Domestic Tariffs and Consumer Welfare in Developing Countries: Evidence from India

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Abstract

This paper studies the unintended welfare consequences of industrial policies designed to encourage domestic production in the context of developing countries. We explore the case of the Indian mobile handset industry, where the Indian government proposed new tariffs on imported ready-to-use mobile handsets and handset components in 2017 to encourage domestic mobile phone production, which was later stalled. We develop and estimate a structural model of India's mobile phone handset industry by allowing firms to endogenously decide supply chain alternatives, product sets, and prices. Our counterfactual simulations suggest that the continuation of the proposed policy would have resulted in firms *lowering* investments in the supply chain within India, defeating the policy's goal. Additionally, the exit of products from the market and price increase due to lower competition would lead to a drop in consumer surplus.

Key Words: Domestic Tariff, Industrial Policy, Mobile handset markets, Developing Economy, Consumer Surplus

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1 Introduction

Firms operating in the electronics industry in developing countries often manufacture sophisticated components in technologically superior production destinations (such as China, South Korea, and Taiwan, among others).[1] Those components are then imported and assembled in the country of operation, and the final products are sold to the consumers. To reduce reliance on such a supply chain and boost employment in the manufacturing sector, several developing countries have recently introduced industrial policies in the form of taxes targeting imports and imported inputs in the electronics industry.

In this article, we focus on the Indian mobile handset manufacturing industry and evaluate the welfare implications of a tax policy introduced by the Indian government that imposes higher taxes on components imported from abroad. Specifically, we analyze the "Phased Manufacturing Program" (PMP, from here on) introduced by the Indian government in 2017. Under PMP, a manufacturer must pay an additional import tax while importing specific components (such as a display module or a camera) for mobile handset production. Most handset firms operating in India either manufacture the handset outside of India and import the entire handset that is ready to sell or choose to sell it after importing a set of components and assembling them in India. Therefore, in the short run, the goal of this policy was to encourage the manufacturers to invest more in the assembly line of mobile handsets within India. Although the policy was planned for four years, the government ended up deferring the implementation of the policy in 2019.[2] In this context, this paper seeks to answer the following questions: how does the design of PMP affect a firm's choice to make assembly decisions in India versus importing a ready-to-sell handset from abroad? How does it affect the prices of handsets sold in India, and how does it impact consumer and producer welfare?

[1] For example, manufacturers in the electronics industry in India procure sophisticated components from China, Japan, The US, South Korea, and Taiwan, among others, by importing those from abroad

[2] A document titled "Make in India 2.0: Revisiting Mobile Manufacturing" published by the Internet and Mobile Association of India, presents a detailed discussion on the deployment of the Phased Manufacturing Program. [Link to Article]

Analysis of this industrial policy requires modeling the economic mechanisms governing firms' supply chain decisions. In particular, the welfare analysis requires us to compare firms' actions and consumers' decisions with and without the tax proposal. In the short run, firms could react to an increase in the cost of production stemming from the increased import tariffs by eliminating the products with higher costs or by choosing to offer the products at a higher price. They may also switch manufacturing locations, import ready-to-use products, and sell them in the Indian market. Therefore, consumers' and producers' welfare depend on the firms' decisions regarding the supply chain alternatives, product offering, and pricing in response to the tariff policy.

To capture these economic factors, we develop a tractable two-stage structural model that estimates the fixed cost of offering a handset conditional on the supply chain alternatives, the marginal cost of producing a handset, and the consumer preferences for different handset attributes. The data used in the estimation comes from Counterpoint Research and consists of detailed information about prices, quantities, handset specifications, manufacturer country of origin, and production location of mobile handsets sold in India from January 2015 to May 2018. We follow Berry, Levinsohn, and Pakes (1995) and Nevo (2001) and estimate consumer preferences using a discrete-choice random coefficient demand model. We recover marginal costs for mobile handset production using equilibrium first-order conditions resulting from firms' profit maximization. To learn the fixed costs associated with introducing or removing a new product conditional on a supply chain specification, we use a revealed preference argument commonly used in empirical entry literature (Pakes, Porter, Ho, and Ishii (2015), Fan and Yang (2020)), specifically, the fact that a firm chooses a supply chain alternative and chooses to offer the product in the Indian market, only if the variable profit from these actions exceeds the corresponding fixed cost that the firm needs to incur.

Our estimation results suggest that consumers are elastic. However, they have a high willingness to pay for specific phone characteristics such as a high-quality camera and better size of the display module, which has significant heterogeneity across consumers. For example, consumers are willing to pay 41 USD to increase the display module by 1 inch and 29 USD to improve the camera quality by 1 megapixel. The estimated mean own-price elasticity is -6 for smartphones and -4 for feature phones.[3] The results from supply estimation suggest that between 2015 and 2017, on average, all things equal, marginal costs do not vary significantly by supply chain alternatives. In other words, the marginal cost of producing a handset by importing it in ready-to-use form does not significantly differ from the case where the firm chooses to import the handset components and conduct assembly operations within India. Our results from fixed cost estimates suggest that the average fixed cost of introducing a feature phone is much lower than smartphones, irrespective of the firm's origin. Additionally, non-Indian firms (Chinese and International firms), on average, face lower fixed costs for introducing a handset if they choose to import the handset in ready-to-use form rather than assemble it in India. Indian firms, on the other hand, face lower fixed costs on average of introducing the handset by conducting assembly operations within India rather than selling them by importing in ready-to-use form.

Using the estimated model, we conduct a counterfactual exercise where we impose a 10% import tariff on the display modules and solve the industry equilibrium to compute the new equilibrium product offering, supply chain alternatives, and prices under the tariff regime. Our counterfactual exercise suggests that introducing a tariff on phone components as a part of the PMP program increases the marginal cost, which is passed on to the consumers almost entirely through a rise in prices. Additionally, we show that the changes in the cost of importing components from abroad and assembling them in India would push firms to import ready-to-use phones or discontinue offering some products that are no longer profitable. In particular, Chinese and global firms would find it beneficial to reduce investments in the supply chain within India and switch to importing ready-to-use handsets from abroad. They may also discontinue offering products in response to this policy. In contrast, the firms of Indian origin would continue to offer most of the products even in the counterfactual

[3]This is consistent with the elasticities reported in the literature. For example, the mean own-price elasticity reported by Fan and Yang (2020) for the United States mobile phone market is -6.5.

world. Therefore, our results suggest that firms' assembly decisions within India would drop significantly if the policy is implemented. Product exit and higher equilibrium prices of the remaining products would also lead to a drop in consumer welfare.

This article relates to several strands of literature. By studying the product offering and pricing decisions of Indian handset manufacturers, the paper contributes to the growing literature on the telecommunication market across different countries. Examples in the literature include Fan and Yang (2020), who studies how product offering affects welfare in the U.S. mobile phone industry, Yang (2020), who studies vertical structure and innovation in the smartphone industry. Other studies in this literature include Bourreau, Sun, and Verboven (2018), Elliott, Houngbonon, Ivaldi, and Scott (2021), Wang (2016) and Chatterjee, Fan, and Mohapatra (2022). Our paper contributes to this literature by exploring the effects of an industrial tax policy not only on firms' product offering decisions but also on its decision on the product supply chain.

By studying the effect of PMP on handset firms' decisions and consumer welfare, this paper relates to the broader literature on the welfare effects of industrial policies. Studies in this literature include Igami (2018), Mohapatra and Chatterjee (2021), Wollmann (2018), Levinsohn (2008), Brambilla (2005), Flaaen, Hortaçsu, and Tintelnot (2020), Fershtman, Gandal, and Markovich (1999), Li (2017), Pavcnik (2002), and Barwick, Kalouptsidi, and Zahur (2021) among others. For example, Igami (2018) studies the benefits and costs of offshoring and investigates the relationship between offshoring and market structure as well as the role of government intervention in the context of the hard disk drive industry. Li (2017) studies how policy choices regarding charging standards for electric vehicles affect product choice decisions and consumer surplus. Similarly, Wollmann (2018) studies how the government bailout of the automobile industry following the 2008 financial crisis prevented the exit of various models of trucks from the market. The model presented in our paper follows this literature. We contribute by quantifying the welfare effect of a tariff policy by estimating the changes in consumption patterns while endogenizing firms' decisions to introduce or remove handsets as the best response to the analyzed policy. This paper is also related to the literature on endogenous product choice and firm entry by studying handset firms' product choice decisions. Examples in this literature include Draganska, Mazzeo, and Seim (2009), Fan (2013), Seim (2006), Lee and Pakes (2009), Eizenberg (2014) and Fan and Yang (2020) among others.

The rest of the article is organized as follows: Section 2 provides a brief background of the mobile phone industry in India. Section 3 presents the data. Section 4 lays out the model. We explain our estimation procedure and present the estimation results in Section 5. The counterfactual simulation results are presented in Section 6. Section 7 concludes.

2 Industry Background

2.1 Policy Details

India presents an attractive market for mobile phone handset firms. According to GSMA Intelligence, the number of unique mobile service subscribers in India increased from 203 million in 2008 to 778 million in 2019 and is estimated to approach 1 billion by 2025. The Indian handset industry is dominated by firms of both Indian and international origin. However, irrespective of origin, firms either import *ready-to-use* handsets from outside of India or import *components* from abroad, assemble them in India, and make them available to consumers. For example, in 2014, there were only two manufacturing units in India whose activities consisted mainly of assembly and testing, with most of the principal components being imported. To encourage the manufacturers to invest more in the assembly line of mobile handsets within India, the Indian government introduced several tax-related regulations starting in 2014. In the short run, the firms were expected to switch from importing ready-to-use handsets to investing more in assembling and selling in India. The long-run aim was to boost local mobile hand-sets production in India with lower import dependency.[4]

[4] An extensive discussion on the evolution of India's mobile phone industry can be found in the document titled: "Competition Issues in India's Mobile Handset Industry" published by the Indian Council for Research

The government introduced import tariffs on ready-to-use mobile handsets as part of the Phased Manufacturing Program (PMP)[5]. The tariffs were implemented starting in 2016. In July 2017, it consisted of a 10% custom duty on imported ready-to-use handsets. In December 2017, this tariff increased to 15% and finally to 20% in January 2018.

In addition to imposing a duty on ready-to-use handsets, in 2017, the Indian government mandated a tariff schedule for different mobile phone components. The program was scheduled for implementation between 2017 and 2020. In 2017, the PMP contemplated a 15% import tariff on chargers, battery packs, and wired headsets. In 2018, components charged with a 15% import tariff included mechanics, die-cut parts, microphones, keypads, and USB cables. The policy aimed to implement a 10% duty for sophisticated phone components such as printed circuit board assemblies, camera modules, and connectors in 2019. Finally, for 2020, the program set a 10% import tariff for display modules, touch panels, cover glass assemblies, vibrator motors, and ringers.[6].

This policy's results led to changes in the industries' domestic supply chain. According to the Internet and Mobile Association of India (IAMAI), several firms switched to assembling imported components, testing, and packaging within India instead of importing ready-to-use handsets. Additionally, by 2017, some manufacturers started producing low-value components, such as chargers, adapters, and battery packs within India. However, even up to the end of 2020, all handset manufacturers continued importing the most sophisticated components (such as camera, display modules, and connectors) from abroad while conducting assembly operations within India. After the partial implementation of the PMP policy, it was halted in 2020.[7] In this paper, our counterfactual exercise evaluates the effect of the continuation of the policy by computing the new equilibrium when a 10% import tariff is

on International Economic Relations, which is accessible in the following link: https://icrier.org/pdf/Competition-Issues-in-India-Mobile-Handset-Industry.pdf

[5]This is part of a flagship initiative of the Indian government's "Make in India" policy aimed at boosting the manufacturing industry in India.

[6]The PMP notification can be found here: https://www.meity.gov.in/writereaddata/files/Notification_PMP_Cellular%20Mobile%20Handsets_28.04.2017.pdf

[7]Reference: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1563771

imposed on display modules as proposed under the PMP.

2.2 Handset Manufacturing Firms in India

Depending on their origin, the firms in the Indian mobile phone industry are classified as global brands, Indian brands, or Chinese brands. The leading international firms are big players in all major markets worldwide and include Samsung and Apple. Their operations, as well as their supply chain, are distributed across different countries. Chinese firms concentrate most of their operations and supply chains in China. Frequently, these firms have direct access to the Shenzhen-based manufacturing ecosystem, allowing them to offer a range of affordable smartphones with stand-out features. Leading Chinese firms operating in India include Xiaomi, Oppo, and Vivo. Firms of Indian origin are located primarily in Uttar Pradesh, Himachal Pradesh, and Uttarakhand in northern India; Karnataka, Tamil Nadu, Andhra Pradesh, and Telangana in southern India; and West Bengal in eastern India. India's flagship firms include Micromax, Intex, Lava, and Karbonn.

While more than 200 firms operated in India between 2015 and 2018, the top 20 players comprised more than 80% of the total units sold in the Indian market. During our sample between 2015 and 2018, Samsung was the market leader and faced fierce competition from Chinese competitors such as Xiaomi, Vivo, and Oppo, as well as from new Indian firms like LYF, which entered the market in 2017. Some of the leading players in the market are engaged in producing a subset of components within India through firm-owned facilities or third-party manufacturers. As mentioned, most of these facilities perform assembling components and testing procedures. After implementing PMP, a few manufacturers invested in producing essential electronic components like batteries, microphones, cables, and chargers within India. Such investments only marginally increased the average local value-added. However, none of the manufacturers incorporated sophisticated components like microphones and receivers, camera modules, display modules, and touch modules into the production process.

3 Data and Descriptive Evidence

We obtained our primary data on mobile handsets from Counterpoint Research. Our sample period is between January 2015 and May 2018. The handset data contain information on sales, prices, handset characteristics, and the location of the handset production. Our data groups the firms into Indian, Chinese, and global categories based on the manufacturer's country of origin. We define a single month as a temporal market and the entire country as a geographical market. We keep a handset firm in the sample if the firm's sales account for at least 1% of the total handset sales. Our final dataset consists of 22,286 handset-month observations from 44 firms that accounted for about 95% of the total sales in the raw data.

Table 1: India's Mobile Handset Industry

Year	Avg. num. of products per market	Avg. proportion of smartphones	Avg. price of smartphones (USD)	Avg. price of feature phones (USD)
2015	574	51%	173	19
2016	576	48%	190	16
2017	421	49%	231	16
2018	339	51%	259	15
No. of Obs: 22,286				

Note: This table displays the average number of products present in each market for each year, the average proportion of products that are smartphones, the average price of smartphones, and the average price of feature phones in each market.

Table 1 documents the summary statistics from the Indian mobile phone market. On average, we observe close to 450 handsets offered by 44 handset manufacturers in the market during our sample period. Around 50% of the handsets are smartphones, and the rest are feature phones suggesting that consumers in India have a strong preference for cheap, low-tech, and simple-to-operate handsets. The prices of feature phones range from USD 14 to USD 61. The average smartphone price is USD 200, which can go as high as USD 1,500. Concerning network technology, 29% of the mobile phones during our sample were compatible with 4G networks, 17% with 3G networks, and the other 54% with 2G networks.

Table 2: Descriptive Statistics Mobile Phone Characteristics

	Feature Phone			SmartPhone		
	Min	Mean	Max	Min	Mean	Max
Back Camera (Megapixels)	0.1	0.6	8.1	0.3	8.6	40
Front Camera (Megapixels)	0.1	0.6	2.0	0.3	4.2	25
Display Module Size (in Inches)	1.3	2.3	5.0	2.8	4.8	7.0
Battery Capacity (mAH)	300	1,509	8,000	406	2,465	6,020
RAM (GB)	0.0	0.2	1.0	0.1	1.7	8.0

Note: This table presents summary statistics for the main characteristics of the products from the sample. The data used to compute these metrics belong to all years from 2015 to 2018.

Table 2 documents the variation of key product characteristics by phone categories. In our sample, smartphone display modules (screen sizes) vary from 2.8 to 7 inches, while in feature phones, the display module ranges from 1.3 to 5 inches. Other important features in mobile handsets are battery size, RAM, and camera module. In our sample, 96% of feature phones have a back camera while only 7% have a front camera. In contrast, almost all smartphones have both back and front cameras. The rear camera modules of smartphones have significantly evolved from basic models in 2015 to sophisticated cameras with 10 megapixels by 2018. This rapid technological evolution in handset technology implies that creating an ecosystem within a developing country so that firms invest in manufacturing sophisticated handset components can be challenging. Therefore, most of the sophisticated components for manufacturers in India are imported from abroad.

A unique feature of our dataset is that we also observe the production location of a handset, i.e., whether a handset is imported in ready-to-use form or the firm performs assembly and testing of the handset in India after importing the components from abroad. Therefore, each handset model in my sample is categorized either as imported (ready-to-use)[8]

[8]These are also known as Completely Built Units (CBU). No additional labor is required to reach its final

or assembled in India[9].

Table 3: Evolution of the Proportion of Imported (Ready-to-use) Handsets by Firm Origin

Year	Share of Imported Handsets		
	Chinese Firms	Global Firms	Indian Firms
2015	92%	31%	78%
2016	34%	18%	36%
2017	22%	9%	43%
2018	14%	3%	47%

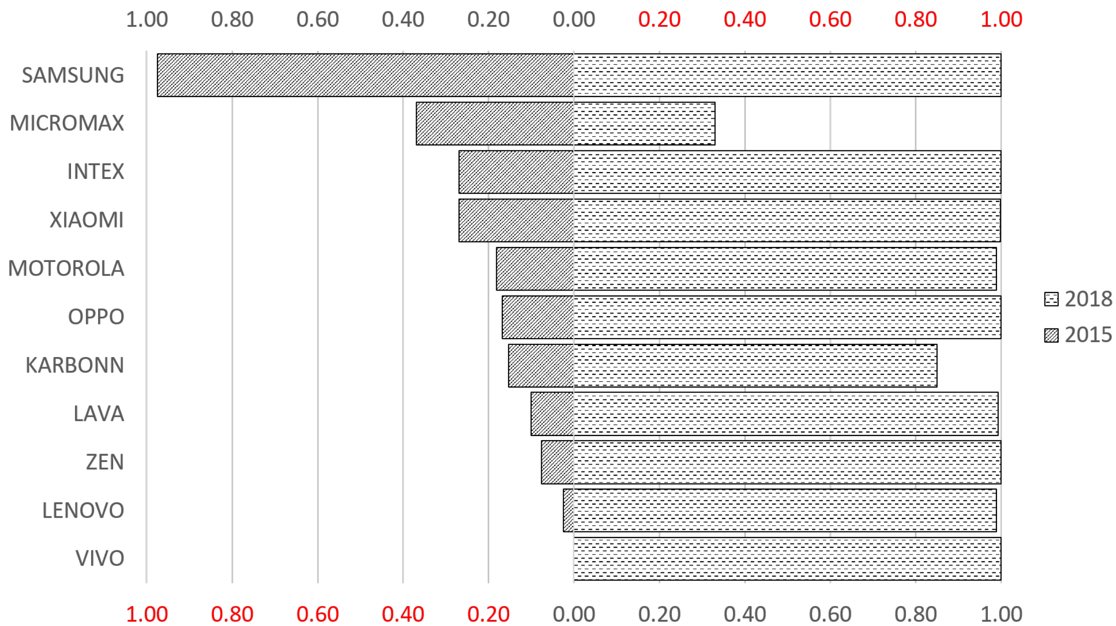
Note: This table reports the share of handsets imported in ready-to-use form over the years by firm origin.

Table 3 documents the share of handsets imported in ready-to-use form over the years by firm origin. In 2015, prior to the policy initiatives by the Indian government, 92% of the handsets sold by Chinese firms were imported in ready-to-use form, and only 8% of the handsets were assembled within India. Even for firms of Indian Origin, 78% of the handsets were imported in ready-to-use form and were sold within India. With the tax policy on ready-to-use handsets starting in 2016, firms, irrespective of their origin, switched from importing handsets and invested in assembly-line within India. This led to a higher share of handsets being assembled within India. In figure 1, we plot the percentage of total handsets assembled in India by 11 leading firms during our sample period. The left side shows the proportions in 2015, and the right side in 2018. Consistent with table 3, we observe almost all firms significantly increasing the share of handsets assembled in India in 2018 compared to the baseline of 2015. We exploit firms' production location variation during our sample period to identify the costs associated with offering a handset conditional on a supply chain alternatives.

sale destination.

[9]These are typically imported either in "Completely Knocked-Down" form or in " Semi Knocked-Down" form where the mobile handset components are imported and these components undergo assembly, inspection, quality control, and testing before they reach the final sale destination

Figure 1: Proportion of handsets assembled in India by leading firms in 2015 and 2018



Note: This figure plots the percentage of total handsets assembled in India by leading firms in our sample. The left side shows the proportions in 2015, and the right side in 2018.

4 Model

This section presents a tractable two-stage structural model of demand and supply to capture how introducing a tax policy on imported phone components affects firms' decisions to choose from different supply chain alternatives, offering a set of products in the market, setting prices of the offered products as well as consumers' decisions on choosing those products.

4.1 Demand

We follow BLP and use a random utility discrete choice model to capture preferences for mobile phone characteristics. Each consumer chooses a mobile phone from a set of differentiated products available at time t denoted by $j = 0, \ldots, J_t$ or chooses the outside option of no purchase. Consumers i's utility at time t for a mobile phone j is given by:

$$\begin{aligned} U_{ijt} &= X_{jt}\beta + \xi_{jt} - \alpha_i p_{jt} + \sum_k X_{jtk}\sigma_k v_{ik} + \epsilon_{ijt}, \text{ where} \\ \alpha_i &= \exp\left(\alpha + \sigma_p \text{Income}_{it}\right) \end{aligned} \tag{1}$$

where X_{jt} is a K-vector of observed product characteristics excluding price and contains a constant term, a dummy for smartphone, and a time trend that captures the change over time in the valuation of the outside option. We include firm-fixed effects in X_{jt} to capture firm-specific unobservable characteristics that are invariant over time. The unobservable demand shifter ξ_{jt} captures product characteristics that are observable to the consumers while making purchase decisions. Following Eizenberg (2014), we define $\alpha_i = \exp\left(\alpha + \sigma_p \text{Income}_{it}\right)$ and allow the price sensitivity to vary with income[10] with parameters (α, σ_p). Specifically, a negative value of σ_p implies that a lower-income consumer will have a higher price sensitivity. σ_k is the coefficient for the interaction of consumer attributes and product characteristics and is meant to capture consumers' heterogeneous tastes for the product specifications. The utility for the outside option is denoted by:

$$U_{i0t} = \epsilon_{i0t} \tag{2}$$

Following Berry, Levinsohn, and Pakes (1995), and Nevo (2000) we divide the indirect utility into two terms, δ_{jt} that is invariant across consumers, and μ_{ijt} that varies across consumers where:

$$\delta_{jt} = X_{jt}\beta + \xi_{jt}$$

$$\mu_{ijt} = \left[-\exp\left(\alpha + \sigma_p \text{Income}_{it}\right)\right] p_{jt} + \sum_k X_{jtk}\sigma_k v_{ik} + \epsilon_{ijt}$$

[10] We obtained the data for income from the India Human Development Survey 2011 - 2012 conducted by 'Data Sharing for Demographic Research'.

We obtain the market share of products j at time t by integrating individual market shares.

$$s_{ijt} = \int \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{z \in J_t} \exp(\delta_{zt} + \mu_{ijt})} dP_D \tag{3}$$

where dP_D represents the joint distribution of income and attributes among consumers.

4.2 Supply

The supply side is modeled as a two-stage static game. In the first stage, each firm f chooses the set of products to be offered at time t denoted by J_{ft} and decides on the supply chain alternative[11] of the offered products denoted by $\{L_{kt}\}_{k \in J_{ft}}$. Having observed the product choice and supply chain decisions, firms simultaneously choose prices in the second stage.

4.2.1 Pricing decision

The second stage decision of the firm involves setting the prices of the products after observing the product offering and supply chain decisions of all firms. At a given time t, firms simultaneously set prices for each available product j in a complete information framework to maximize total variable profits. A firm f's profit maximization problem at time t given its set of products J_{ft} is given by:

$$\max_{p_{jt}, j \in J_{ft}} \left\{ \sum_{j \in J_{ft}} \left(p_{jt} - c_{jt} \left(\{L_{kt}\}_{k \in J_{ft}} \right) \right) * s_{jt} \left(\vec{p}_t, \{L_{kt}\}_{k \in J_{ft}}, \{L_{kt}\}_{k \in J_{-ft}}, J_{ft}, J_{-ft} \right) \right\} \tag{4}$$

where the share s_{jt} depends on $\vec{p}_t$ the entire vector of prices at time t, and supply chain decisions and product offering decisions of firm f as well as its competitors. c_{jt} is the marginal cost for handset j at time t and depends on the supply chain decisions ($\{L_{kt}\}_{k \in J_{ft}}$) by firm f. We parameterize the marginal costs as a function of observed cost shifters W_{jt}

[11] i.e., whether to sell imported ready-to-use handsets or perform assembly and testing of the handset within India

and a supply shock ω_{jt}:

$$\log(c_{jt}) = W_{jt}\gamma + \omega_{jt} \tag{5}$$

where cost shifters (W_{jt}) include the product characteristics that are included in the demand regression in equation 1. Additionally, we include dummies for firm-origin and supply chain combinations to capture the differences in firms' marginal cost of production by choice of the supply chain.[12] We include the log of the quantity produced in W_{jt} to capture any possible returns to scale. Finally, we include dummies for supply-chain choices for different years to capture the changes in the marginal costs induced by the tax policy that varied over the years during our sample. We assume that, at the beginning of stage 2, each firm f observes the realization of demand and cost shocks (ξ_{kt}, ω_{kt}) for each product k chosen in stage 1. The econometrician does not observe these shocks.

The first-order conditions are given by

$$\begin{aligned} &s_{jt}\left(\vec{p}_t, \{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}\right) + \\ &\sum_{j\in J_{ft}} \left(p_{jt} - c_{jt}\left(\{L_{kt}\}_{k\in J_{ft}}\right)\right) \frac{\partial s_{jt}\left(\vec{p}_t, \{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}\right)}{\partial p_{jt}} = 0 \end{aligned} \tag{6}$$

We denote by J_t the set of handsets on the market at time t. Let the $J_t \times J_t$ matrix θ^{Ft} be the product ownership matrix, where the ij-th entry of the matrix assumes a value 1 if at time t both products i and j are offered by the same firm. Denote by $\vec{s}_t$ be the vector of market shares at time t and by $\mathbf{\Delta}\left(\vec{p}_t, \{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}\right) = \partial s_{jt}/\partial p_{jt}$ be the $J_t \times J_t$ Jacobean matrix of derivatives. Finally, let the marginal cost be represented by the $J_t \times 1$ vector $\vec{c}_t$. By using the operator $\odot$ to represent element-wise multiplication, we represent the system of firms' first-order conditions as follows:

$$\vec{s}_t + \left[\theta^{Ft} \odot \mathbf{\Delta}\left(\vec{p}_t, \{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}\right)\right] \times (\vec{p}_t - \vec{c}_t) = 0 \tag{7}$$

[12]In particular, we include separate dummies for Chinese firms importing ready-to-use handsets, Chinese firms assembling handsets in India, global firms importing ready-to-use handsets, global firms assembling handsets in India, Indian firms importing ready-to-use handsets, Indian firms assembling handsets in India.

4.2.2 Product Offering and Supply Chain Decisions

In our model, at time t, each handset manufacturer f is endowed with a set of potential products denoted by $\mathbb{J}_{ft}$. In the first stage, firms simultaneously choose the subset of products to offer from the set of potential products and decide on the supply chain specifications for each product to maximize their expected profits. In our dataset, we observe that a given firm may resort to different supply chain alternatives for its products at a time t. For example, the firm may import technologically advanced 4G handsets in ready-to-use form. At the same time, it may choose to perform assembly and testing operations within India for low-tech feature phones. Therefore, we allow the supply-chain decision to be handset specific rather than firm-specific.

To derive the expected variable profit of a firm, we plugin in the equilibrium prices derived in equation 4 and take the expectation over the demand and marginal cost shocks $(\xi_{\mathbf{t}}, \omega_{\mathbf{t}})$. The equilibrium price of a product k is denoted by $(p^*_{kt}(\mathbf{x_t}, \xi_{\mathbf{t}}, \omega_{\mathbf{t}}, \mathbf{L_t}, \mathbf{J_t}))$, where $\mathbf{x_t} = (x_{jt}, j \in J_t)$, $\xi_{\mathbf{t}} = (\xi_{jt}, j \in J_t)$, $\omega_{\mathbf{t}} = (\omega_{jt}, j \in J_t)$, and $\mathbf{L_t} = (L_{jt}, j \in J_t)$ denote collection of handset characteristics, demand residuals, supply residuals, and supply chain specifications respectively for the products offered at time t. The profit maximization problem of the firm f is given by

$$\max_{\left\{J_{ft} \subseteq \mathbb{J}_{ft}; \{L_{kt}\}_{k \in J_{ft}}\right\}} E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k \in J_{ft}}, \{L_{kt}\}_{k \in J_{-ft}}, J_{ft}, J_{-ft}) - \sum_{j \in J_{ft}} F^{(L_{jt})}_{fjt} \tag{8}$$

where $F^{(L_{jt})}_{fjt}$ denotes firm f's fixed cost of offering handset j at time t. The superscript L_{jt} suggests that the fixed cost is allowed to vary by choice of supply chain alternatives.

5 Estimation and Results

In this section, we explain our estimation procedure and present the estimation results.

5.1 Demand and Marginal Costs

The demand and marginal cost estimation follow Berry, Levinsohn, and Pakes (1995), Nevo (2001). We construct moments using equations 1 and 5 and estimate the parameters using the Generalized Method of Moments. Since we assume that in every period, firms strategically determine price after (ξ_{jt}, ω_{jt}) are realized, in the demand model, the price can be potentially endogenous. We use BLP-style instruments to address the price endogeneity problem. In particular, we use the sum of competitors' characteristics as our instruments. Additionally, following Hiller, Savage, and Waldman (2018), we use the deviation from the average of the characteristics for all products in the market and products within firms as instruments. Similarly, following Gandhi and Houde (2019), we include the number of competitors with similar characteristics in our set of instruments. The validity of our estimation strategy relies on the timing assumption that firms do not observe demand and marginal cost shocks when they choose product characteristics. Such a timing assumption is made in, for example, Eizenberg (2014), Wollmann (2018), and Fan and Yang (2020, 2022). Our demand model includes a rich set of fixed effects to control for systematic variations across handset type, firms, and time. Therefore, though imperfect, it seems reasonable to assume that the transitory shock specific to a handset is unknown to firms when they make their product choice and supply chain decisions. Finally, we include a dummy variable that records the entry of the Jio network into the Indian market in the set of instruments.[13] To construct the supply-side moments, we back out marginal costs based on first-order conditions with respect to prices and then interact the unobservable marginal cost shocks (ω_{jt}) with the marginal cost covariates.

Table 4 reports the demand estimation results. Note that, in our specification, the price coefficient takes the form $[-\exp(\alpha + \sigma_p * \text{Income}_{it})]$, where α is the mean price sensitivity, and σ_p captures the heterogeneity in price sensitivity that varies with income. Our estimates

[13] Jio is a network provider that entered the Indian market in 2016, offering high-speed 4G network plans across all regions in India.

Table 4: Estimation Results: Demand

	Est	Std. Error
Price × Income	-2.31***	(0.05)
Constant × Normal Draw	3.81***	(0.60)
Main Camera (MP) × Normal Draw	0.05**	(0.02)
Front Camera (MP) × Smartphone × Normal Draw	0.001	(0.02)
Price Sensitivity (α in Equation (1))	11.27***	(0.36)
Constant	7.68***	(1.06)
Main Camera (MP)	0.13***	(0.02)
Front Camera (MP) × Smartphone	0.06***	(0.02)
Display Module Size	0.98***	(0.13)
RAM × Smartphone	0.55***	(0.07)
Battery Size × Smartphone	0.33**	(0.13)
3G Dummy	0.65***	(0.11)
4G Dummy	1.77***	(0.18)
Phone-type Dummy	Yes	
Firm Dummy	Yes	
Time Dummy	Yes	
Operating System Dummy	Yes	
No. of Markets	41	
No. of Observations	22,286	

Notes: This table reports the estimated demand parameters and their standard errors.

indicate that the mean price coefficient is positive and significant, while the "price × income" coefficient is negative and significant. This suggests that consumer price sensitivity goes down as her income increases. Our results indicate that consumers prefer handsets with higher-quality cameras where the quality is measured in megapixels. There is, however, heterogeneity in preferences for camera quality, as suggested by the random coefficient of main camera quality. As expected, consumers prefer handsets with bigger screen sizes, better memory, and higher battery life. Regarding technology compatibility, consumers prefer 3G and 4G network-compatible handsets over 2G handsets. The estimated mean own-price elasticity is -6 for smartphones and -4 for feature phones. This is consistent with the elasticities reported in the literature while estimating demand for mobile handsets. For example, the mean own-price elasticity reported by Fan and Yang (2020) for the United States mobile phone market is -6.5. Our estimates suggest that consumers, on average, are willing to pay 28 USD to upgrade from 2G technology to 3G technology and 75 USD to upgrade to 4G technology from 2G technology. Similarly, consumers are willing to pay 41 USD to increase the display module by 1 inch and 29 USD to improve the camera quality by 1 megapixel. Our demand and marginal cost estimates imply a median Lerner Index of 30% for smartphones and 21% for feature phones, while the median markup is USD 91 for smartphones and USD 4 for feature phones.

Table 5: Estimation Results: Marginal Cost

	Est	Std. Err.		Est	Std. Err.
Phone Characteristics			**Firm Origin - Supply Chain Alternative Dummies**		
Log Front Camera (MP)	0.05***	(0.01)	Chinese firm - Import Ready-to-use handset	2.99***	(0.08)
Log Main Camera (MP)	0.09***	(0.01)	Chinese firm - Assemble in India	3.00***	(0.08)
Log Display Module Size	0.83***	(0.02)	Indian firm - Import Ready-to-use handset	3.19***	(0.13)
Log Battery	0.06***	(0.01)	Indian firm - Assemble in India	3.22***	(0.13)
Log RAM × Smartphone Dummy	0.39***	(0.02)	International firm - Import Ready-to-use handset	3.02***	(0.07)
Log Internal Memory	0.11***	(0.01)	International firm - Assemble in India	3.03***	(0.07)
3G Dummy	0.12***	(0.01)	**Supply Chain Alternative-Year Dummies**		
4G Dummy	0.22***	(0.02)	Assemble in India Handset - 2016	-1.19***	(0.10)
Feature phone Dummy	-0.33***	(0.02)	Assemble in India Handset - 2017	-1.04***	(0.10)
Flagship Model Dummy	0.17***	(0.01)	Assemble in India Handset - 2018	-1.01***	(0.11)
Log Quantity	-0.04***	(0.01)	Imported Ready-to-use handset - 2016	-1.16***	(0.10)
Time Trend	-0.01***	(0.00)	Imported Ready-to-use handset - 2017	-1.00***	(0.10)
			Imported Ready-to-use handset - 2018	-0.96***	(0.11)
No. of Markets		41			
No. of Observations		22,286			

Table 5 reports the estimated handset marginal cost parameters. Our estimates suggest that handsets with better camera quality, bigger screen size, higher battery life, better RAM, and phone memory also incur a higher marginal cost of production. Similarly, compared to the 2G-compatible handsets, manufacturing 3G and 4G hands are more costly. The coefficient for the log quantity picks a negative and significant coefficient implying the existence of positive returns to scale. Our estimates suggest that compared to the base year of 2015, marginal costs went down in later years, irrespective of supply chain alternatives. The estimated "firm-origin-supply-chain alternative dummies" indicate that all things being equal, marginal costs do not vary significantly by supply chain alternatives in the status-quo world. This implies that introducing a tariff on imported components in the counterfactual world would increase the marginal cost of production for a handset for which assembly and testing operations are conducted within India without affecting the cost of production when a handset is imported in ready-to-use form. Therefore, a higher tax on a component negatively affects the handset's variable profit if the firm chooses to assemble the handset within India compared to importing the handset in ready-to-use form. Whether the firm chooses not to offer the handset in the market, keeps offering the handset at higher prices, or plans to switch the supply chain in response to the tax policy, would depend on the elasticity of demand, the extent of tax pass-through, and the fixed cost of offering the product conditional on the supply chain alternatives.

5.2 Fixed Costs of product offerings and supply chain alternatives

We estimate the fixed cost $F_{jt}^{(L_{jt})}$ of offering a handset j and choosing a supply chain alternative L_{jt} by exploiting the non-profitable deviation condition of the Nash equilibrium of the product and supply chain choice game. Specifically, Nash equilibrium implies that given the choices made by competitors, a firm's unilateral move to drop a product, add a product, or switch the supply chain choices of the offered products does not increase the total expected profit. We follow Pakes et al. (2015), and Fan and Yang (2020, 2022) and construct profit inequalities by exploiting those necessary equilibrium conditions.

In other words, for any handset j that is offered in the market ($j \in J_{ft}$),

$$\begin{aligned} & E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \\ & \quad - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}\setminus j}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\setminus j, J_{-ft}) \geq F_{fjt}^{(L_{jt})} \end{aligned} \tag{9}$$

and for any $j \notin J_{ft}$, but $j \in \mathbb{J}_{ft}$,

$$\begin{aligned} &E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, L_{jt} = \text{assembly in India}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft} \cup j, J_{-ft}) \\ &\quad - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \leq F_{fjt}^{(L_{jt})} \end{aligned} \tag{10}$$

and

$$\begin{aligned} &E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, L_{jt} = \text{imported in ready-to-use form}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft} \cup j, J_{-ft}) \\ &\quad - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \leq F_{fjt}^{(L_{jt})} \end{aligned} \tag{11}$$

We define the set of potential products for each handset firm ($\mathbb{J}_{ft}$) as follows. Both 2G and 3G technologies were well-developed in India during our sample period. Therefore, for feature phones (mostly compatible with 2G technology) and 3G-compatible smartphones, we include a firm's observed set of products across all periods during our sample in the potential set. However, 4G network was being rolled out and was an evolving technology during our sample period, therefore for any month t; we consider the 4G handsets offered by firm f during $t-2, t-1, t, t+1, t+2$ as the potential set. For $t = 1$ we include periods $t, t+1, t+2$, for $t = 2$ we include periods $t-1, t, t+1, t+2$ in the potential set. Similarly, for periods $t = T$, we include handsets in period $T, T-1, T-2$, and for period $t = T-1$, we include periods $T, T-1, T-2, T-3$ in the potential set.

We assume the following fixed cost structure for a handset. Fixed cost of offering a product and choosing a specific supply chain

$$\begin{aligned} F_{jft}^{(L_{jt})} =& F_{ft}^{1}\mathbf{1}\left\{j \text{ feature phone}, L_{jt} = j \text{ assembled in India}\right\} \\ &+ F_{ft}^{2}\mathbf{1}\left\{j \text{ feature phone}, L_{jt} = j \text{ imported in ready-to-use form}\right\} \\ &+ F_{ft}^{3}\mathbf{1}\left\{j \text{ smart phone}, L_{jt} = j \text{ assembled in India}\right\} \\ &+ F_{ft}^{4}\mathbf{1}\left\{j \text{ smart phone}, L_{jt} = j \text{ imported in ready-to-use form}\right\} \end{aligned} \tag{12}$$

We allow our fixed cost to differ by firm, type of phone (feature phone or smartphone), supply chain alternative, and over time. In other words, for a given firm f to offer a feature phone by conducting assembly and testing operations within India incurs a cost of F^1_{ft}, whereas it costs F^2_{ft} to offer the handset after importing it in ready-to-use form. Similarly, if handset j is a smartphone, then firm f incurs F^3_{ft} and F^4_{ft}, respectively, to assemble the handset within India and import the handset in ready-to-use form. Depending on whether a product is offered and the product's supply chain alternative conditional on being offered, every handset in a firm's potential product set ($\mathbb{J}_{ft}$) at time t falls into one of the six categories. Below we list inequalities for these product categories.

1. j is a feature phone assembled in India and offered at time $t \implies F^1_{ft} \leq F^{1U}_{ft}$, where

$$\begin{aligned} F^{1U}_{ft} = {} & E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}, L_{jt} = j \text{ assembled in India}) \\ & - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}\setminus j}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft} \setminus j, J_{-ft}) \end{aligned} \tag{13}$$

2. j is a feature phone imported in ready-to-use form and offered at time $t \implies F^2_{ft} \leq F^{2U}_{ft}$, where

$$\begin{aligned} F^{2U}_{ft} = {} & E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}, L_{jt} = j \text{ imported in ready-to-use form}) \\ & - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}\setminus j}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft} \setminus j, J_{-ft}) \end{aligned} \tag{14}$$

3. j is a smartphone assembled in India and offered at time $t \implies F^3_{ft} \leq F^{3U}_{ft}$, where

$$\begin{aligned} F^{3U}_{ft} = {} & E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}, L_{jt} = j \text{ assembled in India}) \\ & - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}\setminus j}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft} \setminus j, J_{-ft}) \end{aligned} \tag{15}$$

4. j is a smartphone imported in ready-to-use form and offered at time $t \implies F^4_{ft} \leq F^{4U}_{ft}$,

where

$$F^{4U}_{ft} = E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}, L_{jt} = j \text{ imported in ready-to-use form}) \\ - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}\setminus j}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\setminus j, J_{-ft}) \tag{16}$$

5. j is a feature phone not offered at time t, but inside potential set ($j \notin J_{ft}$, $j \in \mathbb{J}_{ft}$) $\implies F^1_{ft} \geq F^{1L}_{ft}$ and $F^2_{ft} \geq F^{2L}_{ft}$, where

$$F^{1L}_{ft} = E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\cup j, J_{-ft}, L_{jt} = j \text{ assembled in India}) \\ - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \tag{17}$$

$$F^{2L}_{ft} = E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\cup j, J_{-ft}, L_{jt} = j \text{ imported in ready-to-use form}) \\ - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \tag{18}$$

6. j is a smartphone not offered at time t, but inside potential set ($j \notin J_{ft}$, $j \in \mathbb{J}_{ft}$) $\implies$ $F^3_{ft} \geq F^{3L}_{ft}$ and $F^4_{ft} \geq F^{4L}_{ft}$, where

$$F^{3L}_{ft} = E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\cup j, J_{-ft}, L_{jt} = j \text{ assembled in India}) \\ - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \tag{19}$$

$$F^{4L}_{ft} = E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}\cup j, J_{-ft}, L_{jt} = j \text{ imported in ready-to-use form}) \\ - E_{\xi,\omega}(\pi_{ft}(\{L_{kt}\}_{k\in J_{ft}}, \{L_{kt}\}_{k\in J_{-ft}}, J_{ft}, J_{-ft}) \tag{20}$$

We estimate $F^s_{ft}, s = 1, 2, 3, 4$ as follows: if for given F^s_{ft} we have $n^{sU}_{ft} \geq 0$ inequalities for upper bound and $n_{ft}^{sL} \geq 0$ inequalities for lower bound,[14] then

$$F_{ft}^{s} = \frac{\sum_{n_{sU}} 0.8 * F_{ft}^{sU} + \sum_{n_{sL}} 1.2 * F_{ft}^{sL}}{n_{ft}^{sU} + n_{ft}^{sL}} \tag{21}$$

Our fixed cost estimation strategy closely follows the methodology developed in Fan and Yang (2020), which constructs inequalities to compute either an upper bound or a lower bound at the product level.[15] They make assumptions on the missing fixed cost bound (e.g., if only the upper bound is computed for a product, they assume that the lower bound is half of the upper bound) and run the counterfactual exercises by assuming that fixed cost takes random values from the fixed cost set. In contrast, as specified in equation 21, we assume that fixed cost is an average of 0.8 times of estimated upper bounds and 1.2 times of estimated lower bounds. As a robustness check, we use 0.9 and 1.1 as scaling factors instead of 0.8 and 1.2, respectively. Our key results remain robust to this specification. The robustness results are reported in the appendix section A.2.

Table 6: Average Estimated Fixed Cost of Handsets by Country Origin, Phone Type, and Supply Chain Alternative

		Average Fixed Cost (in Million USD)	
Origin	Phone Type	Assembled in India	Imported (Ready-to-Use)
Chinese	Feature Phone	0.09	0.05
	Smart Phone	6.6	2.3
International	Feature phone	0.05	0.03
	Smartphone	4.0	1.9
Indian	Feature phone	0.07	0.08
	Smartphone	3.9	4.7

Note: This table presents the average estimated fixed cost of handsets by origin, phone type, and supply chain alternative.

We report our results from fixed cost estimation in table 6. Following equation (21),

[14] Since every handset firm's potential set always contains feature phones and smartphones, we have $n_{ft}^{sU} + n_{ft}^{sL} > 0 \ \forall f, \forall t$. Also, in our empirical implementation, every firm's potential set always contains feature phones and smartphones that the firm chose not to offer at time t.

[15] An alternative estimation strategy follows Eizenberg (2014), Mohapatra and Chatterjee (2021) that allows unobservables in the fixed cost specification and follows set inference techniques to construct bounds.

the fixed costs are computed for each firm, phone type (smart or feature), and supply chain alternative over time. We report the average fixed costs for phone type and supply chain alternative, where the average is taken over firms of a given origin. The results suggest that the average fixed cost of introducing a feature phone is much lower than smartphones, irrespective of the firm's origin. Additionally, non-Indian firms (Chinese and International firms), on average, face lower fixed costs for introducing a handset if they choose to import the handset in ready-to-use form rather than assemble it in India. Indian firms, on the other hand, face lower fixed costs of introducing the handset by conducting assembly operations within India rather than selling them by importing ready-to-use handsets.

6 Counterfactual Analysis

To quantify how the introduction of an input tariff affects firms' decisions on product offering, choice of the supply chain for the offered products, pricing, and consumer welfare, we conduct a counterfactual exercise where we impose a 10% import tariff on the display modules. Due to this increase in production cost for handsets assembled in India, firms could discontinue selling the handset, continue offering the handset at a higher price, or switch the supply chain alternative to avoid the higher marginal cost.[16]

In response to this tariff policy, computing the counterfactual world requires us to solve the product choice and pricing game to determine the new equilibrium product offering, supply chain alternatives, and prices. This poses a significant computational challenge. We have 44 firms in our sample, and each has around 21 products in its potential set. Since firms can decide to add or remove any subset of products within the potential set and decide on the supply chain alternative for each product, the number of possible actions becomes

[16] A standing assumption is that the firm cannot manufacture the display modules within India in the short run. Due to the rapid technological evolution of mobile phone components, creating an ecosystem within a developing country like India where firms are willing to invest in manufacturing sophisticated handset components is challenging. This is consistent with the Indian mobile handset manufacturing industry, where no manufacturers incorporated sophisticated features like microphones and receivers, camera modules, LCD display modules, and touch modules into the production process during our sample period.

prohibitively large for practical computational purposes. To address this, we conduct our counterfactual analysis by computing the equilibrium during the last twelve months in our sample (from June 2017 to May 2018). Further, we use the best-response-based heuristic algorithm developed in Fan and Yang (2020) to compute the firms' equilibrium product and supply chain choices.

In our counterfactual exercise, we compute the marginal cost component corresponding to the display module (in equation 5) and impose an import tariff on it.[17] As discussed earlier, an import tax would affect the marginal cost of a handset if, for that handset, the supply chain involves importing the components and conducting assembly and testing operations within India. Therefore, in response to the import tax, to avoid the increase in the cost of production, a firm may switch to the alternative supply chain where it imports the product in a "ready-to-use" form by incurring a different fixed cost[18]. Otherwise, the firm may discontinue the product or offer it at a higher price.

We document the results from our counterfactual analysis in table 7. Our results suggest that, in the case of 47% of the handsets for which assembly and testing operations are conducted within India in our sample, firms will choose to switch to the alternative supply chain and keep offering the product by importing it in ready-to-use form. In other words, while in the sample, we observe that firms perform assembly and testing operations in case of 62.2% of the handsets between June 2017 to May 2018, it would go down to 15.1% in the counterfactual world with a higher import tariff. Considering firms of different origins, we observe that 68% of the handsets manufactured by global firms and 80% of the handsets manufactured by Chinese firms would switch from assembly and testing operations within India to importing ready-to-use handsets after the import tax. Our analysis implies that even for firms of Indian origin, in 52% of the cases, firms would switch to importing ready-to-use handsets in response to the import tariff.

[17]In particular, we take the [exp("log display module" × "estimated coefficient of log display module" from table 5)]. We add a 10% ad valorem tax on this and compute the new marginal cost for the handset.

[18]In our model, the firm would incur a fixed cost of F^2_{ft} if the handset is a feature phone and F^4_{ft} if the handset is a smartphone by switching to import the handset in ready-to-use form.

Table 7: Results From Counterfactual Analysis: 10% tax on imported display modules

Effects on MC, Price, and Sales	
Average % Change in Marginal Cost	0.96%
Average % Change in Price	0.91%
% Change in Total Sales	−0.94%
Effects on Product Offering	
Average # of Feature phones Exiting a Market	9
Average # of smartphones Exiting a Market	12
Effects on Supply Chain Decisions	
% of products that switched from "Assembly--in-India" to "Import Ready-to-use handsets"	−47.1%
Welfare Effects	
Change in Consumers' Surplus	−54.2 Million USD
Change in Producers' Surplus	2.8 Million USD

Note: This table documents the results from counterfactual analysis when a 10% tax is imposed on importing display modules. All simulations correspond to the sample's last 12 months (June 2017 to May 2018).

Our analysis suggests modest effects of the import tax policy on marginal costs and prices. Since most firms switched the supply chain away from assembling in India, the tax policy does not affect those products' marginal costs. Therefore, on average marginal cost goes up by 0.96% which is passed on to the consumers leading to a price increase of 0.91%. As a result, we observe a slight drop in overall sales (0.94%).

The policy also leads to the exit of handsets. Our results suggest that, on average, nine feature phone handsets and twelve smartphone handsets would exit the market if the tax policy is implemented. Table 8 compares the products exiting the market with the average characteristics of the observed products. As shown in the table, exiting products in smartphone and feature phone categories have better than average product characteristics suggesting these are high-quality handsets. But, the prices are much lower than the average price in the market, suggesting that high-quality and low-margin handsets will be eliminated from the market due to the import tax policy.

Table 8: Comparison of the Characteristics Between Observed and Exiting Products

	Price (USD)	Front Camera (Megapixels)	Main Camera (Megapixels)	Display Module Size (Inches)	Battery Size (Thousand mAh)	Ram (GB)
Smartphones						
Observed Products	230.5	6.2	9.7	5.1	2.8	2.4
Exiting Products	170.3	7.5	11.1	5.2	3.2	2.6
Feature Phones						
Observed Products	15.4	0.1	0.5	2.2	1.6	NA
Exiting Products	13.1	0.0	0.3	2.0	1.3	NA

Note: This table documents the characteristics of observed products and products that would exit the market due to the import tax policy. The top panel compares smartphones, while the bottom panel compares feature phones.

Due to the increase in prices and the exit of high-quality products from the market, the consumers' surplus goes down by 54.2 million USD in the counterfactual world. Most of the producer profits remain unchanged, leading to a small increase in producers' surplus by 2.8 million USD. This suggests that the counterfactual policy would decrease total welfare by 51.4 million USD.

As a robustness check, in the appendix section A.1, we report results from the counterfactual exercise where we impose a 10% tariff on importing both the display module and the camera module. Our results suggest that the overall effects on marginal cost and prices are similar. At the same time, it leads to even lower investments in the supply chain in India as around 60% of the handsets switch from "assembly-in-India" to importing "ready-to-use" handsets and selling those in India.

Note that the goal of the tax policy was to encourage the manufacturers to invest more in the assembly line of mobile handsets within India in the short run. Our counterfactual analysis suggests that the import tax policy would discourage the firms from doing so, defeating the policy's goal.

7 Conclusion

To boost investments in the supply chain, governments in several developing countries have resorted to industrial policies in the form of taxes targeting imported inputs in the electronics industry. This article focuses on evaluating a similar tariff policy in the context of the Indian mobile handset manufacturing industry. Handset producers in India often resort to two supply chain alternatives. Firms may either import ready-to-use handsets and sell those in the Indian market or may import handset components from abroad and perform assembly and testing operations within India before making those available in the Indian market. In this context, we evaluate the welfare implications of a tariff policy introduced by the Indian government that proposes to impose higher tariffs on sophisticated components imported from abroad.

We build a tractable two-stage structural model of demand, pricing, product offering, and choice of supply chain alternatives among firms. We estimate the model to recover the fixed cost of offering a handset conditional on the supply chain alternative, the marginal cost of producing a handset, and the consumer preferences for different attributes. With the estimates in hand, we conduct a counterfactual exercise where we impose an import tariff when a firm imports the display module from abroad. We solve the product choice and pricing game to determine the new equilibrium product offering, supply chain alternatives, and prices.

Our results reveal that the policy affects the firms' decisions to choose a supply chain alternative to a large extent. In particular, in the case of 47% of the handsets, firms would choose to switch from "assembly in India" to the alternative supply chain of importing ready-to-use handsets. Our analysis suggests that the policy would lead to higher prices. Additionally, due to the policy, firms would discontinue offering a subset of high-quality-low-margin handsets in the market. Higher prices and the elimination of products results in a consumer welfare loss of 54.2 million USD.

Our analysis highlights the unintended consequences of the tariff policy. In particular, the short-run goal of the tariff policy was to encourage the handset manufacturers to invest more in the mobile handset assembly line within India. Our counterfactual results suggest that the tariff policy would incentivize the firms to withdraw investments in India, increase prices, lower the choice set of the consumers, and negatively affect welfare, defeating the policy's goals.

A Appendix: Robustness Checks

A.1 Import Tariff on Display Modules and Camera Modules

Table 9: Results From Counterfactual Analysis: 10% tax on imported display modules and imported camera modules

Effects on MC, Price, and Sales	
Average % Change in Marginal Cost	1.39%
Average % Change in Price	1.30%
% Change in Total Sales	−1.20%
Effects on Product Offering	
Average # of Feature phones Exiting a Market	16
Average # of smartphones Exiting a Market	18
Effects on Supply Chain Decisions	
% of products that switched from "Assembly--in-India" to "Import Ready-to-use handsets"	−59.9%

Note: This table documents the results from counterfactual analysis when a 10% tax is imposed both on importing display modules and camera modules. All simulations correspond to the sample's last 12 months (June 2017 to May 2018).

As a robustness check, here we report results from the counterfactual exercise where we impose a 10% tariff on importing both the display module and the camera module. Our results suggest that the overall effects on marginal cost and prices are similar to those reported in table 7 where a 10% tariff is imposed only on the display module. At the same time, the additional import tariff on camera modules leads to even lower investments in the supply chain in India. Our results show that around 60% of the handsets switch from "assembly-in-India" to importing "ready-to-use" handsets and selling those in India.

A.2 Alternative Fixed Cost Specification

Table 10: Results From Counterfactual Analysis: 10% tax on imported display modules

Effects on MC, Price, and Sales	
Average % Change in Marginal Cost	1.20%
Average % Change in Price	1.10%
% Change in Total Sales	−1.10%
Effects on Product Offering	
Average # of Feature phones Exiting a Market	15
Average # of smartphones Exiting a Market	16
Effects on Supply Chain Decisions	
% of products that switched from "Assembly--in-India" to "Import Ready-to-use handsets"	−56.1%

Note: This table documents the results from counterfactual analysis when a 10% tax is imposed both on importing display modules and camera modules. All simulations correspond to the sample's last 12 months (June 2017 to May 2018). In comparison to results reported in Table 7, here we compute fixed cost using 0.9 and 1.1 as scaling factors in equation 21.

Table 10 reports results from the counterfactual exercise where we compute fixed cost using 0.9 and 1.1 as scaling factors in equation 21 instead of 0.8 and 1.2 respectively. In other words, we use the following specification:

$$F_{ft}^{s} = \frac{\sum_{n_{sU}} 0.9 * F_{ft}^{sU} + \sum_{n_{sL}} 1.1 * F_{ft}^{sL}}{n_{ft}^{sU} + n_{ft}^{sL}} \tag{22}$$

Our analysis suggests that compared to the table 7 the results are robust to alternative fixed cost specifications. In particular, the changes in the marginal costs, prices, and total sales are similar. Additionally, the changes in the supply chain alternatives are slightly higher as around 56% of the handsets switch to importing ready-to-use handsets from abroad rather than conducting assembly and testing operations within India.

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