alternative assumptions about market structure and firm behavior. For example, we constrain wholesale prices across the same models, use different marginal costs of retailing when recovering wholesale prices, and compare several nonlinear pricing strategies to our baseline assumption of linear pricing.

Several structural papers use inferred costs to recover price-cost margins and in some cases, examine unobserved foreclosure or vertical pricing effects (Manuszak, 2001; Sudhir, 2001; Villas-Boas and Zhao, 2005; Villas-Boas, 2007; Bonnet and Dubois, 2010; Richards et al., 2011; Asker, 2016; and Haucap et al., 2021). Only a few of these studies permit multiple wholesalers and retailers, and none conduct counterfactual analyses of vertical integration. In contrast, Crawford et al. (2018) estimate a model of bargaining over the fee paid by distributors to producers in multichannel television markets. They permit a sports-network producer to integrate with the local cable monopoly but solve 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 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. Gil et al. (2024) infer the marginal costs for a movie theatre serving an additional customer and screen, respectively, but assume an exogenous revenue share between the movie distributor and the theatre. The derivatives of retail prices with respect to wholesale prices are not required under this assumption.[2]

Our paper adds to the policy debate by providing new evidence on the effects from vertical integration in markets for high-tech products. In contrast to previous studies, we explicitly measure two anticompetitive pricing incentives for individual product models, compare them to the EDM effects, and assess the overall change in welfare. We also provide a comprehensive empirical framework for analyzing vertical integration in differentiated-product markets with multiple competitors. By applying this framework to the tablet market, we offer insights that can inform antitrust policy and business strategy in similar industries. The paper is organized as follows. The next section discusses United States tablet computer markets. Section 3 describes the empirical model, and the demand estimates are presented in section 4. Section 5 uses the demand estimates to infer marginal costs and wholesale prices and conducts several vertical-disintegration scenarios. Section 6 concludes.

2. United States tablet computer markets

2.1 Production and distribution

Tablets are portable personal computers that run on mobile operating systems such as Android, iOS, or Windows, and provide many applications. Although they've existed since the release of the GRiDPad in 1989, Apple introduced the modern tablet to consumers with the light-weight iPad in April 2010. Consumers 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

[2] Some papers examine EDM and RRC effects by comparing retail prices in vertically integrated and separated markets. See Chipty (2001) for cable television, Hortasku and Syverson (2007) for cement, Gil (2015) for movie tickets, Luco and Marshall (2020) for carbonated beverages (2020), and Hosken and Taylor (2021) for gasoline.

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 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 stores. Comparative advantage in the 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 (United States International Trade Commission, USITC, 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 (2019) 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 vertically-integrated manufacturers, which is a distinct supply-side characteristic from other articles 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 two-thirds 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 stores. About one-half the revenue was through the manufacturer's online stores such as www.apple.com and 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 physical Apple Stores opened in 2001 and by 2017 there were 272 locations throughout the United States. The first two physical Microsoft Stores opened in 2009 and there were 49 in 2017.[3] 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

[3] Between 2013 and 2019, Microsoft had another 58 mall kiosk locations for the Surface product line. Samsung integrated into retail by opening five "experience stores" in 2019 and 2020. They also have "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.

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 was 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 (p_{jt}) to approximate the retail price of product $j = 1, \dots, J$ at time period $t = 1, \dots, T$. 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 large 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.[4]

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[4] Several industry commentators 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, with 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:

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, Samsung typically sold their tablets to retailers at 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. Whereas 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 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.

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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.

This initial period coincides with the introduction of the iPad and the entry of Amazon, Barnes & Noble 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 with reduced-form price 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 model specifies the log of the retail price of product $j = 1, \ldots, J$ in time period $t = 1, \ldots, T$ as:

$$\ln(p_{jt}) = \mu_1 INDIRECT_{jt} + \mu_2 TREND_t + \mu_3 INDIRECT_{jt} \times TREND_t$$
$$+ \mu_{4m(j)} + \mu_{5f(j)} + x_{jt}'\mu_6 + u_{jt} \qquad (1)$$

where $TREND_t$ is a linear time trend, x_{jt} is the vector of product characteristics k for product j in period t and a cost shifter $X86_{jt}$, $X86_{jt}$ equals one when the manufacturer uses a high-end x86 processor in product j in period t and zero otherwise, μ_1 through μ_3 are the coefficients of interest, $\mu_{4m(j)}$ is a vector of model fixed effects with $m(j)$ indicating model m and product j, $\mu_{5f(j)}$ is a vector of brand fixed effects with $f(j)$ indicating firm f and product j, μ_{6t} is the vector of coefficients for the control variables, and u_{jt} 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 $INDIRECT_{jt}$ and $INDIRECT_{jt} \times TREND_t$ are jointly equal to zero. The estimated negative coefficient on $INDIRECT_{jt}$ shows that, all else held constant, the expected price for a tablet sold indirectly to consumers by retailers is about five percent lower than a similar tablet sold by the manufacturer. The estimated positive coefficient on $INDIRECT_{jt} \times TREND_t$ shows that the discount becomes smaller over the sample period and reverts to a price premium.

Columns three and four present estimates of an alternative specification that relaces $INDIRECT_{jt}$ and $INDIRECT_{jt}\times TREND_t$ with interactions between VI_{jt} and 38 quarter fixed effects from June 2010 to September 2019; $INDIRECT_{jt}\times QUARTER_1$, …, $INDIRECT_{jt}\times QUARTER_{38}$. An *F* statistic (F(8, 8321) = 5.14; prob = 0.00) rejects the null that the eight interactions from the December quarter 2012 to the September quarter 2014 are jointly equal to zero and the price discount ranges from about 1.6 to seven percent during this period.[5] Another *F* statistic (F(4, 8321) = 1.91; prob = 0.11) marginally fails to reject the null that the four interactions from the December quarter 2018 to the September quarter 2014 are jointly equal to zero and the price premium ranges from an imprecise 1.8 to about 3.7 percent during this period.

3. Empirical model

The reduced-form regressions suggest that vertically-integrated firms may have higher retail price-cost margins during the former part of our sample, but this relationship reverses over the latter quarters. Because these results are descriptive, it is not possible to identify the specific sources of market power and how they compare to the EDM effects. For example, higher margins could arise from raising rival's cost and/or from stronger consumer demand in the integrated firm's retail stores. We investigate these and other mechanisms with a structural model of supply-and-demand with vertical relations. While the approach is computationally burdensome, it allows the price-cost margins to be decomposed into their anticompetitive RRC and SPC effects and compared to the efficient EDM effect.

The analysis proceeds as follows. First, estimates of consumer demand are obtained from the RCL model of consumer demand. Next, a supply-side model of firm behavior with vertical

[5] The estimated coefficient on the cost-shifter, *X86*, is also positive and statistically different from zero. This is consistent with high-end processors being more valuable to producers and consumers.

relations is specified and solved for the firm's optimal-price conditions. The price conditions are then used with the demand estimates to compute retail and wholesale price-cost markups, and the markups are combined with the retail price to infer the marginal costs to the manufacturer and the retailer, respectively, and the wholesale prices. The inferred marginal costs and wholesale prices are then used in counterfactual analysis to compute the changes in equilibrium prices, sales, and welfare from vertical disintegration.

3.1 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.[6] Consumers maximize utility given their preferences and the equilibrium retail prices and characteristics of the products supplied. The indirect utility consumer $n = 1, \ldots, N$ obtains from purchasing tablet product $j = 1, \ldots, J$ or the outside option of no tablet purchase in time period $t = 1, \ldots, T$ is:

$$V_{njt} = X_{jt}'\beta - \alpha_n p_{jt} + \lambda_{f(j)} + \gamma_t + \xi_{jt} + e_{njt} \tag{2}$$

where the $K \times 1$ vector X_{jt} includes the product characteristics described in Section 2.2, $BATTERY_{jt} \times SCREEN_{jt}$, $BATTERY_{jt} \times CPU_{jt}$ and $INDIRECT_{jt} \times TREND_t$, $\lambda_{f(j)}$ is a time-invariant brand fixed effect that measures preferences for a brand with $f(j)$ indicating firm f and product j, γ_t is a product-invariant time fixed effect that controls for changes in tablet quality over time such as reliability and durability, ξ_{jt} is a structural error term for product j in period t that captures the mean utility from unobserved product characteristics, β is a $K \times 1$ vector of marginal utilities for the k product characteristics, α_n is the marginal utility of income that varies across

[6] 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 α_n towards zero.

consumers, and e_{njt} is an unobserved random error term assumed to be independently and identically distributed type I extreme value. The interactions $BATTERY_{jt} \times SCREEN_{jt}$ and $BATTERY_{jt} \times CPU_{jt}$ 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 $INDIRECT_{jt} \times TREND_t$ 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 $\alpha_n \sim \Phi(\alpha, \Sigma)$. The mean utility for product j at time t is described by $\delta_{jt} = X_{jt}'\beta - \alpha p_{jt} + \lambda_{f(j)} + \gamma_t + \xi_{jt}$ and the mean utility from the outside good $j = 0$ is normalized to zero. Since the random error term e_{njt} is distributed type I extreme value, the market shares for all products and the outside good for a given set of demand parameters and consumers are:

$$s_{jt} = \int \frac{exp(X_{jt} \beta - \alpha_n p_{jt} + \lambda_{f(j)} + \gamma_t + \xi_{jt})}{1 + \sum_{k=1}^{J} exp(X_{kt} \beta - \alpha_n p_{kt} + \lambda_{f(k)} + \gamma_t + \xi_{kt})} \phi(\alpha_n) d\alpha_n \qquad (3)$$

which is the weighted sum of the individual consumer choice probabilities across the whole population, with the weights given by the density function $\phi(\alpha_n)$. The variance parameter Σ and the $J \times 1$ 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 $E[\xi_{jt} \mid z_{jt}] = 0$, where z_{jt} is a $L \times 1$ 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 $f_u = 1, \ldots, N_u$ independent upstream firms that manufacture and sell their products to retailers. There are $f_d = 1, \ldots, N_d$ independent downstream firms that retail the full variety of products produced by independent and vertically-integrated manufacturers to consumers. There are $f_v = 1, \ldots, N_v$ 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. In any given time period, there are $N_u + N_d + N_v$ total firms in the market and each sells a subset of the $j = 1, \ldots, J$ total products in the market to retailers and consumers. The set of products produced by independent manufacturing firm f_u and sold to retailers are $j \in J_u$. The set of products sold by independent retailing firm f_d to consumers are $j \in J_d$. The set of products produced by vertically-integrated firm f_v and sold to independent retailers are $j \in J_v^u$ and the set of products manufactured by vertically-integrated firm f_v and sold directly to consumers through their own retail operations are $j \in J_v^d$.

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

$$\pi_u = \sum_{j \in J_u} \left(w_j - c_j\right) s_j(p(w))M - F_u \tag{4}$$

where w_j is the wholesale price charged to independent retailers for product j, c_j 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, $q_j = s(p(w))M$ is the quantity of product j demanded and sold in the retail market, and F_u is the fixed cost of production for firm f_u. The profit function for independent downstream retailer f_d is:

$$\pi_d = \sum_{j \in J_d} \left(p_j - w_j - rc_j\right) s_j(p(w))M - F_d \tag{5}$$

where p_j is the retail price of product j, rc_j is the retailer's constant marginal cost of selling product j to consumers, and F_d is the fixed cost of production for firm f_d. 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 f_v is:

$$\pi_v = \sum_{j \in J_v^d} \left(p_j - c_j - rc_j\right) s_j(p(w))M + \sum_{k \in J_v^u} \left(w_k - c_k\right) s_k(p(w))M - F_v \tag{6}$$

where the term for retail revenue shows that $w_j = c_j$ is the transfer price charged to vertically-integrated retailers for all products $j \in J_v^d$, and F_v is the fixed cost of production for firm f_v.

Firm decision-making is described in three stages. In stage one, 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 f_u and f_v observe firm types and the set of products available from each firm and choose the wholesale prices w_j to be charged to the retailers. As first movers, firms f_u and f_v 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 f_v commit to wholesale prices in the second stage by writing enforceable contracts with their independent retailers. In the third stage, retail firms f_d and f_v observe firm types, the set of products available from each firm and their wholesale prices and choose the retail price p_j for all products to be charged to consumers. 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. We solve these stages in reverse order and assume that firms choose prices to maximize profits given the demand and characteristics of their own products and the prices, demand and characteristics for rival products. We also assume that the solution for the game is the subgame-perfect Bertrand-Nash equilibrium set of 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 f_d in the third stage of the game must satisfy the first-order condition:

$$\frac{1}{M}\frac{\partial \pi_d(w,\, p)}{\partial p_j} = s_j(p(w)) + \sum_{k \in J_d} \left(p_k - w_k - rc_k \right) \frac{\partial s_k(p(w))}{\partial p_j} = 0 \tag{7}$$

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

$$\frac{1}{M}\frac{\partial \pi_v(w,\, p)}{\partial p_j} = s_j(p(w)) + \sum_{k \in J_v^d} \left(p_k - c_k - rc_k \right) \frac{\partial s_k(p(w))}{\partial p_j} + \sum_{l \in J_v^u} \left(w_l - c_l \right) \frac{\partial s_l(p(w))}{\partial p_j} = 0 \tag{8}$$

for all $j \in J_v^d$. 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:

$$\frac{1}{M}\frac{\partial \pi_u(w,\ p)}{\partial w_j} = s_j(p(w)) + \sum_{k \in J_u} \left(w_k - c_k\right)\left(\sum_{l=1,\dots,J} \frac{\partial s_k(p(w))}{\partial p_l}\frac{\partial p_l}{\partial w_j}\right) = 0 \tag{9}$$

for all $j \in J_u$ products sold by the independent manufacturing firm f_u. The wholesale price must also satisfy the first-order condition:

$$\begin{aligned}\frac{1}{M}\frac{\partial \pi_v(w,\ p)}{\partial w_j} &= s_j(p(w)) + \sum_{k\in J_v^u} \left(w_k - c_k\right)\left(\sum_{l=1,\dots,J} \frac{\partial s_k(p(w))}{\partial p_l}\frac{\partial p_l}{\partial w_j}\right) \\ &+ \sum_{m \in J_v^d} \left(p_m - w_m - rc_m\right)\left(\sum_{l=1,\dots,J} \frac{\partial s_m(p(w))}{\partial p_l}\frac{\partial p_l}{\partial w_j}\right) + \sum_{m \in J_v^d} s_m(p(w))\frac{\partial p_m}{\partial w_j} = 0\end{aligned} \tag{10}$$

for all $j \in J_v^u$ products sold by the vertically-integrated firm f_v to independent retailers.

The optimal-price conditions highlight three important pricing effects in vertically-integrated markets. First, there is the efficiency effect from the elimination of double margins in equation (7). When the wholesale price charged by the manufacturing to the retail division of the same firm is set equal to marginal cost, the tablet models sold at vertically-integrated retail stores should have lower retail prices. When there is strategic complementarity, the models sold at independent retail stores should also have lower retail prices. Second, because the models sold at their own stores are relatively more profitable, vertically-integrated firms have incentive to increase their wholesale prices to independent retail stores and divert sales toward these models. This RRC effect is observed in the third and fourth arguments in equation (10). The third effect describes the integrated firm's incentive to soften price competition by increasing retail prices to divert sales to rival products with higher wholesale margins. This SPC effect is observed in the third argument in equation (8). Below we describe the matrix notation that uses own- and cross price elasticities of demand, displacement ratios, and the extent of cost past-through to identify the RRC and SPC effects.

3.3 Price-cost margins

The $J \times 1$ vector of first-order conditions for wholesale prices is:

$$w - c + (I_u \circ S_w^T)^{-1} \times [s(p(w)) + h] = 0 \tag{11}$$

where w – c is the $J \times 1$ vector of wholesale price-cost margins, I_u is the $J \times J$ 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, $S_w = S_p \times P_w$ is the $J \times J$ matrix of the derivatives of retail market shares with respect to all wholesale prices, S_p is the $J \times J$ matrix of derivatives of retail market shares with respect to all retail prices, P_w is the $J \times J$ matrix of derivatives of retail prices with respect to all wholesale prices, s(p(w)) is the $J \times 1$ vector of market shares, and 0 is the $J \times 1$ vector of zeros. The RRC effect for the vertically-integrated firm is measured by the $J \times 1$ vector:

$$h = [(\Gamma_v{}^T \circ S_w{}^T) \times (p - mc)] + [(\Gamma_v{}^T \circ P_w{}^T) \times s(p(w))]$$

where Γ_v is $J \times J$ 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 $J \times 1$ vector of retail price-cost margins, p is the $J \times 1$ vector of retail prices, mc is the $J \times 1$ 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 $\Gamma_v{}^T$, $S_w{}^T$ and $P_w{}^T$ 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 I_u and S_w^T, 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 (11) describes the standard first-order conditions for wholesale prices with independent upstream and downstream firms.

The $J \times 1$ vector of first-order conditions for retail prices is:

$$p - mc + (I_d \circ S_p)^{-1} \times [s(p(w)) + g] = 0 \tag{12}$$

where I_d is the $J \times J$ 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 SPC effect for the vertically-integrated firm is measured by the $J \times 1$ vector:

$$g = (\Gamma_v \circ S_p^{\,T}) \times (w - c)$$

where the last $J - J'$ lines of matrix $\Gamma_v^{\,T}$ and vector w – c are zeros because they represent products with no wholesale prices. Absent g, equation (12) describes 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 (11):

$$S_w = S_p \times P_w = \begin{pmatrix} \frac{\partial s_1}{\partial p_1} & \cdots & \frac{\partial s_1}{\partial p_J} \\ \vdots & \ddots & \vdots \\ \frac{\partial s_J}{\partial p_1} & \cdots & \frac{\partial s_J}{\partial p_J} \end{pmatrix} \times \begin{pmatrix} \frac{\partial p_1}{\partial w_1} & \cdots & \frac{\partial p_1}{\partial w_J} \\ \vdots & \ddots & \vdots \\ \frac{\partial p_J}{\partial w_1} & \cdots & \frac{\partial p_J}{\partial w_J} \end{pmatrix}$$

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

$$P_w = (D + D_v)^{-1} \times (I_{d'} \circ S_p^{\,T}) \tag{13}$$

where $\mathrm{I}_{d'}$ is the $J \times J$ 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 d_{jk} of the $J \times J$ matrix D are equal to:

$$\frac{\partial s_j}{\partial p_k} + \sum_{l \in J}\left(\Gamma_p(\mathrm{j}, \mathrm{l}) \frac{\partial^2 s_l}{\partial p_j \partial p_k}(p_l - w_l - rc_l) \right) + \Gamma_p(\mathrm{j}, \mathrm{k}) \frac{\partial s_k}{\partial p_j} \tag{14}$$

where $\Gamma_p(\mathrm{j}, \mathrm{l})$ is a scalar that equals one when products *j* and *l* are sold to consumers by the same independent retailer and zero otherwise, and $\Gamma_p(\mathrm{j}, \mathrm{k})$ 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 d_{vjk} of the $J \times J$ matrix D_v are equal to:

$$\sum_{m \in J}\left(\Gamma_{v'}(\mathrm{j}, \mathrm{m}) \frac{\partial^2 s_m}{\partial p_j \partial p_k}(w_m - c_m) \right) \tag{15}$$

where is $\Gamma_{v'}(\mathrm{j}, \mathrm{m})$ 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 $2J \times 1$ vector of non-linear first-order conditions $\Omega(\mathrm{w} - \mathrm{c}, \mathrm{p} - \mathrm{mc})$ that relate wholesale and retail price-cost margins to the estimated demand parameters, observed retail prices and product characteristics:

$$\begin{bmatrix} \Omega_w(\mathrm{w}-\mathrm{c}, \mathrm{p}-\mathrm{mc}) \\ \Omega_p(\mathrm{w}-\mathrm{c}, \mathrm{p}-\mathrm{mc}) \end{bmatrix} = \begin{bmatrix} \mathrm{w}-\mathrm{c} \ + (\mathrm{I}_u \circ \mathrm{S}_w^T)^{-1} \times [\mathrm{s}(\mathrm{p}(\mathrm{w})) + \mathrm{h}] \\ \mathrm{p}-\mathrm{mc} + (\mathrm{I}_d \circ \mathrm{S}_p)^{-1} \times [\mathrm{s}(\mathrm{p}(\mathrm{w})) + \mathrm{g}] \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{16}$$

Given observed retail prices p and market shares s(p(w)) from the sample data, the system of *2J* first-order conditions in equation (16) 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 $\Omega(\mathrm{w} - \mathrm{c}, \mathrm{p} - \mathrm{mc})^T \times \mathrm{I} \times \Omega(\mathrm{w} - \mathrm{c}, \mathrm{p} - \mathrm{mc})$, where I is the $2J \times 2J$ identity matrix.

Note that equation (16) does not identify the wholesale price (w) as it is contained in the wholesale price-cost margin (w – c). We back out the wholesale price in our empirical analysis by first calculating the total marginal cost of production and retailing (mc) from observed retail prices less computed retail and wholesale price-cost margins. We then assume that the retailer's marginal cost of selling a tablet (rc) is ten percent of the total marginal cost and the residual is the manufacturer's marginal cost of production (c).[7] The inferred wholesale price is then the manufacturer's marginal cost of production plus the wholesale price-cost margin.

4. Consumer demand estimates

4.1 Estimation and instrumental variables

We estimate consumer demand by applying BLP's GMM estimator to the sample moment condition $E[\xi_{jt} \mid z_{jt}] = 0$, where z_{jt} is assumed to be mean independent of the unobserved error term ξ_{jt}. We control for price endogeneity with the cost shifter interacted with cellular capability, $X86_{jt} \times CELLULAR_{jt}$, and with the product characteristics of the other tablets from the same firm and rivals as the instruments for price. Identification of the fixed marginal utility parameters in consumer utility comes from the within-brand choice variation across markets. The standard deviation of the random coefficients are identified by the extent to which a low-price, low-quality alternative, for example, attracts probability away from other alternatives. For instance, a standard deviation close to zero indicates that the low-quality tablet draws probability proportionately from all other alternatives and there is not much heterogeneity in consumer preferences. The key assumptions are that conditional on controls and $PRICE_{jt}$ the cost shifter

[7] Robustness tests with five and 15 percent are qualitatively similar to the results presented in Table 5 through Table 8. We also set the marginal cost of production for directly-sold models to the cost of its "nearest neighbor" indirectly-sold model (i.e., the indirect model with the same model name and retail price and highest cost). This ensures that the production costs for similar indirectly- and directly-sold products are about the same.

does not have direct effect on consumer utility, and the product characteristics within choice sets are not correlated with the unobserved demand shocks.

Another important assumption is that each firm's sales-distribution method, measured by $INDIRECT_{jt}$, is exogenous to unobserved demand shocks. Following Chen et al. (2022), Hodgson and Sun (2022) and Gil et al. (2024), we argue that $INDIRECT_{jt}$ is a predetermined variable since firm decisions on vertical integration, such as the make-or-buy decision and store locations, and the extent of contract incompleteness, are largely time invariant and were made prior to our sample period. For example, the major strategic players in our sample, Apple and Microsoft, opened their first physical stores in 2001 and 2009, respectively.

Section 2.3 suggests that $X86_{jt} \times CELLULAR_{jt}$ should be positively correlated with price but not correlated with utility in equation (2), after controlling the demand-side for improved tablet functionality with $CORE_{jt}$, CPU_{jt} and $CELLULAR_{jt}$. 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 utility 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, $X86_{jt} \times CELLULAR_{jt}$. 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, $PIXEL\ DENSITY\ DIFF_{jt}$, $BATTERY\ DIFF_{jt}$ and $CELLULAR\ 4G\ DIFF_{jt}$, where "*DIFF*" indicates deviation from the average of the characteristics for all other products, and $CELLULAR\ 4G_{jt}$ equals one when the tablet has fourth-generation cellular network compatibility and zero otherwise, and $X86_{jt} \times CELLULAR_{jt}$. 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 (χ^2 = 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 Consumer utility

Table 3 presents estimates of consumer utility. 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").[8] 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

[8] 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.

most non-price characteristics and a negative marginal utility for price. The estimated coefficient on p_{jt} in the FCL–OLS specification in column one is 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).[9]

[9] The negative coefficient on $BATTERY_{jt} \times SCREEN_{jt}$ indicates that consumer preferences for the usage time supported by the battery decreases with screen size. Large screens have more surface area and require more power to light up. Because they usually have a larger battery to support their additional power consumption, consumers with these devices may have lower marginal valuations for battery capacity. The positive coefficient on $BATTERY_{jt} \times CPU_{jt}$ indicates that consumers preferences for usage time increase with CPU speed. Because flagship CPUs use more power, consumers with these devices may have higher marginal valuations for battery capacity.

The differences in consumer utility due to indirect versus direct sales distribution are accounted for with the dummy variable $INDIRECT_{jt}$ and the interaction variable $INDIRECT_{jt} \times TREND_t$. As previously mentioned, these differences may arise from customer service, store experience and return policies, and waiting times for new releases, etc. that increase or decrease the demand for models sold in independent retail stores. Overall, the demand findings provide evidence consistent with reduced-form results. One the one hand, the negative coefficient on $INDIRECT_{jt}$ indicates that consumer demand was stronger for models sold at integrated retail stores during the former half of the sample. On the other hand, the positive coefficient on $INDIRECT_{jt} \times TREND_t$ indicates that consumer demand at independent stores became relatively stronger over time.[10] For example, during the second quarter of 2010, the representative consumer is willing to pay an additional \$21.59 (s.e. = 5.10) for a tablet from a vertically-integrated store. By contrast, during the third quarter of 2019, the representative consumer is willing to pay an additional \$45.38 (s.e. = 4.16) at an independent retail store.

4.3 Elasticities and marginal costs

We use the demand estimates 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 elasticities are reported in Table 4. The own-price elasticities range from –3.82 to –6.33 and are broadly similar to estimates for camcorders by Gowrisankaran and Rysman (2012), Lou et al. (2012) and Duch-Brown, et al. (2017) and for the wireless industry by Cullen et al. (2017), but they are smaller for smartphones in Hiller at al. (2018). The cross-price elasticities range from small positive values to 0.203 and are relatively small for most brands when compared to the

[10] Best Buy management argue that improved customer service has been the key to their survival (Verdon, 2019). Best Buy and Target also employ trained consultants to present Apple's full product line in many of their stores.

own-price elasticities. The largest cross-price elasticities are for consumer substitution from the non-premium brands to the premium brands, Apple, Microsoft and Samsung.

The sales-weighted averages of the inferred marginal costs for each brand are reported in columns two through four of Table 5. The average marginal cost of producing and selling a tablet is $188.66, ranging from $87.41 for RCA to $479.58 for Acer. The inferred marginal costs for each tablet model are presented in Appendix B and are plausible for most brands and models. For example, our landed cost estimates for Apple iPads priced around $450 in our sample imply margins of about $248. This is comparable to margins of $224 to $230 for the iPad Air and iPad Air 2 estimated by industry experts considering only hardware costs. Furthermore, our landed cost estimates for Samsung Galaxy priced between $340 and $447 in our sample imply margins of $149 to $161. This is reasonably similar to the $135 margin for the Galaxy Tab Pro 10.1 from industry experts.[11]

5. Counterfactual analysis

5.1 Baseline supply with vertical integration

Our baseline market scenario with vertical integration assumes ten manufacturers and 176 tablet models during the third quarter of 2019. Of the 176 models, 58 are sold directly to consumers by manufacturers through their own online and/or physical stores. 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 models directly to consumers through their own online stores and indirectly through independent retail stores. Apple and Microsoft also sell their models to

[11] See https://www.engadget.com/2014/10/30/ihs-teardown-apple-nets-224-on-each-16gb-wifi-ipad-air-2-it-se/ and https://electronics360.globalspec.com/article/4558/teardown-samsung-galaxy-tab-pro-10-1.

consumers through their own physical stores. We have no sales data for individual retailers. As such, we assume there is a single representative independent online retailer and a single representative independent physical retailer that do not manufacture tablets and assign IDC's online and physical sales data to these two retailers.[12] We also assume that all manufacturers and retailers practice linear pricing when setting retail and wholesale prices, which implies double margins for independent retailers and rules out quantity discounts.[13]

We use our numerical solution method to solve equation (15) for equilibrium wholesale and retail price-cost margins. The prices, costs and sales for the 176 individual product-model versions are presented in Appendix B. A brand-level summary of the wholesale sales in the baseline scenario with vertical integration is reported in Table 5. About 4.836 (= 3.530 from Table 5 + 1.306 from Table 6) million tablets are sold during the third quarter of 2019, with ten brands supplying 118 products and 42 model-versions at the sales-weighted average retail price of $355.69.[14] The average marginal costs of production and retailing for all products are $171.15 and $17.15, respectively, and the average wholesale price is $259. On average, the RRC effect of $23.40 comprises 9.04 percent of wholesale prices for all vertically-integrated firms. At the brand level, Apple's RRC effect is about $33.39 per model and Microsoft's is about $4.02 per model. Both estimates indicate nontrivial wholesale revenues from raising rivals' costs of

[12] We tried alternative market structures but found them too arbitrary without additional information on shares and prices and, in most cases, more computationally difficult to solve in a timely fashion.
[13] For robustness, we used Vuong's test statistic (1989) for nonnested models to compare several pricing assumptions: (1) linear pricing; (2) nonlinear pricing with zero wholesale margins; (3) nonlinear pricing with zero retail margins; and (4) nonlinear pricing with a combination of (2) and (3). 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 strategies (2) through (4) relative to our baseline assumption of linear pricing.
[14] Because they are estimated for the entire sample period, the brand fixed effects require recalibration to the third quarter of 2019. We use Train's (1986) algorithm to recalibrate these fixed effects, so they are specific to each brand and model. We find that 20 iterations removes any significant difference between the calibrated and actual market shares for each model. Overall, about 80.48 (= 3.530/4.836) percent of tablets are indirectly sold to consumers through independent retailers in our baseline. This estimate is close to the 77.12 percent of tablets that were actually indirectly sold to consumers through independent retailers during the third quarter of 2019 (IDC, 2019).

$81.17 million per quarter for Apple and $0.77 million for Microsoft. While Apple is the dominant firm, both Apple and Microsoft share several supply-side characteristics. They sell high-end iPad and Surface tablets with high wholesale price-cost margins, and they both have their own physical retail stores.

A summary of the brand-level retail sales in the baseline scenario with vertical integration is reported in Table 6. About 1.306 million tablets are sold during the third quarter of 2019, with seven vertically-integrated brands supplying 58 products and 24 model-versions at the sales-weighted average retail price of $333.44. The average marginal costs of production and retailing for all products are $162.86 and $74.85, respectively. All of the brand-level marginal costs for direct sales increase when compared to the indirect sales in Table 5, which plausibly reflects the additional marginal costs from operating their own retail stores. This suggests that some of the pricing benefits from using direct distribution may be offset by an increase in retail costs. On average, the SPC effect for vertically-integrated firms to soften competition by raising retail prices comprises 10.6 percent of retail prices. At the brand level, Apple's incentive is about $37.96 per model, Microsoft's is about $9.12 per model, and Samsung's is about $6.06 per model. These estimates correspond to retail revenues of $45.64 million per quarter for Apple, $0.61 million for Microsoft, and $0.006 million for Samsung (with few direct sales).[15]

5.2 Vertical disintegration

Our baseline results show incentives for vertically-integrated firms to use their own prices and retail operations to raise rival costs and to soften price competition. This behavior is broadly consistent with other Big Tech companies using their own marketplace or platform to

[15] We checked the sensitivity of our baseline results to time with a simulation of the first quarter of 2016, which had the largest sales volume. The results, available on request, are qualitatively similar to those in Tables 5 and 6.

favor their products over downstream rivals in, for example, consumer searches, social networking, and music venues. One possible response to this firm behavior is regulatory intervention that prohibits vertical integration. We now use our model to inform policy makers on this form of intervention with a counterfactual analysis of no vertical integration.

The solution values for the 118 product model versions in this counterfactual are presented in the lower panel of Appendix B.[16] A summary of the market's sales with no vertical integration is reported in Table 7. About 3.881 million tablets are sold with ten brands supplying 118 products and 42 model-versions at the sales-weighted average retail price of $382.25. The average marginal costs of production and retailing for all products are $180.07 and $18.01, respectively, and the average wholesale price is $282.19. All else held constant, a comparison of column seven ("wholesale price") with column 4 ("production cost") suggests potential efficiency gains from the elimination of double margins if vertical integration was permitted in the market. For instance, the average wholesale price-cost margin for all firms is about $102.12. At the brand level, the average wholesale price-cost margin for Apple is $120.44, the average margin for Microsoft is $71.93, and the average margin for Samsung is $65.33.

When comparing the results in Table 7 to the 176 products in the vertically-integrated market in Appendix B, we observe that the average sales-weighted retail price decreased by 8.52 percent from $382.25 to $349.68 and total sales increased by 13.03 percent from 3.881 to 4.386 million when the market is vertically integrated. Total wholesale sales decreased from 3.881 to 3.530 million units as expected, since vertically-integrated manufacturers replaced some

[16] This no vertical integration scenario assumes the wholesale price for a given model can be different for the independent online and physical retailers. In practice, manufacturers may charge the same wholesale price to different retailers. We examine this possibility with a counterfactual analysis of no vertical integration with constrained wholesale prices, where the wholesale price for a given model is the same for the online and physical retailers. The solution values for the 118 product model versions in this counterfactual are available on request and are qualitatively similar to those reported in Appendix B.

wholesale distribution with direct sales through their own retail stores.[17] Given the product characteristics and prices for each tablet in the market, the change in expected consumer surplus for consumer *i* between the baseline and new equilibria is:

$$\Delta E[CS_i] = \frac{1}{\alpha_i}\left[ln\left(\sum_{j=1}^{J} e^{v_{jt}^{N}}\right) - ln\left(\sum_{j=1}^{J} e^{v_{jt}^{B}}\right)\right] \qquad (17)$$

where lower-case v_{jt} is the deterministic component of utility for consumer *i*, *N* indicates the (new) counterfactual equilibrium and *B* is the baseline (Small and Rosen, 1981). We calculate the change in consumer surplus by drawing 500 consumers from the normal distribution of the price coefficients. The mean of the consumer surplus distribution is then multiplied by aggregate sales to obtain aggregate consumer surplus with and without vertical integration. The calculation shows that consumer surplus increased by $564 million when the market is vertically integrated. This is because there are more choices for consumers at independent and integrated retail stores (i.e., 176 compared to 118) and many of the models have lower retail prices.

Table B.1 of Appendix B shows that the move from vertical separation to vertical integration results in heterogeneous price changes across all models and brands. The decreases in retail prices range from -0.01 to -13.44 percent for 94 of the 118 models, with an average decrease of -5.28 percent. The increases in retail prices range from 0.13 to 5.9 percent for 24 models, with an average increase of 2.75 percent. The price decreases are typically for lower-end models (i.e., mean price of $298.11 in the baseline) and the price increases are for higher-end models (i.e., mean price of $634.38 in the baseline). All ten firms experience lower retail prices for all or some of their tablet models. The vertically-integrated brands, Apple, HP,

[17] The average sales-weighted wholesale price decreased by 17.42 percent from $282.19 to $233.04.

Lenovo, Microsoft and Samsung also experience retail price increases for some of their models, as does the independent manufacturer Acer.

These contrasting price changes are explained by the theory in our structural model. First, there is the efficiency effect from the elimination of double margins. Tablet models sold at vertically-integrated retail stores have lower retail prices and a relatively large number of sales accrue to the Apple Store and, to a lesser extent, the Microsoft Store. Many of these are lower-end tablet sales and because they are strategic complements we also observe lower prices and more sales for similar models in all other retail stores.[18] Second, because higher-end models sold at their own stores are more profitable, vertically-integrated firms have incentive to increase their wholesale prices to independent retailers and divert sales toward these models. For example, in the baseline with vertical integration, the mean retail price-cost margin for the 24 models experiencing retail price increases is $238.32 relative to $126.29 for the 94 models experiencing retail price decreases. The third SPC effect shows the vertically-integrated firms' increasing their retail prices to divert sales to rival products with more-profitable wholesale margins. For example, the mean wholesale price-cost margin for models experiencing wholesale price increases is $101.77 relative to $58.85 for the models experiencing decreases. In summary, the relative sizes of the anticompetitive RRC and SPC effects increase prices for higher-end models, but the relative size of the EDM effect decreases prices for lower-end models.

For completeness, we observe that consumer welfare and total variable profits are higher under vertical integration, resulting in an increase in welfare that is equivalent to 18.4 percent of

[18] When the EDM effect dominates some products, the price-sensitive consumers will substitute toward those cheaper products. This means the consumers with relatively inelastic demands are left to buy at higher prices and the firms charge higher prices to these customers considering higher-margin, higher-end models. These nonlinear demand effects are similar to those described in previous studies of differentiated product markets with RCL demand (Levisohn, 1997; Kim and Cotterill, 2008, Hiller and Savage, 2020).

total firm profits in the baseline.[19] Variable profits rise with increased sales, but the change in profits are smaller than the change in sales because of lower prices. The firms with little or no sales through vertically-integrated distribution channels, ASUS, E Fun, Lenovo, RCA, and Samsung, are hurt the most, with variable profits falling on average by 46.2 percent. The more integrated firms, Acer, Amazon, Apple, HP, and Microsoft, see variable profits rise by 27.5 percent. The dominant firm in the market, Apple, experiences a 13.6 percent increase in variable profits (equivalent to $0.78 billion) when moving from the vertical disintegration to the vertical integration market structure.

6 Conclusions

We estimated a structural model with vertical relations for tablet computers. The novel features of our model are multiple upstream and downstream firms, upstream firms setting wholesale prices first and accounting for their expected indirect impacts on retail prices when considering their first-order conditions for profit maximization, and vertically-integrated firms only selling their own product models in their retail stores. This latter feature contrasts existing studies on subscription television, for example, where AT&T have offered the independent Altitude Sports channel and the integrated AT&T Sports Net Rocky Mountain channel in their satellite-television plans for Colorado.

Given our baseline vertical-integration equilibrium, we conducted several counterfactual vertical-disintegration scenarios that revealed interesting insights on the efficiency and

[19] The change in welfare is $\Delta W = CS^N - CS^B + \pi^N - \pi^B$, where consumer surplus (CS) is calculated from equation (17). For easier interpretation, we divide the change in welfare by the baseline profits when discussing our results. The long-run transition from vertically disintegrated to an integrated (or, *vice versa*) market structure may also involve fixed costs, which could affect total profitability. While fixed costs are beyond the scope of our study, they are an important consideration for a comprehensive understanding of the economic impacts of vertical integration.

anticompetitive effects from vertical integration. Our comparison of the vertically-integrated and vertically-disintegrated equilibria shows heterogenous price changes across all models and brands. For instance, a vertically-integrated firm with significant market share can have strong anticompetitive incentives for some of its products and strong efficiency effects for others. This results in a market outcome where the RRC and SPC effects increase retail prices for higher-end models, and the EDM effect decreases prices for lower-end models. While vertical integration generates a shift in market share and profits to larger firms/market leaders, the overall sales, consumer surplus and total welfare in the market increase. The policy implication is that vertical integration can be efficient in markets where there is sufficient consumer heterogeneity and product differentiation.

Although convenient, our assumption of two independent retail firms likely contributes to more market power in our model estimates. Future work should consider a more explicit market structure that better approximates the United States retail sector. While we focus on tablet sales due to data availability, we note that none of the major brands in our data produce and sell tablets exclusively and instead offer a more extensive product line of consumer electronics. For example, the dominant firm, Apple, sells computers, smartphones, streaming consuls and watches through their Apple stores. In contrast, Microsoft has a more limited consumer electronics line that has lacked a competitive smartphone. It is possible that Apple’s scale and scope created benefits in cost structure and demand complementarities that Microsoft struggled to achieve. In this respect, Apple provides a clear example of a company able to pressure upstream and downstream rivals along an extensive product line in dual distribution channels, but there are other applications to explore. For example, Adidas, Coach, and Nike in fashion and apparel, Avenue Supermarts, Budweiser and Coca-Cola in food and beverages, Tesla in automobiles, and Live Nation in entertainment.

Finally, our empirical finding that prices increase for higher-end models and decrease for lower-end models suggests that vertical integration may provide an economic (and legal) mechanism for second-degree price discrimination. In this respect, our paper has historical similarities with Stigler (1951) and Perry (1978) who explored how an upstream monopolist supplying a critical product input practiced third-degree price discrimination among downstream firms by integrating into all but the firm with the most inelastic derived demand curve. Exploring these similarities in the context of "versioning" and vertical integration could be an interesting future line of theoretical inquiry.

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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
INDIRECT	0.699	0.459	0	1

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 *INDIRECT* interacted with the time trend		With *INDIRECT* interacted with the quarter fixed effects	
	Coefficient	s.e.	Coefficient	s.e.
CONSTANT	10.410***	0.5172	8.9957***	0.5756
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
INDIRECT	-0.0510***	0.0115		
INDIRECT×TREND	0.0021***	0.0005		
$INDIRECT \times QUARTER_1$			0.0054	0.0429
$INDIRECT \times QUARTER_2$			0.0054	0.0429
$INDIRECT \times QUARTER_3$			-0.0063	0.0361
$INDIRECT \times QUARTER_4$			-0.0124	0.0274
$INDIRECT \times QUARTER_5$			0.0012	0.0333
$INDIRECT \times QUARTER_6$			-0.0274	0.0392
$INDIRECT \times QUARTER_7$			-0.0075	0.0268
$INDIRECT \times QUARTER_8$			0.0148	0.0287
$INDIRECT \times QUARTER_9$			0.0430	0.0276
$INDIRECT \times QUARTER_{10}$			0.0105	0.0241
$INDIRECT \times QUARTER_{11}$			-0.0347*	0.0200
$INDIRECT \times QUARTER_{12}$			-0.0264	0.0221
$INDIRECT \times QUARTER_{13}$			-0.0161	0.0253
$INDIRECT \times QUARTER_{15}$			-0.0665***	0.0219
$INDIRECT \times QUARTER_{16}$			-0.0534***	0.0203
$INDIRECT \times QUARTER_{17}$			-0.0696***	0.0197
$INDIRECT \times QUARTER_{18}$			-0.0660***	0.0209
$INDIRECT \times QUARTER_{19}$			0.0155	0.0226

Table 2. Reduced-form retail price regressions

	With *INDIRECT* interacted with the time trend		With *INDIRECT* interacted with the quarter fixed effects	
	Coefficient	s.e.	Coefficient	s.e.
$INDIRECT \times QUARTER_{20}$			0.0176	0.0184
$INDIRECT \times QUARTER_{21}$			0.0113	0.0188
$INDIRECT \times QUARTER_{22}$			0.0126	0.0183
$INDIRECT \times QUARTER_{23}$			0.0205	0.0170
$INDIRECT \times QUARTER_{24}$			0.0214	0.0189
$INDIRECT \times QUARTER_{25}$			0.0160	0.0179
$INDIRECT \times QUARTER_{26}$			0.0140	0.0190
$INDIRECT \times QUARTER_{27}$			-0.0231	0.0215
$INDIRECT \times QUARTER_{28}$			-0.0130	0.0218
$INDIRECT \times QUARTER_{29}$			-0.0152	0.0169
$INDIRECT \times QUARTER_{30}$			0.0368	0.0277
$INDIRECT \times QUARTER_{31}$			0.0249	0.0266
$INDIRECT \times QUARTER_{32}$			0.0320	0.0280
$INDIRECT \times QUARTER_{33}$			0.0372	0.0197
$INDIRECT \times QUARTER_{34}$			0.0184	0.0182
$INDIRECT \times QUARTER_{35}$			0.0221	0.0181
$INDIRECT \times QUARTER_{36}$			0.0314	0.0232
$INDIRECT \times QUARTER_{37}$			0.0051	0.0246
$INDIRECT \times QUARTER_{38}$			0.0072	0.0192
Joint test of trend	10.27***			
Joint test of interactions 1			5.14***	
Joint test of interactions 2			5.14***	
Brand fixed effects	Yes		Yes	
Model fixed effects	Yes		Yes	
Quarter fixed effects	No		Yes	
Adjusted R^2	0.8860		0.8988	

Notes. Dependent variable is $\ln(p_{jt})$. 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 is an F test of the null that estimated coefficients on $INDIRECT_{jt}$ and $INDIRECT_{jt} \times TREND_t$ are jointly equal to zero. Joint test of interactions 1 is an F test of the null that the estimated coefficients on the interactions $INDIRECT_{jt} \times QUARTER_{11}$ through $INDIRECT_{jt} \times QUARTER_{18}$ are jointly equal to zero. Joint test of interactions 2 is an F test of the null that the estimated coefficients on the interactions $INDIRECT_{jt} \times QUARTER_{33}$ through $INDIRECT_{jt} \times QUARTER_{36}$ are jointly equal to zero.

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
MEGAPIXELS^2	-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.

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 during the third quarter of 2019.

Table 5. Wholesale sales by brand in the baseline with vertical integration

Brand	Models)[+] (versions)	Sales (000)	Marginal cost ($)	Production cost ($)	Retail cost ($)	Retail price[+] ($)	Wholesale price ($)	RRC ($)
ASUS[++]	2 (5)	0.7922	157.86	143.51	14.35	246.54	180.07	na
Acer[++]	2 (4)	1.7138	479.58	435.98	43.60	723.28	528.94	na
Amazon	1 (2)	9.4752	61.11	55.55	5.56	136	84.75	0.096
Apple	6 (29)	2,431.2	178.49	162.27	16.23	357.25	263.40	33.39
E Fun[++]	1(2)	0.9872	95.62	86.93	8.69	174	120.36	Na
HP	5 (5)	0.9872	178.13	161.93	16.19	275.92	202.34	0.0005
Lenovo	9 (21)	26.957	185.38	168.53	16.85	291.22	206.25	0.004
Microsoft	2 (10)	191.80	380.50	345.91	34.59	614.85	438.75	4.02
RCA	1 (2)	33.937	87.41	79.47	7.95	161	112.37	0.0005
Samsung	13 (38)	832.46	179.41	163.10	16.31	303.60	214.12	0.069
All	42 (118)	3,530.1	188.66	171.15	17.15	355.69	259.00	na
VI	37 (107)	3,526.7	188.56	171.42	17.14	355.59	258.92	23.40

Notes. Third quarter of 2019. Wholesale sales are to the representative independent physical retail store and to the representative independent online retail store. Models is the number of unique tablet models. Versions is the number of model versions. Marginal cost is the sum of production and retail costs. Production cost is the marginal production cost. Retail cost is the marginal retail cost. Prices and costs are sales-weighted calculations for all models sold during the third quarter of 2019. na is not applicable. RRC is the raising rivals' cost effect for the vertically-integrated firm. All is the ten manufacturers. VI is the seven vertically-integrated manufacturers. [+]Obtained from IDC (2019). [++]Not vertically integrated.

Table 6. Retail sales by brand in the baseline with vertical integration

Brand	Models (versions)[+]	Sales (000)	Marginal cost ($)	Production cost ($)	Retail cost ($)	Retail price[+] ($)	SPC ($)
Amazon	1 (1)	26.231	102.61	61.56	41.05	136	0.047
Apple	3 (22)	1,202.4	229.21	156.61	72.60	326.07	37.96
HP	3 (3)	0.2491	262.17	189.35	72.82	315.10	0.004
Lenovo	6 (8)	0.9723	232.62	163.68	68.94	278.27	0.196
Microsoft	2 (12)	66.465	459.84	327.30	132.55	568.14	9.12
RCA	1 (1)	0.1831	125.08	79.86	45.21	161	0.130
Samsung	8 (11)	0.9558	138.60	87.87	50.72	179.85	6.06
All	24 (58)	1,306.1	237.73	162.86	74.85	333.44	35.45

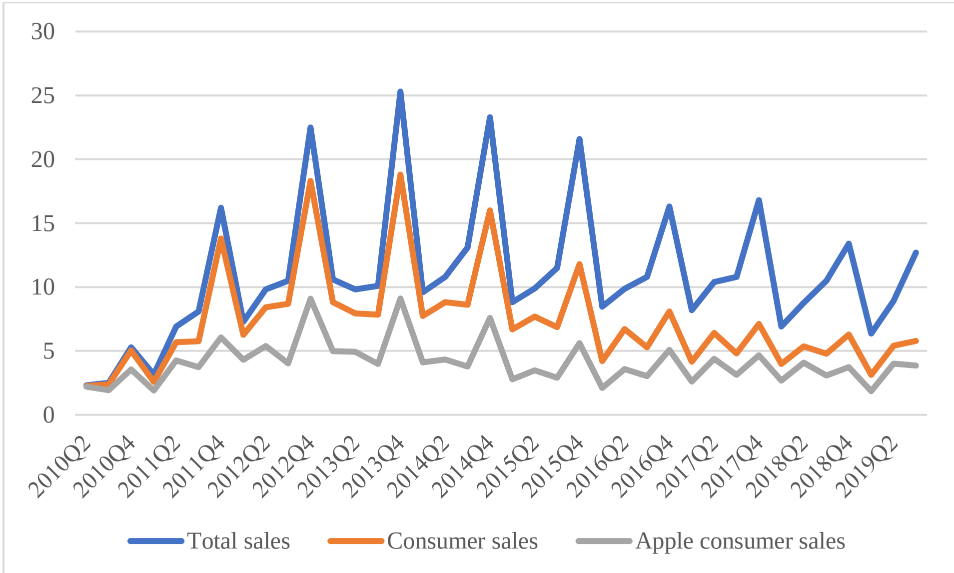
Notes. Third quarter of 2019. Retail sales are through the manufacturer's physical retail store and/or their online retail store. Retailer equals two when sold at the representative independent physical retail store. Retailer equals three when sold at the representative independent online retail store. Models is the number of unique tablet models. Versions is the number of model versions. Marginal cost is the sum of production and retail costs. Production cost is the marginal production cost. Retail cost is the marginal retail cost. Prices and costs are sales-weighted calculations for all models sold during the third quarter of 2019. na is not applicable. SPC is the incentive for vertically-integrated manufacturers to soften retail-price competition. All is the seven vertically-integrated manufacturers. [+]Obtained from IDC (2019).

Table 7. Wholesale sales by brand with no vertical integration

Brand	Models)[+] (versions)	Sales (000)	Marginal cost ($)	Production cost ($)	Retail cost ($)	Retail price[+] ($)	Wholesale price ($)
ASUS	2 (5)	1.0355	158.04	143.67	14.37	253.03	186.92
Acer	2 (4)	2.6158	480.86	437.15	43.71	685.70	491.31
Amazon	1 (2)	11.400	61.14	55.58	5.56	141.88	90.67
Apple	6 (29)	2,599.2	182.53	165.94	16.59	381.40	286.38
E Fun	1(2)	1.1915	95.73	87.03	8.70	179.18	125.66
HP	5 (5)	1.0406	187.27	170.25	17.02	290.61	215.29
Lenovo	9 (21)	35.641	187.48	170.44	17.04	302.27	217.50
Microsoft	2 (10)	273.87	389.18	353.80	35.38	605.07	425.73
RCA	1 (2)	41.985	87.44	79.49	7.95	165.46	116.86
Samsung	13 (38)	913.09	191.60	174.18	17.42	333.59	239.52
All	42 (118)	3,881.1	198.08	180.07	18.01	382.25	282.19
VI	37 (107)	3,876.2	197.93	179.94	17.99	382.14	282.12

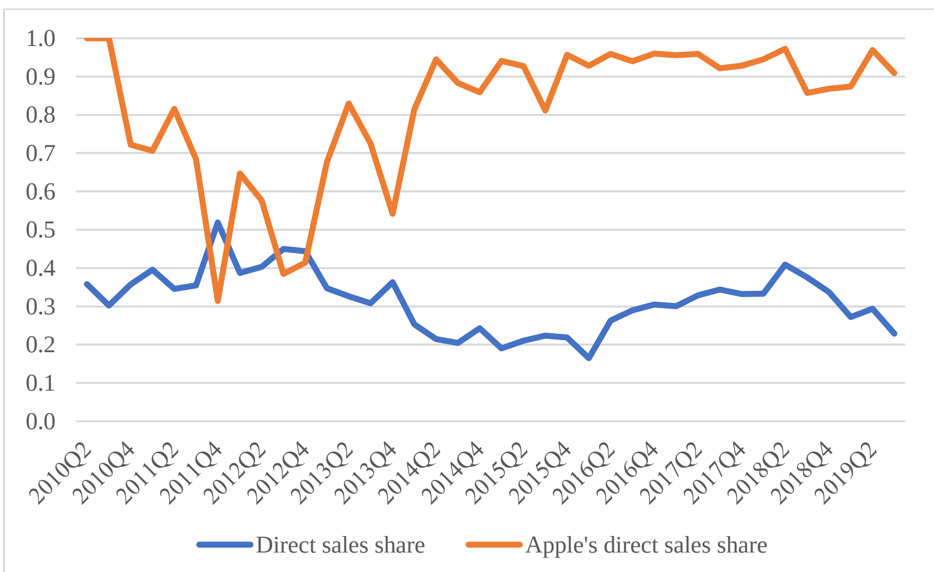
Notes. Third quarter of 2019. Wholesale sales are to the representative independent physical retail store and to the representative independent online retail store. Models is the number of unique tablet models. Versions is the number of model versions. Marginal cost is the sum of production and retail costs. Production cost is the marginal production cost. Retail cost is the marginal retail cost. Prices and costs are sales-weighted calculations for all models sold during the third quarter of 2019. All is the ten manufacturers. VI is the seven manufacturers that are integrated in Table 5. [+]Obtained from IDC (2019).

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



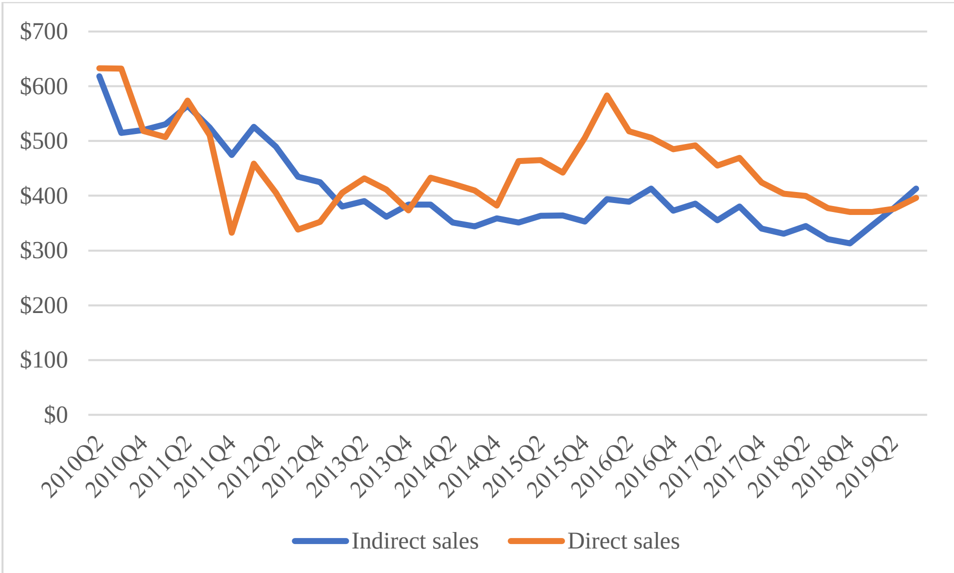
Source. IDC (2019)

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 Total differentiation of optimal retail prices

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

$$\sum_{l=1,\dots,J} \frac{\partial s_j(p(w))}{\partial p_l} \frac{dp_l}{dw_j} + \sum_{k \in J_d} (p_k - w_k - rc_k) \left(\sum_{l=1,\dots,J} \frac{\partial^2 s_k(p(w))}{\partial p_j \partial p_l} \frac{\partial p_l}{\partial w_j} \right) + \sum_{k \in J_d} \frac{\partial s_k(p(w))}{\partial p_j} \left(\frac{\partial p_k}{\partial w_j} - \frac{\partial w_k}{\partial w_j} \right) = 0 \qquad (13')$$

where $\frac{\partial w_k}{\partial w_j}$ equals one when $j = k$ and zero otherwise.

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

$$\sum_{l=1,\dots,J} \frac{\partial s_j(p(w))}{\partial p_l} \frac{dp_l}{dw_j} + \sum_{k \in J_v^d} (p_k - w_k - rc_k) \left(\sum_{l=1,\dots,J} \frac{\partial^2 s_k(p(w))}{\partial p_j \partial p_l} \frac{\partial p_l}{\partial w_j} \right) + \sum_{k \in J_v^d} \frac{\partial s_k(p(w))}{\partial p_j} \left(\frac{\partial p_k}{\partial w_j} - \frac{\partial w_k}{\partial w_j} \right) + \sum_{m \in J_v^u} (w_m - c_m) \left(\sum_{l=1,\dots,J} \frac{\partial^2 s_m(p(w))}{\partial p_j \partial p_l} \frac{\partial p_l}{\partial w_j} \right) + \sum_{m \in J_v^u} \frac{\partial s_m(p(w))}{\partial p_j} \frac{\partial w_k}{\partial w_j} = 0 \qquad (14')$$

where $\frac{\partial w_k}{\partial w_j}$ equals one when $j = k$ and zero otherwise.

Appendix B Counterfactual analysis

Table B.1 Prices, costs and sales for individual models

						Vertical separation			Vertical integration		
Firm	Model	Retailer	mc ($)	c ($)	rc ($)	s (%)	p ($)	w ($)	s (%)	p ($)+	w ($)
ASUS	ZenPad 3S 10	0	175.53	159.58	15.96	0.000673	268.28	203.36	0.000495	263	198.08
ASUS	ZenPad 3S 10	1	162.34	147.58	14.76	0.000343	273.56	193.86	0.000283	263	183.30
ASUS	ZenPad 3S 10	0	168.86	153.51	15.35	0.002770	260.26	196.75	0.002045	255	191.49
ASUS	ZenPad 3S 10	1	156.09	141.90	14.19	0.001288	265.29	187.48	0.001067	255	177.19
ASUS	ZenPad 3S 8.0	0	98.01	89.10	8.91	0.000679	174.73	125.92	0.000511	170	121.20
Acer Group	Aspire Switch 12	0	495.23	450.21	45.02	0.012316	701.75	503.15	0.007820	746	547.41
Acer Group	Aspire Switch 12	1	453.57	412.33	41.23	0.000691	717.17	475.85	0.000506	746	504.68
Acer Group	Switch Alpha 12	0	396.83	360.75	36.08	0.001307	555.10	418.00	0.000867	565	427.89
Acer Group	Switch Alpha 12	1	365.22	332.02	33.20	0.000417	568.78	396.97	0.000328	565	393.19
Amazon.com	Fire HD 10 (2017)	0	67.72	61.56	6.16	0.005994	140.11	96.48	0.004734	136	92.36
Amazon.com	Fire HD 10 (2017)	1	60.46	54.96	5.50	0.057336	142.07	90.06	0.047904	136	84.00
Apple	iPad (2017)	0	100.34	91.22	9.12	0.003950	234.95	181.08	0.003895	219	165.13
Apple	iPad (2017)	1	87.72	79.74	7.97	0.000503	243.31	177.35	0.000606	219	153.04
Apple	iPad (2017)	0	151.57	137.79	13.78	0.001405	313.71	247.56	0.001345	295	228.85
Apple	iPad (2017)	0	151.57	137.79	13.78	0.001979	313.71	247.56	0.001895	295	228.85
Apple	iPad (2017)	1	132.88	120.80	12.08	0.000240	326.71	244.15	0.000300	295	212.44
Apple	iPad (2018)	0	142.61	129.65	12.96	2.798882	296.75	232.95	2.551714	281	217.20
Apple	iPad (2018)	1	129.22	117.47	11.75	1.518549	305.22	225.47	1.658806	281	201.25
Apple	iPad (2018)	0	203.15	184.68	18.47	0.360327	388.77	308.05	0.309813	373	292.28
Apple	iPad (2018)	1	178.08	161.89	16.19	0.180258	403.45	301.21	0.201404	373	270.76
Apple	iPad (2018)	0	221.18	201.07	20.11	1.310855	412.33	325.93	1.057215	400	313.60
Apple	iPad (2018)	1	196.10	178.27	17.83	0.686063	425.03	315.03	0.687271	400	290.01
Apple	iPad (2018)	0	277.43	252.21	25.22	0.090619	492.77	385.52	0.067493	488	380.76
Apple	iPad (2018)	1	241.15	219.23	21.92	0.048597	506.04	369.43	0.043891	488	351.39
Apple	iPad (2019)	1	189.69	172.44	17.24	1.404796	403.89	298.68	1.314916	383	277.79
Apple	iPad (2019)	1	135.15	122.86	12.29	1.214488	315.87	233.86	1.314843	291	208.99
Apple	iPad (2019)	1	194.40	176.72	17.67	1.430982	410.96	303.53	1.314928	391	283.58
Apple	iPad (2019)	1	254.82	231.66	23.17	1.759239	497.43	359.23	1.315001	493	354.79
Apple	iPad Air (2019)	1	221.77	201.61	20.16	0.181234	472.53	348.29	0.171544	451	326.75

Table B.1 Prices, costs and sales for individual models

						Vertical separation			Vertical integration		
Firm	Model	Retailer	mc ($)	c ($)	rc ($)	s (%)	p ($)	w ($)	s (%)	p ($)+	w ($)
Apple	iPad Air (2019)	1	221.77	201.61	20.16	0.181240	472.53	348.29	0.171550	451	326.75
Apple	iPad Pro (2017)	0	280.55	255.05	25.50	0.020504	497.29	388.75	0.015233	493	384.46
Apple	iPad Pro (2017)	1	243.49	221.36	22.14	0.002642	510.64	372.43	0.002379	493	354.79
Apple	iPad Pro (2017)	0	356.00	323.63	32.36	0.024264	596.04	453.09	0.016450	611	468.05
Apple	iPad Pro (2017)	1	310.56	282.32	28.23	0.003255	607.00	427.24	0.002512	611	431.24
Apple	iPad Pro (2017)	0	345.87	314.43	31.44	0.010689	583.07	445.14	0.007314	595	457.07
Apple	iPad Pro (2017)	1	301.34	273.94	27.39	0.001433	594.25	420.38	0.001123	595	421.13
Apple	iPad Pro (2017)	0	416.63	378.75	37.88	0.009723	673.91	498.24	0.006358	710	534.33
Apple	iPad Pro (2017)	1	367.43	334.03	33.40	0.001325	684.11	467.15	0.000962	710	493.04
Apple	iPad mini (2019)	1	176.64	160.58	16.06	0.595671	393.41	293.06	0.632734	366	265.65
Apple	iPad mini (2019)	1	176.64	160.58	16.06	0.595673	393.41	293.06	0.632739	366	265.65
E Fun	nextbook 10.1	0	98.28	89.35	8.93	0.004498	178.39	127.80	0.003650	174	123.41
E Fun	nextbook 10.1	1	90.32	82.11	8.21	0.002121	180.84	121.12	0.001834	174	114.28
HP Inc	ElitePad 900	0	398.65	362.41	36.24	0.000727	547.09	415.70	0.000472	559	427.61
HP Inc	Omni 10	0	245.45	223.14	22.31	0.000574	354.73	272.93	0.000406	350	268.20
HP Inc	Pro Tablet 408	0	188.43	171.30	17.13	0.002502	285.53	217.05	0.001861	280	211.52
HP Inc	Spectre x2	1	213.20	193.82	19.38	0.000454	345.66	248.58	0.000389	332	234.91
HP Inc	Stream 8	1	54.87	49.88	4.99	0.001524	135.96	85.12	0.001333	131	80.16
Lenovo	Miix 510	0	477.63	434.21	43.42	0.000525	710.37	500.44	0.000322	749	539.07
Lenovo	Miix 700	0	430.61	391.47	39.15	0.001803	628.73	457.14	0.001189	644	472.41
Lenovo	Miix 700	1	397.10	361.00	36.10	0.000809	649.65	440.95	0.000650	644	435.30
Lenovo	Tab 4 10 Plus	0	229.33	208.48	20.85	0.000467	327.06	253.30	0.000300	323	249.24
Lenovo	Tab 4 10 Plus	0	243.31	221.19	22.12	0.000471	343.53	266.65	0.000300	340	263.12
Lenovo	Tab 4 10 Plus	1	223.19	202.90	20.29	0.017870	349.98	251.35	0.013092	340	241.37
Lenovo	Tab 4 10 Plus	1	210.27	191.16	19.12	0.017697	333.23	238.86	0.013047	323	228.64
Lenovo	Tab 4 10 Plus	1	223.19	202.90	20.29	0.017809	349.98	251.35	0.013047	340	241.37
Lenovo	Tab 4 8 Plus	1	218.93	199.02	19.90	0.023442	353.96	254.72	0.020093	340	240.76
Lenovo	Tab 4 8 Plus	0	235.18	213.80	21.38	0.000512	345.94	265.16	0.000378	340	259.22
Lenovo	Tab 4 8 Plus	1	218.93	199.02	19.90	0.023448	353.96	254.72	0.020099	340	240.76
Lenovo	ThinkPad 10	0	380.25	345.68	34.57	0.000425	540.49	406.56	0.000289	545	411.07
Lenovo	Xyboard 10.1	1	94.74	86.12	8.61	0.008079	185.98	125.23	0.006740	178	117.25
Lenovo	Xyboard 10.1	1	122.19	111.08	11.11	0.008211	221.16	153.05	0.006784	212	143.89

Table B.1 Prices, costs and sales for individual models

Firm	Model	Retailer	mc ($)	c ($)	rc ($)	Vertical separation			Vertical integration		
						s (%)	p ($)	w ($)	s (%)	p ($)[+]	w ($)
Lenovo	Xyboard 10.1	1	149.25	135.68	13.57	0.008415	256.23	180.46	0.006890	246	170.23
Lenovo	Yoga Tab 3 Pro	0	322.04	292.76	29.28	0.014420	431.23	338.45	0.008391	433	340.21
Lenovo	Yoga Tab 3 Pro	1	294.51	267.74	26.77	0.007798	437.75	316.01	0.005163	433	311.26
Lenovo	Yoga Tablet 3 10	0	86.72	78.84	7.88	0.012047	162.26	116.31	0.008201	155	109.04
Lenovo	Yoga Tablet 3 10	1	75.84	68.94	6.89	0.006116	167.20	109.06	0.004812	155	96.86
Lenovo	Yoga Tablet 3 8	0	70.26	63.88	6.39	0.018276	143.99	100.89	0.012457	136	92.90
Lenovo	Yoga Tablet 3 8	1	60.09	54.62	5.46	0.009360	149.42	94.68	0.007512	136	81.25
Microsoft	Surface Go	0	164.65	149.68	14.97	0.089627	260.92	196.53	0.071777	254	189.61
Microsoft	Surface Go	1	153.56	139.60	13.96	0.093696	265.26	187.78	0.082490	254	176.51
Microsoft	Surface Go	0	291.49	264.99	26.50	0.030592	432.25	332.87	0.023562	423	323.62
Microsoft	Surface Go	1	271.19	246.54	24.65	0.028993	444.82	321.55	0.027063	423	299.73
Microsoft	Surface Pro 6	0	422.29	383.90	38.39	0.137398	616.43	459.33	0.090251	638	480.90
Microsoft	Surface Pro 6	1	432.81	393.46	39.35	0.183104	707.81	471.70	0.124918	747	510.89
Microsoft	Surface Pro 6	0	422.29	383.90	38.39	0.137432	616.43	459.33	0.090273	638	480.90
Microsoft	Surface Pro 6	1	387.59	352.36	35.24	0.165219	628.95	432.73	0.124880	638	441.78
Microsoft	Surface Pro 6	0	457.57	415.98	41.60	0.287730	671.98	490.75	0.180528	712	530.78
Microsoft	Surface Pro 6	1	422.12	383.74	38.37	0.367641	679.85	456.14	0.249789	712	488.29
RCA	Pro12	0	87.85	79.86	7.99	0.220642	165.34	117.22	0.177756	161	112.88
RCA	Pro12	1	80.17	72.88	7.29	0.012599	167.56	110.55	0.010773	161	103.99
Samsung	Galaxy Book 10.6	0	350.26	318.41	31.84	0.002721	506.49	385.96	0.001917	506	385.48
Samsung	Galaxy Book 10.6	1	319.59	290.54	29.05	0.000505	517.30	366.78	0.000411	506	355.48
Samsung	Galaxy Tab A 10.1	0	97.76	88.88	8.89	0.549505	196.31	147.09	0.518796	181	131.78
Samsung	Galaxy Tab A 10.1	1	83.84	76.22	7.62	0.097585	203.02	142.30	0.110470	181	120.29
Samsung	Galaxy Tab A 10.1	0	96.36	87.60	8.76	0.009820	195.83	146.82	0.009418	180	130.99
Samsung	Galaxy Tab A 10.1	1	82.41	74.92	7.49	0.000610	202.49	142.04	0.000700	180	119.56
Samsung	Galaxy Tab A 10.5	1	160.58	145.98	14.60	0.662404	295.69	213.97	0.636599	275	193.28
Samsung	Galaxy Tab A 10.5	1	178.04	161.86	16.19	0.328883	321.95	234.51	0.318304	300	212.57
Samsung	Galaxy Tab A 8.0	0	74.45	67.68	6.77	0.006113	165.41	120.09	0.005834	153	107.68
Samsung	Galaxy Tab A 8.0	1	63.56	57.78	5.78	0.000865	169.82	115.20	0.000933	153	98.38
Samsung	Galaxy Tab A 8.0	0	60.82	55.29	5.53	0.085411	148.72	105.88	0.082063	137	94.16
Samsung	Galaxy Tab A 8.0	1	50.99	46.35	4.64	0.052761	152.58	101.22	0.056622	137	85.64
Samsung	Galaxy Tab A 8.0	0	60.74	55.22	5.52	0.001564	148.78	105.95	0.001506	137	94.17

Table B.1 Prices, costs and sales for individual models

						Vertical separation			Vertical integration		
Firm	Model	Retailer	mc ($)	c ($)	rc ($)	s (%)	p ($)	w ($)	s (%)	p ($)[+]	w ($)
Samsung	Galaxy Tab A 8.0	1	50.82	46.20	4.62	0.001001	152.70	101.35	0.001078	137	85.65
Samsung	Galaxy Tab A 8.0 (2018)	0	83.46	75.87	7.59	0.095107	177.96	131.18	0.091038	164	117.23
Samsung	Galaxy Tab A 8.0 (2018)	1	74.11	67.37	6.74	0.800847	180.77	123.53	0.828413	164	106.76
Samsung	Galaxy Tab Active 2	0	248.56	225.96	22.60	0.071930	372.38	290.90	0.056013	361	279.52
Samsung	Galaxy Tab Active 2	1	224.33	203.94	20.39	0.074944	380.60	277.23	0.068483	361	257.63
Samsung	Galaxy Tab Active 2	0	314.08	285.52	28.55	0.043350	452.07	351.92	0.031254	447	346.85
Samsung	Galaxy Tab Active 2	1	283.49	257.72	25.77	0.045681	460.55	332.39	0.037972	447	318.84
Samsung	Galaxy Tab E 8.0	0	78.57	71.43	7.14	0.053350	174.18	128.42	0.052034	159	113.24
Samsung	Galaxy Tab E 8.0	1	66.06	60.05	6.01	0.003237	180.38	124.34	0.003756	159	102.97
Samsung	Galaxy Tab E 8.0 (2018)	0	115.97	105.43	10.54	0.027440	219.19	166.57	0.025676	203	150.38
Samsung	Galaxy Tab E 8.0 (2018)	1	100.46	91.33	9.13	0.016280	226.24	160.89	0.018314	203	137.65
Samsung	Galaxy Tab E 9.6	0	82.98	75.44	7.54	0.035207	171.51	123.75	0.032520	162	114.24
Samsung	Galaxy Tab E 9.6	1	73.33	66.67	6.67	0.006891	174.60	118.07	0.006906	162	105.47
Samsung	Galaxy Tab S3 9.7	0	273.86	248.96	24.90	0.011712	403.13	315.96	0.008852	393	305.83
Samsung	Galaxy Tab S3 9.7	1	245.86	223.51	22.35	0.002132	411.72	300.01	0.001895	393	281.28
Samsung	Galaxy Tab S3 9.7	0	301.42	274.02	27.40	0.001624	436.25	341.34	0.001189	429	334.08
Samsung	Galaxy Tab S4 10.5	1	316.67	287.88	28.79	0.168329	505.56	360.01	0.132258	498	352.45
Samsung	Galaxy Tab S4 10.5	0	389.14	353.77	35.38	0.005699	550.96	419.38	0.003846	560	428.42
Samsung	Galaxy Tab S5e 10.5	1	175.82	159.84	15.98	0.144263	318.90	232.18	0.141978	297	210.28
Samsung	Galaxy Tab S5e 10.5	1	263.71	239.74	23.97	0.166667	433.08	314.44	0.141967	417	298.35
Samsung	Galaxy Tab S5e 10.5	1	209.20	190.18	19.02	0.307886	360.18	262.59	0.283954	340	242.41
Samsung	Galaxy Tab S5e 10.5	1	234.23	212.94	21.29	0.320970	392.50	285.86	0.283926	374	267.36
Samsung	Galaxy Tab S6	1	372.16	338.33	33.83	0.216051	578.83	407.45	0.157206	587	415.62
Samsung	Galaxy Tab S6	1	374.64	340.58	34.06	0.437115	577.73	406.12	0.313256	587	415.39
Samsung	Galaxy Tab S6	1	372.16	338.33	33.83	0.216058	578.83	407.45	0.157211	587	415.62
Amazon.com	Fire HD 10 (2017)	3	102.61	61.56	41.05				0.0014572	136	
Apple	iPad (2017)	2	146.50	91.22	55.28				0.0000367	219	
Apple	iPad (2017)	3	146.50	91.22	55.28				0.0000260	219	
Apple	iPad (2017)	2	205.80	137.79	68.00				0.0000131	295	
Apple	iPad (2017)	3	205.80	137.79	68.00				0.0000091	295	
Apple	iPad (2017)	2	205.80	137.79	68.00				0.0000182	295	
Apple	iPad (2017)	3	205.80	137.79	68.00				0.0000128	295	

Table B.1 Prices, costs and sales for individual models

						Vertical separation			Vertical integration		
Firm	Model	Retailer	mc ($)	c ($)	rc ($)	s (%)	p ($)	w ($)	s (%)	p ($)+	w ($)
Apple	iPad (2018)	2	194.99	129.65	65.34				0.0244113	281	
Apple	iPad (2018)	3	194.99	129.65	65.34				0.0177838	281	
Apple	iPad (2018)	2	265.16	184.68	80.48				0.0029638	373	
Apple	iPad (2018)	3	265.16	184.68	80.48				0.0021592	373	
Apple	iPad (2018)	2	285.44	201.07	84.37				0.0101138	400	
Apple	iPad (2018)	3	285.44	201.07	84.37				0.0073683	400	
Apple	iPad (2018)	2	351.03	252.21	98.82				0.0006452	488	
Apple	iPad (2018)	3	351.03	252.21	98.82				0.0004703	488	
Apple	iPad Pro (2017)	2	354.75	255.05	99.70				0.0001497	493	
Apple	iPad Pro (2017)	3	354.75	255.05	99.70				0.0001072	493	
Apple	iPad Pro (2017)	2	442.55	323.63	118.91				0.0001623	611	
Apple	iPad Pro (2017)	3	442.55	323.63	118.91				0.0001162	611	
Apple	iPad Pro (2017)	2	430.62	314.43	116.19				0.0000718	595	
Apple	iPad Pro (2017)	3	430.62	314.43	116.19				0.0000515	595	
Apple	iPad Pro (2017)	2	516.69	378.75	137.94				0.0000626	710	
Apple	iPad Pro (2017)	3	516.69	378.75	137.94				0.0000446	710	
HP Inc	ElitePad 900	3	475.02	362.41	112.61				0.0000033	559	
HP Inc	Omni 10	3	297.92	223.14	74.78				0.0000052	350	
HP Inc	Stream 8	3	96.32	49.88	46.43				0.0000053	131	
Lenovo	Miix 700	3	525.32	391.47	133.86				0.0000029	644	
Lenovo	Tab 4 10 Plus	3	292.98	221.19	71.78				0.0000055	340	
Lenovo	Tab 4 10 Plus	3	277.60	191.16	86.44				0.0000054	323	
Lenovo	Tab 4 10 Plus	3	292.98	202.90	90.08				0.0000054	340	
Lenovo	Tab 4 8 Plus	3	287.47	202.90	84.57				0.0000088	340	
Lenovo	Yoga Tab 3 Pro	3	378.53	292.76	85.77				0.0000034	433	
Lenovo	Yoga Tablet 3 10	3	122.57	78.84	43.73				0.0000088	155	
Lenovo	Yoga Tablet 3 8	3	104.76	63.88	40.88				0.0000138	136	
Microsoft	Surface Go	2	209.13	149.68	59.45				0.0002502	254	
Microsoft	Surface Go	2	354.23	264.99	89.24				0.0000820	423	
Microsoft	Surface Go	3	209.13	139.60	69.53				0.0004866	254	
Microsoft	Surface Go	3	354.23	264.99	89.24				0.0001595	423	
Microsoft	Surface Pro 6	2	543.99	393.46	150.53				0.0001617	676	

Table B.1 Prices, costs and sales for individual models

						Vertical separation			Vertical integration		
Firm	Model	Retailer	mc ($)	c ($)	rc ($)	s (%)	p ($)	w ($)	s (%)	p ($)[+]	w ($)
Microsoft	Surface Pro 6	3	543.99	393.46	150.53				0.0002906	676	
Microsoft	Surface Pro 6	2	518.22	393.46	124.75				0.0001617	638	
Microsoft	Surface Pro 6	2	512.72	352.36	160.37				0.0003236	630	
Microsoft	Surface Pro 6	3	512.72	352.36	160.37				0.0005812	630	
Microsoft	Surface Pro 6	3	518.22	352.36	165.86				0.0002906	638	
Microsoft	Surface Pro 6	2	568.07	415.98	152.09				0.0003235	712	
Microsoft	Surface Pro 6	3	568.07	415.98	152.09				0.0005812	712	
RCA	Pro12	3	125.08	79.86	45.21				0.0000102	161	
Samsung	Galaxy Tab A 10.1	3	139.80	88.88	50.92				0.0002932	181	
Samsung	Galaxy Tab A 10.1	3	138.87	87.60	51.28				0.0000105	180	
Samsung	Galaxy Tab A 8.0	3	113.96	67.68	46.28				0.0000033	153	
Samsung	Galaxy Tab A 8.0	3	99.12	55.29	43.83				0.0000192	137	
Samsung	Galaxy Tab A 8.0 (2018)	3	124.13	75.87	48.26				0.0001066	164	
Samsung	Galaxy Tab Active 2	3	303.49	225.96	77.53				0.0000071	361	
Samsung	Galaxy Tab Active 2	3	377.68	285.52	92.15				0.0000041	447	
Samsung	Galaxy Tab E 8.0	3	119.42	71.43	47.99				0.0000596	159	
Samsung	Galaxy Tab E 8.0 (2018)	3	160.17	105.43	54.74				0.0000032	203	
Samsung	Galaxy Tab E 9.6	3	122.08	75.44	46.64				0.0000178	162	
Samsung	Galaxy Tab S3 9.7	3	332.04	248.96	83.08				0.0000064	393	
Average			201.92	169.18	32.73	0.0018272	382.25	282.19	0.0015265	349.68	233.04

Third quarter of 2019. The market size is 18,000,717. Retailer equals zero when sold at the manufacturer's physical retail store. Retailer equals one when sold at the manufacturer's online retail store. Retailer equals two when sold at the representative independent physical retail store. Retailer equals three when sold at the representative independent online retail store. mc is the sum of production and retail costs. c is the marginal production cost. rc is the marginal retail cost. p is the retail price. w is the wholesale price. s is market share. Averages are sales-weighted averages except for s, which are arithmetic means. [+]Obtained from IDC (2019).