

Tariff Pass-Through and Welfare in the Tablet Computer Market

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ABSTRACT

This paper estimates the short-run effects of tariffs on United States tablet computer prices and welfare. Market-level data are used to estimate a model of demand, supply and trade policy and to simulate equilibria prices and sales in scenarios with tariffs on Chinese production. A 25 percent tariff on firms assembling in China results in a tariff elasticity for consumer prices of 1.108, a 29.6 percent decline in profits for firms assembling in China, and a deadweight loss of 28.8 percent of total economic surplus. Firms assembling elsewhere benefit from the reduction in rival's competitiveness by increasing their prices, market shares and profits. A long-run implication is that firms may be incented to shift production from "uncompetitive" facilities in China to lower-cost countries that are politically favored by the United States.

Key words: differentiated goods, pass-through, tablet computers, tariffs

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1. Introduction

After many years of promoting lower barriers to international trade and increased import-competition, the recent policy discussion in the United States has become protectionist. Under the umbrella of national security, the executive branch has imposed tariffs on several major trading partners and sectors such as aluminum, steel and lumber. The administration's biggest concern is China, where a ten percent tariff was imposed on about \$200 billion worth of imported goods in 2018 and was raised to 25 percent in 2019 (Swanson and Rappeport, 2019). While popular consumer electronics, such as computers and smartphones, have avoided these trade costs, the administration has proposed tariffs of ten and 25 percent on mobile devices coming from China. Moreover, President Trump has frequently used Apple as an example of a company that manufactures in China but should instead produce more in the United States.

Public discussion of the effects of tariffs has been informal. Fieldhack (2018) suggested "a 15 or 25 percent tariff would be substantial and likely drive prices higher." President Trump is less concerned saying "I can make it ten percent and people could stand that very easily," and "There is no reason for the U.S. Consumer to pay the Tariffs" (Trump, 2018; Daugherty, 2019). Elder (2018) observed that "a tariff wouldn't necessarily result in higher prices immediately as manufacturers could absorb the profit hit to keep prices the same." This paper estimates the short-run effects of tariffs on prices and welfare in the United States consumer market for tablet computers. Market-level data are used to estimate a structural model of demand, supply and trade policy and to simulate equilibria prices and sales in scenarios with tariffs on Chinese production. The empirical results help shed light on several questions on market behavior when firms incorporate tariffs into their pricing decisions. These include: how much of the tariff is passed through to consumer prices; how do tariffs affect the structure of prices across firms and

heterogeneous products; do higher tariffs incent consumer substitution towards low-quality models; and what are the welfare effects?

We study short-run impacts because many firms and industry experts expect the tariffs to be temporary and because it would take significant time to move production out of China.² We study tablets because we have high-quality market-level data on sales, prices and product characteristics from 2010 to 2018, which coincides with the introduction of the iPad. Because the look, feel and functionality of a tablet is somewhere between a smartphone and a notebook computer, we construct tariff scenarios that potentially generalize to other mobile devices and popular consumer electronics. Our results show that consumers and United States firms assembling in China are harmed by tariffs and that tariffs may be passed through to consumers by more than 100 percent in a differentiated-products oligopoly. A 25 percent tariff results in a 27.7 percent increase in their sales-weighted average price of tablets with tariffs, implying a tariff elasticity of consumer prices of 1.108. Firms assembling in China experience a 29.6 percent decline in profits and, after accounting for tariff revenue, there is a deadweight loss in the tablet market equal to 28.8 percent of total economic surplus. Firms assembling elsewhere benefit from the reduction in competitiveness of rivals by increasing their prices, market shares and profits. A long-run implication is that firms may be incented to shift more production outside of China to lower-cost countries that are politically favored by the United States.

Tablets are not subject to tariffs so there is no natural experiment to compare prices before and after changes in trade policy. We adopt a similar empirical approach of Levinsohn (1997), Fershtman et al. (1999) and Brambilla (2007) and simulate the welfare effects from

² For example, in a best case scenario, it would require three years for Apple to move 20 percent of production out of China. See <https://www.bloomberg.com/news/articles/2019-08-26/apple-s-44-billion-drop-shows-growing-cost-of-china-reliance>.

tariffs. Levinsohn estimated the effects of a 100 percent tariff on thirteen Japanese luxury automobiles imported into the United States in 1994. He found the tariff would have drastically reduced sales and profits from Japanese models and that European firms would have captured many of these lost sales. Fershtman et al. examined the effects of tax increases on automobiles imported into Israel and showed that consumers purchased relatively more low-quality cars. Brambilla found that the trade and welfare effects from the automobile market in Argentina and Brazil are largely driven by the removal of non-tariff barriers rather than convergence to a common tariff. Amiti et al. (2019) use a reduced-form approach to regress the change in import unit values at the six-digit level on the change in tariffs. They find a tariff elasticity of domestic prices of about unity. Flaaen et al. (2019) use a similar approach for washing machines and estimate an elasticity of between 1.1 and 2.3. Beyond these papers we cannot find recent empirical analyses of the partial equilibrium effects from increasing tariffs within a structural framework. With tariffs becoming a crucial part of trade and industry policy, our paper contributes to the literature by offering new evidence on the potential effects of tariffs on domestic firms assembling consumer electronics outside of the United States. We can also comment on the relationship between tariffs and welfare, which may be non-linear. Moreover, while our results are short-run, and specific to tablets, they provide broader insights into the long-run choices of firms on production, outsourcing and product variety.

The paper is organized as follows. Section 2 presents the data and the empirical model is described in Section 3. Section 4 presents the demand results. Section 5 uses the demand estimates and recovered marginal costs to simulate equilibria prices, market shares and welfare for oligopoly firms under several tariff scenarios. Section 6 concludes.

2. The tablet computer market

2.1 Sample data

Tablets are portable personal computers that run on mobile operating systems such as Android, iOS or Windows. While portable computers have existed since the late 1980s, Apple is typically credited with introducing the modern tablet computer to consumers with the iPad in April 2010. Modern tablets share characteristics with smartphones, such as touchscreen display, camera, rechargeable battery, Wi-Fi capability and a thin design, but are larger and do not typically provide access to the cellular telephone network. They are also like notebook computers but use a touchscreen as the primary input device and are smaller and weigh less.

We analyze the consumer market for tablet computers in the United States with quarterly data on sales, prices and product characteristics from IDC (2018). The sales data are aggregated to the product model level across 33 quarterly markets from June 2010, coinciding with the release of the iPad, to June 2018, which was the most recent quarter available from IDC. The initial dataset comprised over 6,000 product-market observations on quarterly sales in children's toy markets, commercial markets and consumer markets.³ 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 tablet price with the average sales price (ASP) retailers pay to the tablet manufacturer, which is calculated from all transactions in a given quarter. We adjust the ASP with the

³ 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.

consumer price index and use this normalized price to approximate the full retail price (p_{jt}) of tablet product $j = 1, 2, \dots, J$ at time period $t = 1, 2, \dots, T$. Because low-price models have limited functionality and are typically marketed to children, and high-price models are marketed to commercial customers (e.g., employees in the entertainment, finance and security industries), we limited our sample to models with an ASP between \$150 and \$900. The final sample for empirical analysis comprises 2,803 product-market observations.

Because tablets are not customized to individual consumers and are typically not bundled with a phone plan from a cellular service provider, we assume all consumers face the same product characteristics and price for tablet j .⁴ The measured product characteristics are similar to those described on mobile device company and tablet-comparison web sites (e.g., www.apple.com/ipad-9.7/specs/, www.GSMArena.com, www.PhoneArena.com and www.Specout.com). *STORAGE* is the storage capacity of the tablet in gigabytes (GB), *SCREEN SIZE* 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, *4G* equals one when the tablet has fourth-generation (4G) cellular network compatibility and zero otherwise, *DETACH* equals one when the tablet has a detachable keyboard and zero otherwise, and *AGE* is the number of quarters since the product's release.

⁴ About 25 percent of sample tablets have some cellular capability. Industry reports suggest that few consumers bundle their tablet with a long-term cellular service contract and typically use a temporary pre-paid monthly service plan when cellular network connectivity is needed, for example, on vacations.

2.2 Summary statistics

The sample includes 546 models from 15 firms over 33 quarters. Table 1 presents summary statistics. Quarterly sales are 91,570 for each product with a mean price of about \$440. On average, storage capacity was 45.4 GB, screen size was 9.17 inches and CPU speed was 1.62 GHz. Almost 95 percent of sample tablets have a camera. The average number of camera megapixels was 4.92, the number of pixels per square inch of screen size was about 214, the number of hours of viewing time supported by the battery was 9.4, and the number of processors in the CPU was 2.60. About 22 percent of tablets have 4G capability, and the average number of quarters since the release date in our sample was 4.05. Columns two through four show there is substantial variation in prices and characteristics across tablets with nominal prices ranging from \$150.86 to \$899, storage ranging from one to 512 GB, screen size from seven to 13 inches, and CPU speed from one to 2.6 GHz.

The release dates for tablets follow a similar pattern to smartphones described in Hiller et al. (2018). A tablet is most often released into the highest price category it will ever reach, and steadily falls in price and status as time on the market increases. The highest class of tablet is usually the newest release, what may be called a flagship product. The flagship is usually equipped with the latest technologies, sold globally, and is released into one of the highest price brackets. Any non-flagship tablet may start their product life with components and characteristics that are inferior to flagship tablets and have relatively lower prices. The downward price trajectory is similar for flagship and non-flagship tablets, but with longer sales lifespans for those tablets with a higher initial price. Flagship tablets may be replaced by a newer version, for example, a new edition of the Apple iPad (varying primarily by storage and screen size) is released each year in our sample. This new version does not necessarily eliminate

sales for the previous versions, but rather the older version is often sold at a lower price as a non-flagship tablet for several quarters following replacement. Unlike phone sales, firms rely less on the same flagship and non-flagship brands, tending to experiment more with alternate specifications and using different names for each. Of the 470 tablets in our sample where we observe sales every quarter, the average period of sales is 4.87 quarters with a standard deviation of 4.56 quarters. The Lenovo Stylistic and Acer Iconia Tab were the longest selling tablets in our sample with sales in 21 consecutive quarters.

Firms regularly release new tablets. On average we observe about 17 new products per quarter and about 17 product exits as older products exhaust demand and are retired in favor of the newer versions. As time since release increases, the price of products tends to decrease. Figure 1 shows this trend, adjusted for inflation, as a percentage of its initial price as the tablet model ages. Figure 2 shows quality-adjusted prices declining steadily throughout the sample period, which is consistent with increasing quality and relatively stable prices. Figure 3 shows the number of firms in the consumer market from 2010 to 2018 and compares their evolution to the total number of firms in the commercial, consumer and children's markets. The number of firms in the consumer market initially increased in the first year or two following the introduction of the iPad and remained stable at around twelve to 15 from 2013 onwards.

2.3 Market trends

Figure 4 shows the consumer market for tablets is reasonably large in the United States, but like other mobile devices, it is no longer growing strongly with total revenue per quarter of about five billion United States dollars (USD) in 2018. Revenues also consistently peak in the fourth quarter suggesting that tablets are popular holiday gifts. Between the second quarters of

2010 and 2018, 15 firms regularly sold tablets to United States consumers with total sales of about 257 million at an average price per unit of \$440. The three largest firms in the market were Apple with 54.8 percent of total sales at an average price of \$556, Samsung with 16.3 percent of sales and an average price of \$394, and Amazon with 8.18 percent of sales and an average price of \$341.

Table 2 shows that eight of the 15 firms are headquartered in the United States, two are headquartered in China, South Korea and Taiwan, respectively, and one is headquartered in France. Absent Hewlett Packard, all United States name-brand tablets are produced by original design manufacturers (ODMs) who typically design and build products in mainland China according to the specifications of the name-brand firm. Figure 5 plots estimates of the monthly manufacturing wage in USD for the 15 firms in our sample. Not surprisingly, Hewlett Packard have the highest wage costs since they assemble all their tablets in the United States. Pandigital, Barnes and Noble and Samsung have the lowest wage costs with the latter two firms producing their tablets in China, India, South Korea and Vietnam. Table 3 presents estimates of a regression of the natural log of tablet prices on the natural log of the firm's manufacturing wages (*WAGE*) and control variables. The wage coefficients range from 0.499 to 0.957 and suggest incomplete pass-through of input costs to consumer prices. While these estimates can shed light on the extent to which the proposed tariffs will be passed through to tablet prices, they should be interpreted cautiously due to the likely endogeneity of wages.⁵

Although we do not observe United States international trade of tablet computers in Census data, we do observe more general data on computers, computer accessories,

⁵ Because we observe the locations of firm's facilities but not where particular tablet models are assembled, wages are likely measured with error which attenuates our estimate of input cost pass-through. Moreover, unobserved cost factors correlated with wages and prices could bias our estimate in a positive or negative direction.

semiconductors and related devices. Figure 6 shows the annual value of international exports and imports of this computer equipment from 2002 to 2018 along with the total value of imports and exports. We note that the overall trade deficit for the United States has been relatively stable since the great recession of 2008. This deficit as a share of total trade (i.e., total imports less exports divided by total trade) was 10.79 percent in 2009 and 10.52 percent in 2017. In contrast, the trade deficit for computer equipment increased from 21 to 32.06 percent during the same period with imports growing at an annual average rate of four percent and exports growing at one percent. Despite relatively strong growth, computer equipment comprises a small share of total United States imports. The average annual share of computer equipment in total imports was about six percent between 2002 and 2017, ranging from 4.96 percent in 2008 to 7.23 percent in 2002. While computer imports are low compared to pharmaceuticals, televisions, clothing and automobiles, they are popular consumer items and by increasing prices the proposed tariffs would, *prima facie*, almost certainly harm United States consumers.

3. Empirical model

3.1 Consumer demand

Our analysis of the welfare effects from tariffs begins with the estimation of the substitution patterns of consumers. We allow for random taste variation and unrestricted substitution patterns by specifying a random-coefficient logit (RCL) model of consumer demand in the differentiated product market for tablets. The United States consumer chooses to purchase a tablet or the outside option of no purchase. The utility consumer $i = 1, 2, \dots, N$ obtains from purchasing product j in time period t is:

$$u_{ijt} = X_{jt}\beta - \alpha_i p_{jt} + \lambda_{f(j)} + \nu_{m(j)} + \gamma_t + \xi_{jt} + \varepsilon_{ijt} \quad (1)$$

where X_{jt} is a $K \times 1$ vector of product characteristics k for product j in period t , $\lambda_{f(j)}$ is a time-invariant brand fixed effect that measures the average preferences for a brand with $f(j)$ indicating the manufacturing firm f for product model j , $v_{m(j)}$ is a time-invariant fixed effect that measures the consumer's average preferences for an operating system (OS) with $m(j)$ indicating the mobile operating system m for product model j , γ_t is a product-invariant fixed effect that controls for changes in consumer's preferences for tablets through time, ξ_{jt} is an unobserved demand shock for product j in period t , β is a $K \times 1$ vector of marginal utilities for the k non-price product characteristics, α_i is the marginal utility of income that is allowed to vary across consumers, and ε_{ijt} is an unobserved random error term that is assumed to be independently and identically distributed type I extreme value. Demand is static with consumers not considering future changes in prices and characteristics when making current choices.⁶

We follow a standard approach in the literature by assuming that the marginal utility of income varies across the population of consumers according to the normal distribution $\alpha_i \sim N(\alpha, \Sigma)$, where α and Σ are the reparameterization to be estimated. The mean utility for product j at time t is described by $\delta_{jt} = X_{jt}\beta - \alpha_i p_{jt} + \lambda_{f(j)} + v_{m(j)} + \gamma_t + \xi_{jt}$ and the mean utility from the outside good $j = 0$ is normalized to zero. Since the error term ε_{ijt} is distributed type I extreme value, the market shares for all products and the outside good for a given set of parameters is:

$$s_{jt} = \int \frac{\exp(X_{jt}\beta - \alpha_i p_{jt} + \lambda_{f(j)} + v_{m(j)} + \gamma_t + \xi_{jt})}{1 + \sum_{k=1}^J \exp(X_{jt}\beta - \alpha_i p_{kt} + \lambda_{f(k)} + v_{m(j)} + \gamma_t + \xi_{kt})} dG(\alpha) \quad (2)$$

which is the weighted sum of the individual consumer choice probabilities across the whole

⁶ Because they are not transported and stored in pockets it is not surprising that the average replacement cycle of tablets in the United States is five years compared to 18 to 24 months for smartphones (see www.statista.com). However, tablets have evolved less over time with size and weight being the prominent upgrades. Because tablets have a relatively longer replacement cycle, we follow Lou et al. (2011) and Decarolis et al. (2018) by including age since initial product release date in our demand specification to control for potential dynamic effects.

population, with the weights given by the probability distribution $G(\alpha)$. 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) (BLP hereafter). The identifying assumption for the generalized method of moments (GMM) estimator is $E[\zeta_{jt} | z_{jt}] = 0$, where z_{jt} is a $R \times 1$ vector of instruments with $R - K > 0$ excluded instruments correlated with price but uncorrelated with the structural error. Given demand parameters, the change in expected consumer surplus for consumer i between the baseline and new equilibria is:

$$\Delta E[CS_i] = \frac{1}{\alpha_i} \left[\ln \left(\sum_{j=1}^J e^{V_{ijt}^N} \right) - \ln \left(\sum_{j=1}^J e^{V_{ijt}^B} \right) \right] \quad (3)$$

where V_{ijt} is the deterministic component of utility for consumer i , N indicates the value for the relevant economic variables in the new equilibrium and B is their value in the baseline equilibrium (Small and Rosen, 1981).

3.2 Supply

Supply is described by a static Bertrand game with constant marginal costs. Like most consumer electronic goods, we assume constant marginal costs based on commentary by industry insiders and technology websites. For ease of notation, we assume a given time period for supply and omit the time subscript from subsequent description of the economic model. There are $f = 1, 2, \dots, F$ firms, with each firm producing some subset, κ_f , of the j different products. Profits for firm f are:

$$\pi_f = \sum_{j \in \kappa_f} (p_j - mc_j) M s_j(p) - FC_f \quad (4)$$

where mc_j is the constant marginal cost of product j , M is market size or the number of

consumers who may potentially buy a product⁷, $s_j(p)$ is the market share of product j , which is a function of all product prices represented by the vector p , $Ms_j(p)$ is the quantity of product j sold in the market, and FC_f is the fixed cost of production for firm f .

In the Bertrand oligopoly, each firm is assumed to choose prices that maximize profits given the demand functions and characteristics of its own products and the prices, demand functions and characteristics for competing products. Firm entry and exit decisions are assumed exogenous to the pricing decision. Given the existence of a pure-strategy Bertrand-Nash equilibrium in prices, the price p_j of any product j produced by firm f must satisfy the first-order condition for profit maximization:

$$s_j(p) + \sum_{k \in \kappa_f} (p_k - mc_k) \frac{\partial s_k(p)}{\partial p_j} = 0 \quad (5)$$

The J equations of all the first-order profit-maximizing conditions for the J products for multi-product firms can be rearranged into the vector of product markups:

$$p - mc = -\Omega(p)^{-1} \times s(p) \quad (6)$$

where p is the $J \times 1$ vector of product prices, mc is the $J \times 1$ vector of product marginal costs, $\Omega(p)$ is the element-by-element multiplication of the $J \times J$ matrix of share price derivatives

$\frac{\partial s_k(p)}{\partial p_j}$ and the $J \times J$ ownership structure matrix, and $s(p)$ is a $J \times 1$ vector of product market

⁷ In the model to be estimated, market share for each tablet j in market t (s_{jt}) is the quarterly sales of that particular product ($SALES_{jt}$) divided by the quarterly market size (M_t), where market size is the sum of total tablet sales and total mini and ultra-mini laptop (“notebook”) sales in the United States for the quarter. We chose this definition of market size because it is correlated with the stock of consumers who are likely in the market for a tablet and also to ensure that the market was large enough to permit a non-zero share of the outside good. We checked the sensitivity of our demand estimates in section 4.2 to different definitions of market size including total tablet, notebook and desktop consumers, and total tablet and smartphone consumers. The demand results from these alternative specifications are available on request and are qualitatively similar to those reported in Table 4.

shares. Each of the (j, k) elements of the ownership structure matrix equal one when products j and k are produced by the same firm and zero otherwise.

Absent exemptions, there are currently no tariffs on tablets imported into the United States. In practice, they would be applied to tablets at the price at which they are internationally traded. We do not observe these international prices in our sample data and assume instead that firms trade their tablets internationally at marginal cost or the “landed price” (Levinsohn, 1997; Brambilla, 2007).⁸ Applying the effective tariff rate to each firm’s landed prices gives the $J \times 1$ vector of adjusted marginal costs for all firms in the market as:

$$\tilde{mc} = mc(1 + (1 - \eta)\tau) \quad (7)$$

where “1” is a $J \times 1$ vector of ones, η is a $J \times 1$ vector that indicates the value of each firm’s production or components that are sourced outside of China (as a percentage of marginal cost), and τ is the common tariff rate applied to all firms with production in China (as a percentage of marginal cost). The firms subjected to the tariff will face a higher adjusted marginal cost and will re-optimize prices for all their tablet products. Rivals’ responses to changes in these market conditions will result in new set of equilibrium prices, market shares and profits. We model this price-setting behavior by using the estimated demand parameters from equation 1 to calculate $s(p)$ and $\Omega(p)^{-1}$. Given actual prices p from the sample data, $s(p)$ and $\Omega(p)^{-1}$, equation 7 can be solved for marginal costs. Given $s(p)$, $\Omega(p)^{-1}$ and marginal costs, equation 7 can be solved again for equilibrium prices with the tariff imposed.⁹ With the baseline and new equilibria prices and

⁸ We do not have a direct mechanism for foreign exchange in our model but note that any increase in marginal cost would be attenuated for all ODMs within the country of origin by a devaluation. A similar consideration could be made for firms that re-negotiate more favorable terms with their individual ODMs within the country affected by the tariff. This would reduce the effective tariff rate faced by an individual firm to the extent of their bargaining power.

⁹ The solutions to the first-order conditions for estimating the supply side are obtained by minimizing $(p - mc + \Omega(p)^{-1} \times s(p))' W (p - mc + \Omega(p)^{-1} \times s(p))$ with respect to prices or marginal costs, where W is the identity matrix with dimensions equal to the J price equations.

market shares calculated, the change in profits due to the tariff rate under consideration is easily calculated with equation 4. We run several hypothetical scenarios in Section 5 that investigate the effects of tariffs on prices, market shares, profits, consumer surplus and tariff revenue.

4. Demand estimates

4.1 Estimation and instrumental variables

We estimate demand by applying BLP's GMM estimator to the sample moment condition $E[\xi_{jt} | z_{jt}] = 0$. We control for the endogeneity of price with cost shifters and with BLP-type product characteristics of the other tablets from the same firm and rivals as the instruments for price. Identification of the demand parameters in consumer utility comes from variation in consumer choices across the different tablet products supplied by firms within each market. The key assumptions are the cost shifters are exogenous to consumer preferences and the product characteristics within choice sets are exogenous to unobserved demand shocks.

The cost shifters are *X86* (equals one when the manufacturer uses a high-end X86, processor in the tablet and zero otherwise) and *CELLULAR* (equals one when the tablet can connect to a cellular telephone network and zero otherwise). High-end processors are typically more expensive than the common ARM processor and cellular functionality requires an enhanced chipset in the baseband processor of the tablet.¹⁰ As such, *X86* and *CELLULAR* should be positively correlated with price in equation 6 but not correlated with utility in equation 1 (after controlling the demand-side for improved tablet functionality with *CORE*, *CPU* and *4G*). In equilibrium, the price of a tablet depends on its location in the product characteristics space

¹⁰ A regression of the recovered marginal costs in section 5.1 on product characteristics, OS, brand and time fixed effects, *X86* and *CELLULAR* shows that *X86* and *CELLULAR* are important individual determinants of marginal cost. All else held constant, an X86 processor increases tablet costs by \$105 and a cellular-capable chip by \$32.

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; Hiller et al., 2018). When a particular tablet model is in a market with other models with superior (inferior) characteristics, more (less) competition will force the price of that plan to be low (high) conditional on its own characteristics. As such, the BLP instruments would be expected to be non-negatively correlated with prices through the price-cost markups but not correlated with unobserved utility.

4.2 Results

Table 4 presents the demand estimates for equation 1. Columns one and two of Table 4 report GMM estimates with fixed coefficients (“Logit–GMM”), columns three and four report BLP estimates with a random coefficient on price (“RCL–BLP”), and columns five and six report RCL-BLP estimates with a random coefficient on price and an additional excluded instrument.¹¹ The data fit the demand specifications reasonably well as judged by the signs of the estimated marginal utility coefficients. The instrumental-variable estimators report positive marginal utilities for most non-price characteristics and a negative marginal utility for price.

The RCL-BLP estimates from our preferred specification in columns three and four of Table 4 show that the mean and standard deviation of the price coefficient are precisely estimated. The standard deviation is about 40 percent of the mean and suggests that tastes for

¹¹ The RCL-BLP specifications were estimated with Chamberlain (1987) optimal instruments. One thousand consumer draws were used to approximate the market share integrals. We used a starting value of 0.5 on the random coefficient and, for robustness, specified starting values ranging from 0.05 to 0.95 to check that the objective function was globally concave. Columns five and six show RCL-BLP estimates with the log of manufacturing wages as an additional excluded instrument. The results are similar to columns three and four although a weak identification test suggests that the specification without wages is preferable.

tablet prices vary in the consumer population. The mean willingness-to-pay (WTP) for most of the non-price product characteristics conform to *a priori* expectations. All else held constant, the representative consumer is willing to pay \$0.33 (standard error (s.e.) = 0.07) for an additional GB of storage, \$29.14 (s.e. = 1.95) for an additional inch of screen size, \$14.72 (s.e. = 5.43) for an additional Ghz of processing power, \$0.25 (s.e. = 0.05) for an additional pixel per square inch of screen size, \$2.81 (s.e. = 0.76) for an additional hour of battery time, and \$27.77 (s.e. = 5.22) for 4G capability. There is a large premium for the dominant firm's brand with the representative consumer willing to pay about \$265 (s.e. = 21.9) for an Apple tablet. These estimates are consistent with smartphone studies. Fan and Yang (2016) estimate an Apple premium of about \$390. Sun (2012) estimates a WTP for 3G compatibility of \$41 and an Apple premium of about \$381. Hiller et al. (2018) find WTPs of \$33.30 for an additional inch of screen size, \$2.82 for an additional core in the processor, and an Apple premium of \$373.

Given the general trend of increased camera quality in mobile devices, our *a priori* expectation was that the marginal utility for *MEGAPIXELS* would be positive. In an initial demand specification, not reported in this paper, *MEGAPIXELS* entered the utility function in linear form and the RCL-BLP model estimated a small, negative and imprecise marginal utility for an additional megapixel of camera resolution. We accounted for potential non-linear effects in this paper with a quadratic specification for camera resolution but note that the coefficients on *MEGAPIXELS* and *MEGAPIXELS*² are small and statistically insignificant. One possible explanation for this result is that our measure of camera quality captures some of the effects from the size of the image sensor and the slimness of the tablet. Increasing megapixels without increasing the size of the image sensor can degrade photo quality by letting in less light than you would get with fewer megapixels. A slim device also limits the sensor size. This relationship

between pixels, the size of the sensor and the slimness of the tablet is why eight-megapixel cameras often outperform some 12-, 13- or 16-megapixel cameras (Dolcourt, 2013).¹²

5. Supply-side simulations

Since the General Agreement on Tariffs and Trade, United States trade and industry policy has focused on reducing trade barriers and market power in concentrated industries. This changed when the Trump administration imposed a ten percent tariff on \$200 billion of Chinese goods in September 2018. Given the tax wedge between the price consumers pay and the price firms receive, microeconomic models with standard competitive and Cournot assumptions predict that consumers will pay higher prices in the short-run and the incidence of cost pass-through will depend on the relative size of price elasticities. Domestic firms increase sales and profits and foreign firms decrease sales and profits. Applying these predictions to tablet markets is somewhat problematic because firms are not price takers and instead supply a variety of models to heterogeneous consumers in a differentiated products oligopoly. Several United States firms also manufacture and sell their tablets in China. These deviations from perfect competition and Cournot make the evaluation of tariffs on tablets an interesting question for simulation.

5.1 Baseline equilibrium

Our baseline equilibrium comprises twelve firms supplying 86 product models during the June quarter of 2018, the last quarter of our sample. Given observed prices and estimated

¹² An alternative possibility is that consumers have greater valuations for improved cameras in their smartphones, which they use more for photography. We do not believe that this excludes value for tablet cameras but recognize that it could explain the lack of significance in our results. We estimated alternative specifications with megapixels measured with a cubic term and another with a simple yes-no indicator for camera availability and the demand results were almost the same as those reported in Table 4.

demand parameters, simulation of the baseline equilibrium requires finding values of marginal costs for each product model to minimize equation 6. Because we are simulating a single quarter, but our demand estimates are for the entire sample period, we use the iterative process described by Train (1986) to recalibrate the brand fixed effects and baseline market shares to the second quarter of 2018. We run 20 iterations of this correction, which is enough to remove any significant difference between the simulated and actual market shares.

Table 5 summarizes the firm's own-price elasticities of demand for the 86 products in the baseline equilibrium. The own-price elasticities are between -3.02 and -5.33 and the cross-price elasticities, not reported, are between $2.03e-06$ and 0.866 .¹³ Together, these elasticities imply an average markup of 29.7 percent, ranging from 18.8 percent for the Lenovo ThinkPad to 44.8 percent for the Apple iPad mini 4. These markups 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. (2016), but they are smaller for smartphones in Hiller et al. (2018). This latter finding suggests tablets are “less necessary” to consumers than smartphones. Sales-weighted averages of recovered marginal costs are reported in panel A of Table 6 and are plausible for most products. For example, our landed cost estimates for Apple iPads priced between \$460 and \$550 in our sample imply margins between \$176 and \$219. 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

¹³ For comparison, we also calculated price elasticities from the fixed-coefficient logit model. Own-price elasticities are larger in absolute values than the RCL estimates, ranging from -2.24 to -11.99 , and imply implausibly small margins for some products. Cross-price elasticities have less variation, ranging from $1.05e+05$ to 0.422 .

tablets priced between \$348 and \$453 in our sample imply margins of \$72 to \$92. This is reasonably similar to the \$135 margin for the older Galaxy Tab Pro 10.1 from industry experts.¹⁴

5.2 Tariff scenarios

Given the baseline equilibrium, we run several hypothetical policy scenarios to quantify the effects of tariffs on prices, market shares, profits, consumer surplus and deadweight loss. Deadweight loss is the reduction in net economic benefit following the imposition of the tariff and is calculated as the sum of the differences in consumer surplus, tariff revenue and profits for firms headquartered in the United States. Given product characteristics and prices for each tablet in the market, consumer surplus is calculated with equation 3 by drawing 500 consumers from the normal distribution of the price coefficients. The mean of the distribution of consumer surplus is then multiplied by aggregate sales to obtain aggregate consumer surplus before and after the imposition of the tariff.

5.2.1 Scenario (i)

The Trump administration initially proposed a ten percent tariff on mobile devices coming from China. In scenario (i) the seven firms that assemble at least 90 percent of their tablets in China, as described in Table 2, experience this ten percent tariff on their 54 product models. These firms are also assumed to have sourced all of their components from China so that $\eta = 0$. Under these assumptions, Amazon, Apple, E-Fun, Lenovo, Microsoft, RCA and Verizon have adjusted marginal costs of $mc(1 + 0.1)$. Panel B of Table 6 reports the results from

¹⁴ 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>.

scenario (i) and shows that the firms with tariffs pass-through much of their additional costs to consumers.¹⁵ The 8.4 percent increase in the average price for their 54 models implies a tariff elasticity of consumer prices for tablet models with tariffs of 0.84.¹⁶ Firms with tariffs lose 4.9 percentage points of market share (equivalent to a 19.6 percent decline in market share), with 0.8 percentage points of sales accruing to firms without tariffs and the remaining 4.1 percentage points to the outside option of not buying. The overall profits for the seven firms with tariffs decline by 13.1 percent with similar losses across all firms ranging from 8.5 percent for E-Fun to 13.2 percent for Apple. The five firms without tariffs benefit from the reduction in competitiveness of rivals by strategically increasing their price, shares and profits. The 3.2 percent increase in the average price for their 32 models implies a tariff elasticity of consumer prices for models without tariffs of 0.32. Samsung benefit the most with a 12.7 percent increase in market share and a 19.8 percent increase in profits.

Overall there is a 5.3 percent increase in the average price of all 86 tablet models which implies a tariff elasticity for all consumer prices of 0.53. The simulated deadweight loss of \$340 million, or 12.1 percent of total pre-tariff surplus, implies a tariff elasticity of welfare of -1.21 . When the profits for firms headquartered outside of the United States are included in the calculation, deadweight loss declines to \$328.7 million, or 11.4 percent of total surplus. Cremer and Thisse (1994) show an increase in taxes reduces the quality of products that a price-setting differentiated oligopoly will provide. While our simulation predicted a 16.4 percent decline in the total sales of tablet models, panel B of Table 7 shows that the distribution of low-quality

¹⁵ Simulated prices increase for all 54 models with the ten percent tariff and for 27 models without the tariff and decline for five models without the tariff. These results are consistent with previous studies of differentiated product markets with random coefficients logit demand (Levisohn, 1997; Kim and Cotterill, 2008).

¹⁶ Average price is the sales-weighted average price across tablet models. Similarly, average marginal costs are sales-weighted across models in Table 5. The tariff elasticity of consumer prices is $\% \Delta p / \% \Delta mc = 8.4/10 = 0.84$.

(pre-tariff price below \$300), medium-quality (between \$300 and \$600) and high-quality (above \$600) models is similar before and after the ten percent tariff. There is a significant decline in the sales of “high-quality” iPads, which is expected since Apple is by far the dominant firm in the market and assembles all its tablets in China.¹⁷

5.2.2 Scenario (ii)

Scenario (ii) repeats scenario (i) but assumes a 25 percent tariff for the seven firms that assemble at least 90 percent of their tablets in China. The results, reported in panel C of Table 6, are qualitatively similar to the ten percent tariff, but the pass-through effects are disproportionately larger which suggests a non-linear relationship between tariffs and welfare. The 27.7 percent increase in the average price for the 54 models with tariffs implies a tariff elasticity of consumer prices of 1.108, compared to 0.84 for the same models with the ten percent tariff. Our finding that tariffs may be passed through to consumers by more than 100 percent in a differentiated-products oligopoly is consistent with the theoretical results from Anderson et al. (2001) and the empirical results on washing machines from Flaaen et al. (2019). Firms with tariffs lose 11.4 percentage points of market share (equivalent to 46 percent decline in market share), with 1.87 percentage points of sales accruing to firms without tariffs and the remaining 9.53 percentage points to the outside option of not buying. The overall profits for the

¹⁷ Because cost pass-through depends on firm behavior we repeated scenario (i) under two alternative pricing assumptions. First, we merged two firms of equal size, ASUS and RCA, after the imposition of the tariff. Because ASUS tablets are not subject to tariffs, we thought this would be an attractive merger scenario as it provides a potential mechanism for RCA tablets to avoid tariffs. The price effects from this scenario were similar to scenario (i) and not that interesting. Given the dominance of Apple, any merger of interest with substantial effects on the market would have to involve an implausible scenario such as Apple merging with Samsung, or Samsung acquiring several smaller tablet manufacturers. In another scenario we assumed collusive behavior between all firms in the market before and after the imposition of the tariff. As expected, marginal costs are lower, and margins are higher than the non-collusive pricing scenario (i). The tariff elasticity of consumer prices for tablet models with tariffs is 1.06 and the elasticity for all models is 0.46. Results from these simulations are available on request.

seven firms with tariffs decline by 29.6 percent where Apple is harmed the most with a 46.8 percent decline in market share and a 29.9 percent decline in profits. The five firms without tariffs increase their prices, shares and profits. The 8.54 percent increase in the average price for their 32 models implies a tariff elasticity of consumer prices for models without tariffs of 0.34. Samsung benefit the most with a 29.2 percent increase in market share and a 53.9 percent increase in profits.

Overall there is a 15.26 percent increase in the average price of all 86 tablet models which implies a tariff elasticity for consumer prices of 0.612, compared to 0.53 for the same models with the ten percent tariff. The simulated deadweight loss of \$810.7 million, or 28.8 percent of total pre-tariff surplus, implies a tariff elasticity of welfare of -1.152 , which is slightly smaller than the elasticity of -1.21 under the ten percent tariff. When the profits for firms headquartered outside of the United States are included in the calculation, deadweight loss declines to \$779 million, or 27.0 percent of total surplus.¹⁸

5.2.3 Scenario (iii)

Scenario (iii) imposes the 25 percent tariff on the ten firms that produce a positive quantity of tablets in China (i.e., $1 \geq \eta > 0$). The firms with tariffs, ASUS, Acer, Amazon, Apple, E-Fun, Lenovo, Microsoft, RCA, Samsung and Verizon now produce 80 of the 86 tablet models in the market. Because we assume that some of their production and components are sourced from outside of China, three of the ten firms, ASUS, Acer and Samsung, have relatively

¹⁸ The percentage change in the sales-weighted average price and the percentage change in total market sales that result from the tariff scenarios can be used to calculate price elasticity of market demand. The price elasticity of market demand from scenario (i) is -2.49 and from scenario (ii) is -2.04 . For robustness, when we increased our measure of market size to include smartphone consumers, the demand-supply results give a price elasticity of market demand of -2.92 for scenario (i) and -2.71 for scenario (ii).

lower adjusted marginal costs. For example, Samsung produce 31.25 percent of their models in China so their adjustment to marginal cost is 1.078 ($= (1 + (1 - 0.6875)0.25)$). In contrast, Lenovo produce all tablet models in China so their adjustment to marginal cost is 1.25.

The results from scenario (iii) in Panel C of Table 6 are similar to scenario (ii). This is expected as the main difference is that three additional firms have the tariff imposed on their tablet models and all firms that produce outside of China have a lower effective tariff rate. All ten firms with tariffs pass-through much of their additional costs to consumers at the expense of market share. The 19.2 percent increase in the average price for their 80 models implies a tariff elasticity for consumer prices of 0.768. Firms with tariffs lose 10.7 percentage points of market share (equivalent to a 34.9 percent decline in market share), with 0.03 percentage points of sales accruing to firms without tariffs and the remaining 10.67 percentage points to the outside option of not to buy. The overall profits for the ten firms with tariffs decline by 20.6 percent where Apple is again harmed the most with a 39.9 percent decline in market share and a 24.7 percent decline in profits. The two firms without tariffs, Hewlett Packard and LG Electronics, increase the average price of their six tablet models by 3.46 percent which implies a tariff elasticity of consumer prices for models without tariffs of 0.14.

Overall there is a 19.6 percent increase in the average price for all 86 tablet models which implies a tariff elasticity for consumer prices of 0.78. The simulated deadweight loss of \$684 million, or 24.3 percent of total surplus, implies a tariff elasticity of welfare of -0.972. When we include the profits for firms headquartered outside of the United States in the calculation, deadweight loss declines to \$672 million, or 24.3 percent of total surplus. This deadweight loss is smaller than scenario (ii), primarily because Apple faces a lower effective tariff rate with about

ten percent of its components sourced outside of China, and accounts for a large share of the total sales in the market.

5.2.4 Scenario (iv)

Scenario (iv) repeats scenario (ii) but assumes that the dominant firm in the market, Apple, holds tablet prices at pre-tariff levels to maintain market share and revenue. Panel B of Table 8 reports the results from this simulation and shows that besides Apple the other six firms who assemble in China are forced to absorb much of the additional tariff costs. The 1.4 percent increase in average price implies a tariff elasticity of consumer prices for tablets with tariffs of 0.056. Firms with tariffs lose 1.3 percentage points of market share (equivalent to a 5.2 percent decline in market share). The overall profits for the seven firms with tariffs decline by 40.1 percent with Apple experiencing a modest 0.6 percent decline in market share but a 39.9 percent decline in profits. Because Apple maintains its pre-tariff prices and market share, two of the five firms without tariffs decrease their price levels after the imposition of the 25 percent tariff and two firms keep their price levels the same. The 5.6 percent decrease in the average price for their 32 models implies a tariff elasticity of consumer prices for models without tariffs of -0.22 .¹⁹ Samsung increase their market share by 41.9 percent from 4.8 to 6.81 percentage points with all sales gains in low- and medium-quality models. This increase in market share is associated with a 5.68 percent decline in Samsung's prices and a 10.2 percent decline in profits.

Interestingly, the average price of all 86 tablet models declines by 2.1 percent which implies a positive tariff elasticity of consumer prices for the market of -0.084 . Consumers

¹⁹ By decreasing prices by 5.6 percent, the firms without tariffs capture 1.3 percentage points of market share from the firms with tariffs and another 2.2 percentage points from the outside option.

benefit from this slight decrease in prices with increased consumer surplus and when combined with tariff revenues the simulated gain of \$46.1 million, or 1.64 percent of total surplus, implies a tariff elasticity of welfare of 0.066.²⁰ When the profits for firms headquartered outside of the United States are included, the gain falls to \$36.4 million, or 1.26 percent of total surplus. In terms of welfare, scenario (iv) represents an improved policy outcome but is unlikely in the long run due to the 33.7 decrease in profits for Apple compared to scenario (ii), where they freely increase prices across all their models.

5.3 Other mobile devices

A final question for our analysis is how well to our results generalize to other mobile devices and popular consumer electronics? To shed light on this question we use the data and demand estimates from Hiller et al. (2018) to investigate the effects of tariffs on the United States smartphone market. Following Hiller et al., we simplify the simulation of prices and welfare by assuming there are eight firms, Alcatel, Apple, HTC, LG Electronics, Motorola, Nokia, Samsung and ZTE, supplying a flagship and non-flagship smartphone during the June quarter of 2015. The firms account for over 90 percent of total sales in the market. The flagship phone is the product with the most sales of high-end phones with a price of \$400 or more and the non-flagship phone is the product with the greatest revenue from the middle-range phones with a price between \$199 and \$400. See Table 5 of Hiller et al. for the description of model names, prices, market shares and product characteristics for the 16 smartphone products.

²⁰ The relatively small impact of the tariff on net economic benefit is achieved at the expense of profit. Together, all firms in the market lose 37.1 percent of profits and firms with the tariff lose 40.1 percent of profits.

Alcatel, Apple, Motorola and ZTE are assumed to assemble at least 90 percent of their smartphones in China and experience the 25 percent tariff on their product models. Table 9 reports the results from the smartphone scenario and shows that the firms with tariffs perfectly pass-through the additional cost of the tariff on to consumers. The 25.1 percent increase in the average price for their eight models implies a tariff elasticity of consumer prices for smartphones with tariffs of about unity. Firms with tariffs lose 2.85 percentage points of market share (equivalent to a 49 percent decline in market share), with 0.59 percentage points of sales accruing to firms without tariffs and the remaining 2.26 percentage points to the outside option of not buying. The overall profits for the four firms with tariffs decline by 18.9 percent with Apple again experiencing a 37.6 percent decline in market share and a 31.2 percent decline in profits. The three percent increase in average price for the four firms without tariffs implies a tariff elasticity of consumer prices for models without tariffs of 0.12. Samsung benefit the most with a 10.7 percent increase in market share and a 21.3 percent increase in profits.

There is a 9.8 percent increase in the average price for all 16 smartphones which implies a tariff elasticity for consumer prices of 0.392, compared to 0.612 for tablets. Pass-through is lower in the smartphone market as consumers seem to have more options with considerable market share that do not have tariffs imposed on them. The simulated deadweight loss of \$472 million, or 12.6 percent of total pre-tariff surplus, implies a tariff elasticity of welfare of -0.504 . When the profits for firms headquartered outside of the United States are included in the calculation, deadweight loss declines to 3.9 percent of total surplus. Overall, our smartphone results have a qualitatively similar pattern to tablets. The percentage decrease in welfare for smartphones is smaller, 12.6 percent compared to 28.8 percent.

6. Conclusions

We used market-level data to simulate equilibrium prices and sales for tablet computers with tariffs on Chinese production. A 25 percent tariff on firms assembling in China results in a tariff elasticity of consumer prices of 1.108, a 29.6 percent decline in profits for firms assembling in China, and a deadweight loss of 28.8 percent of total economic surplus. A comparison of proposed tariff rates shows that the 25 percent tariff results in pass-through effects that are disproportionately larger than the ten percent rate which suggests a non-linear relationship between tariffs and economic welfare. For example, the tariff elasticity of consumer prices is 0.84 with ten percent tariffs and 1.108 for the same models with 25 percent tariffs. In all plausible scenarios where prices are allowed to adjust freely, consumers are harmed by having to pay higher prices. This results in lower consumer surplus for those that still purchase and induces many to switch to the outside option of not purchasing.

Our results show that firms that do not assemble in China benefit from the reduction in competitiveness of their rivals with tariffs by increasing their prices, market shares and profits. The dominant firm in the market, Apple, can maintain share and revenue in the short run by holding its prices at pre-tariff levels and forgoing an additional 14 percent of profits per quarter. However, this strategy is not sustainable unless the “trade war” with China is relatively short and/or Apple can successfully renegotiate supply arrangements with its ODMs. A long-run implication is that firms may be incented to shift more production from their “uncompetitive” facilities in China to lower-cost countries that are politically favored by the United States. This incentive would strengthen to the extent that our results generalize to other mobile devices assembled by ODMs such as smartphones and notebook computers.

Our pass-through elasticities are similar to the structural estimates of Kim and Cotterill

(2008) of 0.73 to 1.03 for processed cheese. They are also similar to reduced-form estimates for heavy motorcycles of 0.71 by Feenstra (1989), for import unit values of about unity by Amiti et al. (2019) and for washing machines of 1.1 to 2.3 by Flaaen et al. (2019). While these similarities are reassuring given the differences in assumptions, empirical approaches and product markets, there are several caveats to our findings. First, our model is a partial equilibrium description of the short-run effects of tariffs on welfare in the United States consumer market for tablet computers. Firms are assumed to maximize profits from all of their product models under Bertrand competition. The number of firms and tablets in the market, and where they are produced, do not change when the tariff is imposed in the simulated market. Demand is also static so that individual consumers do not consider future changes in prices in their current choice decisions. Future research should explore the welfare effects from tariffs when one or more of these standard assumptions is relaxed.

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Table 1. Summary statistics

	Mean	S.D.	Min	Max
<i>M</i>	2.01e+07	6,341,194	6,568,836	3.58e+07
<i>SALES</i>	91,570	232,934	50	4,745,859
<i>p (nominal)</i>	439.8	195.8	150.9	899
<i>STORAGE</i>	45.37	44.39	1	512
<i>SCREEN SIZE</i>	9.174	1.534	7	13
<i>CPU</i>	1.623	0.426	1	2.6
<i>CORE</i>	2.596	1.089	1	6
<i>MEGAPIXELS</i>	4.923	2.910	0	13
<i>PIXEL DENSITY</i>	214.0	72.58	103.7	377.4
<i>BATTERY LIFE</i>	9.355	2.793	3.150	25
<i>4G</i>	0.220	0.414	0	1
<i>DETACH</i>	0.284	0.451	0	1
<i>AGE</i>	4.052	3.979	0	21
<i>X86</i>	0.285	0.451	0	1
<i>CELLULAR</i>	0.253	0.435	0	1
<i>WAGES</i>	1,056	919.1	349	3,719
<i>M^a</i>	2.73e+07	6,509,843	1.85e+07	4.22e+07
<i>M^b</i>	4.06e+07	1.07e+07	2.33e+07	6.57e+07

Notes. S.D. is standard deviation. Number of observations is 2,803, except market size where the statistics are drawn from 33 quarters. *STORAGE* is measured in gigabytes, *SCREEN SIZE* in inches, *CPU* in Ghz, *PIXEL DENSITY* in pixels per square inch of screen size, *BATTERY LIFE* in hours, *AGE* in quarters since release and *WAGES* in United States dollars. *M^a* is total tablet, notebook and desktop consumers. *M^b* is total tablet and smartphone consumers. Since they are recorded by IDC (2018) as band, for example, “1GB – 4GB” for *STORAGE*, we assigned the midpoint of the band as the value to *STORAGE*, *MEGAPIXELS* and *CPU*. 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. Four observations for the Acer PC Slate were dropped from our sample because we did not know its battery life.

Table 2. Tablet computer firms and production

Firm	Headquarters	Production / assembly	Made in China at 2018Q2	Mean wage (S.D.)
ASUS	Taiwan	43 percent in Taiwan. 25 percent in China. 21 percent in Mexico. 11 percent in Czech Republic.	No	\$1,018 (41.04)
Acer	Taiwan	45 percent in China (Compal Electronics Inc.), 25 percent in China (Quanta Computer). 30 percent in Taiwan.	No	\$887 (76.31)
Amazon	USA	China (Foxconn).	Yes	\$661 (61.93)
Apple	USA	China (Foxconn). About ten percent of parts are sourced from the USA.	Yes	\$687 (117.7)
Barnes & Noble	USA	China prior to September 2015. Made by Samsung thereafter.	No	\$539 (67.49)
E-Fun	China	China.	Yes	\$691 (100.6)
HP	USA	USA. Components sourced from Asia and the USA.	No	\$3,489 (102.8)
LG Electronics	South Korea	90 percent in South Korea. 10 percent in India.	No	\$1,812 (174.8)
Lenovo	China	China.	Yes	\$662 (113.1)
Microsoft	USA	China.	Yes	\$699 (73.21)
Nabi	USA	China.	Yes	\$656 (74.20)
Pandigital	USA	China.	Yes	\$460 (49.84)
RCA	France	China (Alco Electronics Ltd).	Yes	\$759 (55.20)
Samsung	South Korea	31.25 percent in China. 10 percent in India. 8.75 percent in South Korea. 50 percent in Vietnam.	No	\$516 (63.54)
Verizon	USA	China (Quanta Computer).	Yes	\$757 (65.62)

Notes. Mean wage is the mean of the estimated monthly manufacturing wage for each firm over the sample period in United States dollars. S.D. is standard deviation. Data are sourced from IDC (2018), various firm annual reports and websites, industry reports, media articles, country statistical offices and tradingeconomics.com.

Table 3. Tablet prices and manufacturing wages

	Model A.		Model B.		Model C.	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
<i>CONSTANT</i>	2.8803***	0.7908	0.8219	1.3168	-1.4865	1.0447
<i>ln WAGE</i>	0.4994***	0.1247	0.8018***	0.1989	0.9573***	0.1565
<i>ln WAGE</i> × <i>CHINA</i>			-0.2351*	0.1248	-0.2572**	0.1055
Controls	No		No		Yes	
OS fixed effects	Yes		Yes		Yes	
Brand fixed effects	Yes		Yes		Yes	
Time fixed effects	Yes		Yes		Yes	
Adjusted R ²	0.326		0.517		0.722	

Notes. Dependent variable is *ln p*. s.e. is robust standard error. Number of observations is 2,803. *CHINA* equals one for firms that have “Yes” for “Made in China at 2018Q2” in Table 2 and zero otherwise. *WAGE* is the estimated monthly manufacturing wage for each firm and time period in United States dollars. Controls are *STORAGE* and *SCREEN SIZE*.

*significant at ten percent. **significant at five percent. ***significant at one percent.

Table 4. GMM estimates of consumer demand

	(i) Logit-GMM		(ii) RCL-BLP		(iii) RCL-BLP	
	MU	s.e.	MU	s.e.	MU	s.e.
<i>CONSTANT</i>	-9.9315***	0.8247	-7.1027***	0.7282	-7.0957***	0.6964
<i>STORAGE</i>	0.0129***	0.0020	0.0084***	0.0023	0.0070***	0.0022
<i>SCREEN SIZE</i>	0.7450***	0.1100	0.7434***	0.0908	0.6748***	0.0860
<i>CPU</i>	0.1645	0.1508	0.3756***	0.1359	0.3598***	0.1312
<i>CORE</i>	0.0445	0.0455	0.0722	0.0464	0.0685	0.0453
<i>MEGAPIXELS</i>	-0.1376**	0.0560	-0.0301	0.0541	-0.0289	0.0523
<i>MEGAPIXELS</i> ²	0.0135**	0.0054	0.0034	0.0050	0.0025	0.0048
<i>PIXEL DENSITY</i>	0.0059***	0.0017	0.0063***	0.0015	0.0054***	0.0015
<i>BATTERY</i>	0.0405**	0.0186	0.0716***	0.0177	0.0732***	0.0172
<i>4G</i>	0.6553***	0.1919	0.7087***	0.1642	0.6040***	0.1562
<i>DETACH</i>	0.2107	0.1653	0.0920	0.1544	0.0612	0.1484
<i>AGE</i>	-0.0662***	0.0177	-0.0648***	0.0167	-0.0683***	0.0160
<i>PRICE (p)</i>						
Mean	-0.0153***	0.0020	-0.0255***	0.0016	-0.0236***	0.0015
S.D.			0.0100***	0.0013	0.0095***	0.0013
Relevance	24.81***		36.79***		34.00***	
Validity	6.804					

Notes. MU is marginal utility. s.e. is robust standard error. S.D. is standard deviation. Number of observations is 2,803. Brand, OS and time fixed effects are not reported. RCL-BLP specifications are estimated with optimal instruments. Relevance is an *F* test of the significance of first-stage excluded instruments. Excluded instruments in specifications (i) and (ii) are *X86*, *CELLULAR* and the deviation from average *SCREEN SIZE*, *CORE*, *DETACH* and *4G* for all other products produced by the firm in a given market. The excluded instruments in (iii) also include *ln WAGE*. Validity is the Hansen *J* statistic.

significant at five percent. *significant at one percent.

**Table 5. Summary of own-price elasticities of demand
(baseline equilibrium)**

Firm	Models	Mean	S.D.	Min	Max
ASUS	5	-4.112	0.550	-4.735	-3.416
Acer	5	-4.033	0.724	-4.881	-3.066
Amazon	1	-3.526	0	-3.526	-3.526
Apple	27	-4.684	0.516	-5.312	-3.647
E Fun	1	-3.413	0	-3.413	-3.413
HP	3	-4.770	0.487	-5.206	-4.090
LG	3	-4.093	0.563	-4.794	-3.415
Lenovo	15	-4.419	0.736	-5.330	-3.122
Microsoft	2	-5.067	0.200	-5.267	-4.867
RCA	5	-3.357	0.224	-3.655	-3.023
Samsung	16	-4.280	0.710	-5.274	-3.247
Verizon	3	-4.252	0.199	-4.506	-4.021

Notes. S.D. is standard deviation.

Table 6. Effects of tariffs on firms with assembly in China for June quarter 2018

		A. Baseline: no tariffs						B. Scenario i: ten percent tariffs on firms with almost all assembly in China					
Firm	Models	Price	MC	Tariff	Margin	Share	Profit	Price	MC	Tariff	Margin	Share	Profit
ASUS	5	\$237	\$183	\$0	\$54	0.84%	\$7.97m	\$245	\$184	\$0	\$61	1.17%	\$12.5m
Acer	5	\$386	\$285	\$0	\$102	0.17%	\$3.03m	\$403	\$306	\$0	\$97	0.22%	\$3.69m
Amazon	1	\$164	\$117	\$0	\$47	0.26%	\$2.17m	\$178	\$117	\$12	\$49	0.23%	\$1.97m
Apple	27	\$349	\$211	\$0	\$138	23.4%	\$567m	\$379	\$209	\$21	\$149	18.7%	\$492m
E Fun	1	\$156	\$110	\$0	\$46	0.08%	\$0.67m	\$170	\$110	\$11	\$48	0.07%	\$0.61m
HP	3	\$480	\$383	\$0	\$97	0.01%	\$0.16m	\$481	\$385	\$0	\$96	0.01%	\$0.20m
LG	3	\$170	\$74	\$0	\$47	0.03%	\$0.28m	\$172	\$123	\$0	\$48	0.04%	\$0.33m
Lenovo	15	\$191	\$140	\$0	\$51	0.27%	\$2.40m	\$204	\$136	\$14	\$54	0.23%	\$2.18m
Microsoft	2	\$522	\$417	\$0	\$106	0.12%	\$2.22m	\$582	\$416	\$42	\$124	0.09%	\$1.96m
RCA	5	\$157	\$111	\$0	\$46	0.65%	\$5.32m	\$170	\$110	\$11	\$49	0.57%	\$4.87m
Samsung	16	\$229	\$171	\$0	\$58	4.80%	\$49.4m	\$236	\$174	\$0	\$62	5.41%	\$59.2m
Verizon	3	\$214	\$163	\$0	\$51	0.007%	\$0.06m	\$234	\$163	\$16	\$54	0.006%	\$0.06m
T = 0; π = \$641.1m								$\Delta CS = -\$336.7m$; $\Delta T = \$72.0m$; $\Delta \pi = -\$75.3m$					
		C. Scenario ii: 25 percent tariff on firms with almost all assembly in China						D. Scenario iii: 25 percent tariff on firms with a positive quantity of tablets assembled in China					
ASUS	5	\$240	\$183	\$0	\$56	0.97%	\$9.61m	\$245	\$184	\$0	\$61	1.18%	\$12.6m
Acer	5	\$420	\$325	\$0	\$95	0.29%	\$4.88m	\$420	\$325	\$0	\$95	0.29%	\$4.89m
Amazon	1	\$201	\$117	\$29	\$54	0.18%	\$1.75m	\$201	\$117	\$29	\$54	0.19%	\$1.76m
Apple	27	\$450	\$215	\$54	\$181	12.4%	\$398m	\$444	\$214	\$48	\$181	13.1%	\$421m
E Fun	1	\$190	\$110	\$28	\$52	0.06%	\$0.55m	\$190	\$110	\$28	\$52	0.06%	\$0.55m
HP	3	\$482	\$388	\$0	\$94	0.02%	\$0.28m	\$481	\$387	\$0	\$94	0.02%	\$0.28m
LG	3	\$175	\$124	\$0	\$51	0.05%	\$0.41m	\$175	\$124	\$0	\$51	0.05%	\$0.41m
Lenovo	15	\$225	\$133	\$33	\$59	0.19%	\$1.93m	\$225	\$133	\$33	\$59	0.19%	\$1.94m
Microsoft	2	\$671	\$416	\$104	\$151	0.06%	\$1.67m	\$671	\$416	\$104	\$151	0.06%	\$1.67m
RCA	5	\$191	\$110	\$28	\$53	0.46%	\$4.35m	\$191	\$110	\$28	\$53	0.47%	\$4.39m
Samsung	16	\$249	\$179	\$0	\$70	6.20%	\$76.0m	\$256	\$173	\$14	\$69	5.01%	\$60.8m
Verizon	3	\$264	\$163	\$41	\$60	0.004%	\$0.05m	\$264	\$163	\$41	\$60	0.005%	\$0.05m
$\Delta CS = -\$764.2$; $\Delta T = \$123.7m$; $\Delta \pi = -\$170.1m$								$\Delta CS = -\$676.9m$; $\Delta T = \$133.9m$; $\Delta \pi = -\$141.0m$					

Notes. Price and MC are sales-weighted averages. Difference in MC between scenarios is due to the shift in sales to products with different marginal cost. Share is aggregate market share across all firm products. Market share is each product's sales divided by market size. Margin is price minus marginal cost. m is million. CS is expected consumer surplus. T is tariff revenue. π is variable profits for firms headquartered in the United States.

Table 7. Effects of tariffs on the distribution of product quality for June quarter 2018

A. Baseline: no tariffs				B. Scenario i: ten percent tariff on firms with almost all assembly in China			C. Scenario ii: 25 percent tariff on firms with almost all assembly in China			D. Scenario iii: 25 percent tariff on firms with a positive quantity of tablets assembled in China		
Firm	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
ASUS	0.84%	0.00%	0.00%	0.97%	0.00%	0.00%	1.17%	0.00%	0.00%	1.18%	0.00%	0.00%
Acer	0.11%	0.00%	0.06%	0.14%	0.00%	0.08%	0.16%	0.00%	0.13%	0.16%	0.00%	0.13%
Amazon	0.26%	0.00%	0.00%	0.23%	0.00%	0.00%	0.18%	0.00%	0.00%	0.19%	0.00%	0.00%
Apple	10.6%	11.6%	1.24%	8.55%	9.46%	0.75%	5.08%	6.61%	0.76%	5.46%	6.98%	0.75%
E Fun	0.08%	0.00%	0.00%	0.07%	0.00%	0.00%	0.06%	0.00%	0.00%	0.06%	0.00%	0.00%
HP	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%
LG	0.03%	0.00%	0.00%	0.04%	0.00%	0.00%	0.05%	0.00%	0.00%	0.05%	0.00%	0.00%
Lenovo	0.25%	0.02%	0.00%	0.21%	0.01%	0.00%	0.17%	0.01%	0.00%	0.18%	0.01%	0.00%
Microsoft	0.00%	0.12%	0.00%	0.00%	0.09%	0.00%	0.00%	0.06%	0.00%	0.00%	0.06%	0.00%
RCA	0.65%	0.00%	0.00%	0.57%	0.00%	0.00%	0.46%	0.00%	0.00%	0.47%	0.00%	0.00%
Samsung	3.89%	0.90%	0.02%	4.29%	1.09%	0.02%	4.79%	1.38%	0.03%	3.99%	1.00%	0.02%
Verizon	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.004%	0.00%	0.00%	0.005%	0.00%	0.00%
Aggregate	16.73%	12.62%	1.31%	15.07%	10.66%	0.86%	12.13%	8.08%	0.92%	11.73%	8.07%	0.90%

Notes. Low-quality tablets are assumed to have a pre-tariff price below \$300. Medium-quality tablets are between \$300 and \$600. High-quality tablets are above \$600.

Table 8. Effects of tariffs on firms with assembly in China with Apple price constrained for June quarter 2018

A. Baseline: no tariffs								B. Scenario iv: 25 percent tariff on firms with almost all assembly in China but with Apple's prices constrained to pre-tariff levels					
Firm	Models	Price	MC	Tariff	Margin	Share	Profit	Price	MC	Tariff	Margin	Share	Profit
ASUS	5	\$237	\$183	\$0	\$54	0.84%	\$7.97m	\$225	\$183	\$0	\$41	1.03%	\$7.54m
Acer	5	\$386	\$285	\$0	\$102	0.17%	\$3.03m	\$392	\$301	\$0	\$91	0.18%	\$2.96m
Amazon	1	\$164	\$117	\$0	\$47	0.26%	\$2.17m	\$192	\$117	\$29	\$46	0.14%	\$1.14m
Apple	27	\$349	\$211	\$0	\$138	23.4%	\$567m	\$349	\$211	\$53	\$85	22.8%	\$341m
E Fun	1	\$156	\$110	\$0	\$46	0.08%	\$0.67m	\$185	\$110	\$28	\$47	0.04%	\$0.36m
HP	3	\$480	\$383	\$0	\$97	0.01%	\$0.16m	\$480	\$383	\$0	\$96	0.01%	\$0.15m
LG	3	\$170	\$74	\$0	\$47	0.03%	\$0.28m	\$169	\$123	\$0	\$47	0.03%	\$0.28m
Lenovo	15	\$191	\$140	\$0	\$51	0.27%	\$2.40m	\$213	\$128	\$32	\$53	0.13%	\$1.25m
Microsoft	2	\$522	\$417	\$0	\$106	0.12%	\$2.22m	\$716	\$416	\$104	\$196	0.03%	\$1.05m
RCA	5	\$157	\$111	\$0	\$46	0.65%	\$5.32m	\$183	\$110	\$28	\$45	0.36%	\$2.88m
Samsung	16	\$229	\$171	\$0	\$58	4.80%	\$49.4m	\$216	\$179	\$0	\$37	6.81%	\$44.3m
Verizon	3	\$214	\$163	\$0	\$51	0.01%	\$0.06m	\$259	\$163	\$41	\$55	0.003%	\$0.03m
T = 0; π = \$641.1m								Δ CS = \$58.1m; Δ T = \$216.3m; $\Delta\pi$ = -\$228.4m					

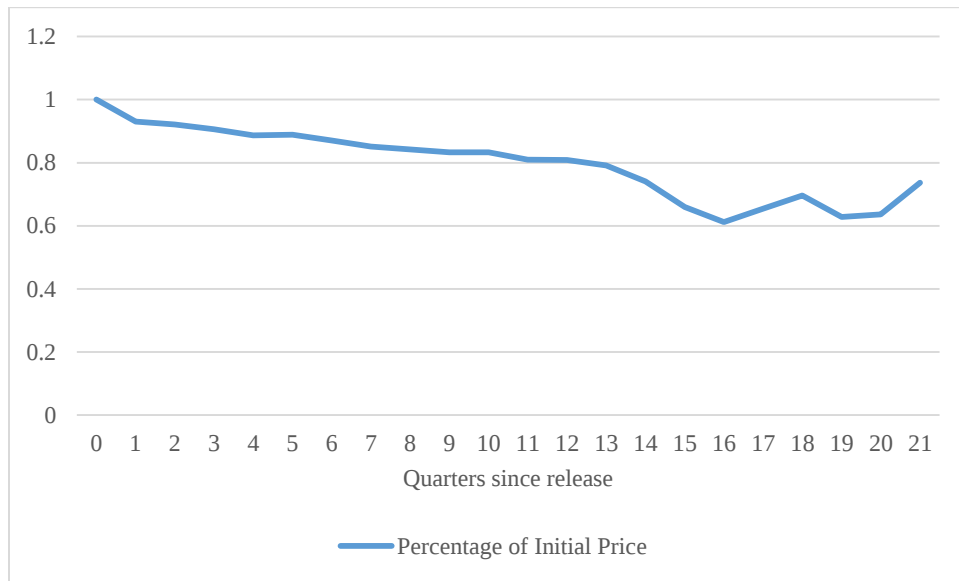
Notes. Price and MC are sales-weighted averages. Difference in MC between scenarios is due to the shift in sales to products with different marginal cost. Share is aggregate market share across all firm products. Market share is each product's sales divided by market size. Margin is price minus marginal cost. m is million. CS is expected consumer surplus. T is tariff revenue. π is variable profits for firms headquartered in the United States.

Table 9. Effects of tariffs on smartphone firms with assembly in China for June quarter 2015

Firm	Models	A. Baseline: no tariffs						B. Robustness: 25 percent tariff on smartphone firms with almost all assembly in China					
		Price	MC	Tariff	Margin	Share	Profit	Price	MC	Tariff	Margin	Share	Profit
Alcatel	2	\$249	\$165	\$0	\$84	0.37%	\$100	\$302	\$165	\$41	\$96	0.23%	\$71
Apple	2	\$612	\$403	\$0	\$209	4.23%	\$2,868	\$804	\$401	\$100	\$304	2.01%	\$1,973
HTC	2	\$593	\$427	\$0	\$165	0.28%	\$151	\$600	\$432	\$0	\$168	0.35%	\$188
LG	2	\$507	\$361	\$0	\$147	1.62%	\$769	\$523	\$366	\$0	\$158	1.85%	\$943
Motorola	2	\$523	\$384	\$0	\$139	0.40%	\$182	\$665	\$382	\$95	\$188	0.20%	\$124
Nokia	2	\$396	\$287	\$0	\$108	0.19%	\$67	\$402	\$287	\$0	\$114	0.22%	\$80
Samsung	2	\$479	\$339	\$0	\$139	2.58%	\$1,163	\$493	\$340	\$0	\$153	2.85%	\$1,410
ZTE	2	\$228	\$146	\$0	\$81	0.82%	\$217	\$274	\$146	\$36	\$92	0.53%	\$158
T = 0; π = \$2,868m								Δ CS = -\$383.6m; Δ T = \$806.7m; $\Delta\pi$ = -\$895.0m					

Notes. Price and MC are sales-weighted averages. Difference in MC between scenarios is due to the shift in sales to products with different marginal cost. Share is aggregate market share across each firm's assumed flagship and non-flagship models. The two Market share is each product's sales divided by market size. Margin is price minus marginal cost. m is million. CS is expected consumer surplus. T is tariff revenue. π is variable profits for firms headquartered in the United States.

Figure 1. Tablet price evolution as a percentage of initial price



Source. IDC (2018).

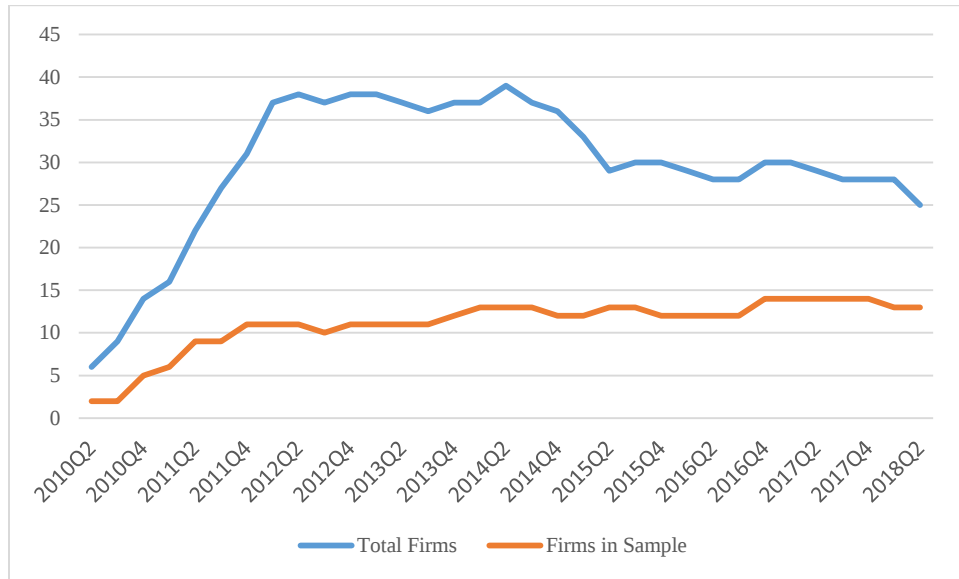
Figure 2. Quality-adjusted prices



Source. IDC (2018).

Notes. Quality-adjusted prices are the residuals of a regression of log prices on product characteristics, tablet fixed effects and brand fixed effects.

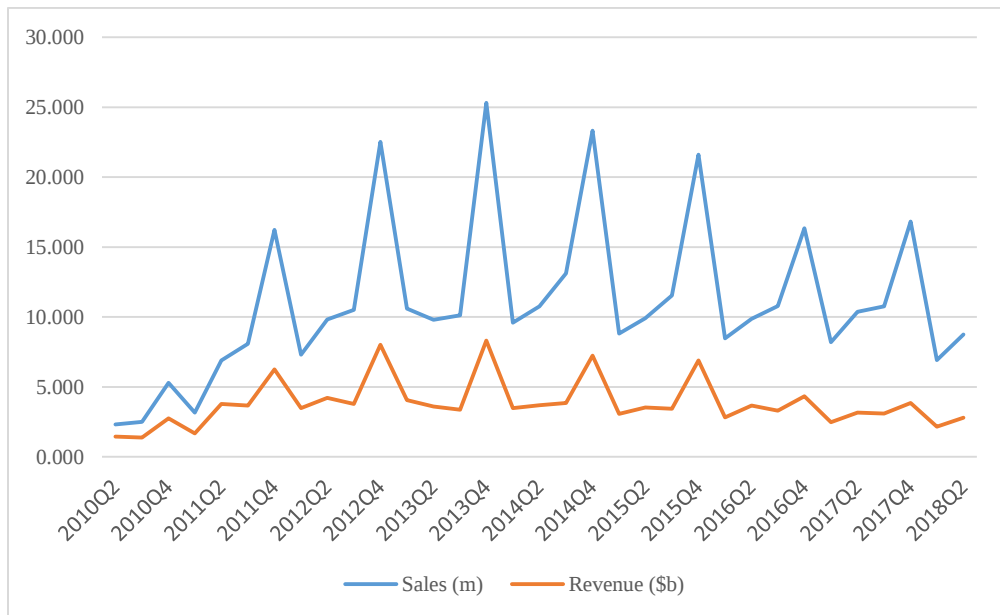
Figure 3. Number of firms



Source. IDC (2018).

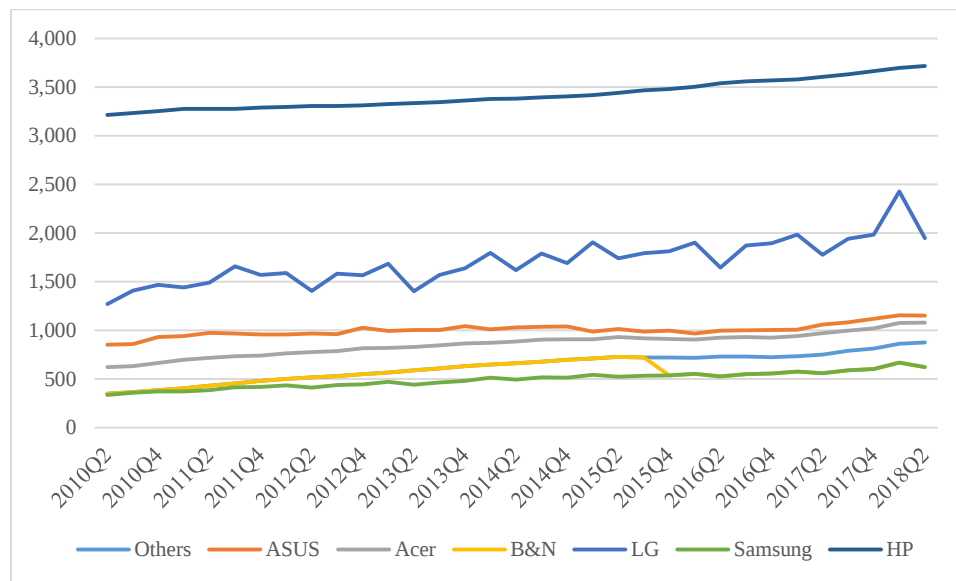
Notes. “Total Firms” is the number of firms in the commercial, consumer and children’s markets. “Firms in Sample” is the number of firms in the consumer market only.

Figure 4. Tablet computer sales and revenue 2010 to 2018



Source. IDC (2018).

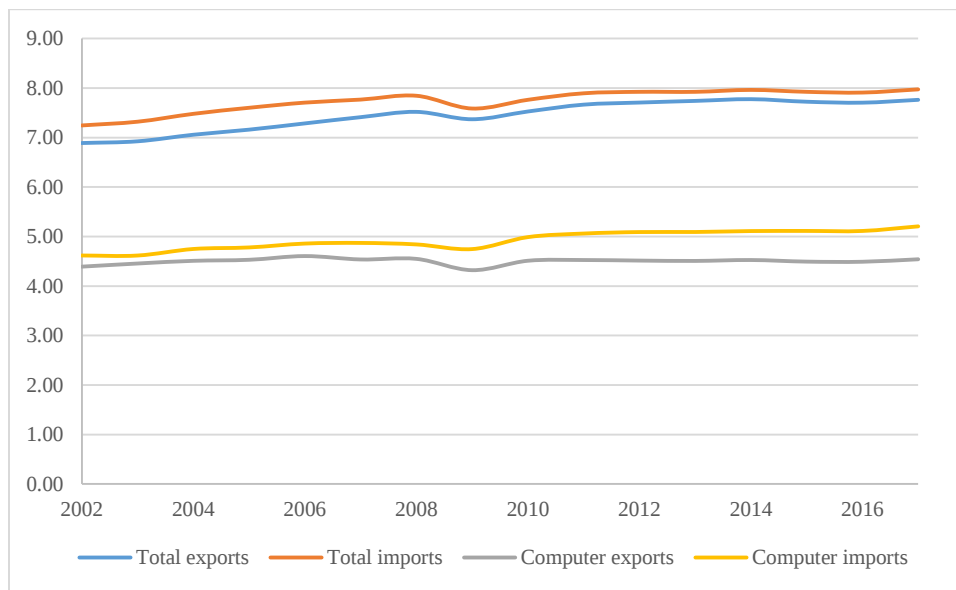
Figure 5. Monthly manufacturing wage (USD) 2010 to 2018



Notes. “Others” are firms with all assembly facilities in China, i.e., Amazon, Apple, E-Fun, Lenovo, Microsoft, Nabi, Pandigital, RCA and Verizon. “B&N” is Barnes & Noble. “HP” is Hewlett Packard. HP assembles in the United States.

Source. See notes for Table 2.

Figure 6. United States trade 2002 to 2017 (ln \$billion)



Notes. “Computers” are exports and imports of computers, computer accessories, semiconductors and related devices, expressed in the natural log of billions of dollars.

Source. US Census Bureau (2018).