Domestic Industrial Policy and Consumer Surplus in Developing Countries.

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Abstract

Seeking to encourage domestic mobile handset production, the Indian government proposed new tariffs on imported mobile phone components in 2017. I evaluate the welfare consequences of this policy by calculating the consumer surplus as well as the producer surplus changes due to changes which would have resulted from the continuing implantation of this policy. Toward this end, I develop and estimate a structural model of India's mobile phone market, one where firms endogenously decide production location, product set, and prices. I evaluate the effects of the policy through counterfactuals simulated using the estimated structural parameters. The results suggest that the continuation of this policy will lead to large-scale production relocation, products exiting the market, and price increases leading to a drop in consumer surplus.

Key Words: Industrial Policy, Mobile Phone Markets, Developing Economy, Consumer Welfare.

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1 Introduction

Global supply chain disruptions have become a prominent concern in the past few years, most notably in the electronics industry that depends on sophisticated components primarily produced in East Asian countries like China, South Korea, and Taiwan. In an effort to reduce foreign dependency, countries around the globe have introduced policies aiming to improve the domestic supply chain, mainly in the form of taxes targeting imported inputs. However, these policies may adversely impact consumer welfare in the short run, as the tariffs may induce less favorable cost structures that may increase prices and reduce the variety of products offered in the market.

Assessing the welfare effects of such a domestic industrial policy that aims to alleviate the supply chain bottleneck is particularly important for developing countries. A policy in the form of a tax on imported supplies demands fewer resources than a fiscal policy based on tax breaks and subsidies. As such, countries are likely to "default" to taxes over other policy instruments. Therefore, evaluating the cost-effectiveness of a tax-based domestic industrial policy will require the assessment of the potential harm to consumers. Also, as mentioned above, introducing a domestic industrial policy may harm consumers because of products exiting the market due to low profitability, leaving fewer options in the market from where consumers can choose to maximize their utility. In the context in which digitalization is thriving around the globe and accessing the internet may have important repercussions on people's wellbeing, analyzing how consumers' access to technological goods is affected by a domestic industrial policy is crucial, since unintended consequences could deny vulnerable consumers access to digital-based markets and government services.

In this article, I study a domestic industrial policy introduced by the Indian government that seeks to encourage investment in the mobile phone industry supply chain. Specifically, the policy analyzed is the "Phased Manufacturing Program" (PMP) - introduced in 2017. Under PMP, a manufacturer has to pay an additional tax while importing specific components for mobile handset production. Since most handset firms operating in India either import the entire handset or some components of handsets from outside of India, this policy was designed to encourage firms to switch away from importing and towards investing more in domestic production of handset components.

The four-year policy initially targeted simple components like chargers, adapters, and battery packs leading to a wave of investments in India. The policy then targeted advanced components like microphones, keypads, camera modules, and handset displays. Due to manufacturers' inability to produce these advanced components within India, the government ended up deferring the policy in 2019 [1]. In this context, this paper seeks to answer the following questions: How does the design of PMP affect a firm's decision to produce in

[1] To read a detailed discussion of the deployment of the Phased Manufacturing Program, please refer to the document titled "Make in India 2.0: Revisiting Mobile Manufacturing" published by The Internet and Mobile Association of India available in the following url: https://www.iamai.in/KnowledgeCentre

India versus to produce abroad, and how does this policy affect consumer and producer welfare?

Analysis of the domestic industrial policy requires modeling the economic mechanisms governing firms' supply chain decisions. The welfare analysis requires comparing firm conduct with and without the tariff. Firms could react to an increase in the cost of production stemming from the tariff by stopping offering the now higher cost product, offering the product at a higher price, or switching to a ready-to-use product. Embedded in these options are firms' decisions regarding production location, product offering, and pricing. To capture this behavior, I develop a tractable three-stage structural model that estimates the sunk cost of production allocation decisions and the fixed cost of product entry and exit decisions.

Demand and marginal cost of India's mobile phone market are estimated following (Berry, Levinsohn and Pakes, 1995) and (Nevo, 2000), with demand modeled using a discrete-choice random coefficient framework and supply modeled using Bertrand-Nash competition. Here, I compute firms' variable profits, which allows me to determine how costly it is to produce in India versus to produce abroad. The demand model allows the marginal cost to vary by firm origin, production location, and time. This modeling decision helps me capture the effect of tariffs on ready-to-use phones and phone components on the firms' marginal cost of producing in India or abroad. Then, using the estimations for the variable profit, I compute the sunk cost related to switching production locations and the fixed cost associated with introducing or removing a new product, respectively. Here, I use the approach proposed by (Pakes et al., 2015), and (Fan and Yang, 2020). With the estimation at hand, I compute a counterfactual, which consists of a scenario where the last stage of the PMP is not deferred. The data used in the estimation comes from Counterpoint Research and consists of detailed information about prices, quantities, specifications, manufacturer origin, and production location of mobile phones sold in India from January 2015 to May 2018.

Estimation results suggest that consumers are elastic and have a high willingness to pay for phone characteristics related to sophisticated components like camera modules and screen size. The estimated own-price elasticities are close to -6 for smartphones and to -4 for feature phones which is in line with the elasticities reported in the literature[2]. My supply results suggest that the marginal cost of producing a phone outside India was smaller during the first period of the sample than that of producing a phone in India. However, after the introduction of tariffs on ready-to-use phones in 2017, my estimates suggest that assembling in India represented a smaller marginal cost than producing outside India. Results from the counterfactual exercise suggest that introducing a tariff on phone components generates an increase in marginal cost, which is translated to the consumer almost entirely through a rise in prices. The change in the cost structure of products manufactured in India would push firms to choose to import ready-to-use phones or drop some products that are no longer profitable. Chinese and global firms would use both alternatives dropping products and relocating production outside India, while Indian firms would relocate most of their production

[2] The own-price elasticities reported by (Fan and Yang, 2020) for the United States market are close to -6.5

outside India and drop only a handful of products from their product set. In this sense, the results suggest that Indian production would have dropped significantly if the policy had been implemented as scheduled instead of halting the program. Additionally, product exit and the price increase of the remaining products would have decreased consumer surplus.

Results from the demand estimation suggest that consumers are elastic and have a high willingness to pay for phone characteristics related to sophisticated components like camera modules and screen size. The estimated own-price elasticities are close to -6 for smartphones and to -4 for feature phones which is in line with the elasticities reported in the literature.[3]. My supply results suggest that the marginal cost of producing a phone outside India was smaller during the first period of the sample than that of producing a phone inside India. However, after introducing tariffs over ready-to-use phones in 2017, my estimates suggest that assembling in India represented a smaller marginal cost than producing outside India. Results from the counterfactual exercise suggest that introducing a tariff over phone components generates an increase in marginal cost, which is translated to the consumer almost on its entirely through a rise in prices. The change in the cost structure of products manufactured in India pushes firms to choose to import ready-to-use phones or drop some products that are no longer profitable. Chinese and Global firms would use both alternatives, dropping products and relocating production outside India, while Indian firms would relocate most of their production outside India and drop only a handful of products from their product set. In this sense, the results suggest that Indian production would have dropped significantly if the policy had been implemented as scheduled instead of halting the program. Additionally, product exit and the price increase of the remaining products would have decreased the consumer surplus.

This article broadly relates to three pieces of literature. The first one looks into the telecommunication market similar to the work of (Fan and Yang, 2020), (Wang, 2016), (Elliott et al., 2021) and (Bourreau, Sun and Verboven, 2018). Fan and Yang analyze how product offering affects welfare in the U.S. mobile phone industry using a static game entry model based on the revealed preference argument to define the profit-maximizing equilibrium. Wang studies the effect of government industrial policy on product offering decisions in the Chinese mobile phone industry using a static game entry model and the revealed preference argument complemented by business cycles to estimate entry sunk costs. This paper differs from the cited articles because it uses the revealed preference argument not only to assess the bounds of the fixed cost associated with product entry and exit but also to estimate the bounds of the sunk cost associated with switching production allocation.

The second area of literature is the industrial policy literature such as by (Wollmann, 2018), (Mohapatra and Chatterjee, 2021), (Levinsohn, 2008), (Brambilla, 2005), (Flaaen, Hortaçsu and Tintelnot, 2020), (Fershtman, Gandal and Markovich, 1999), (Li, 2017), (Pavcnik, 2002), and (Barwick, Kalouptsidi and Zahur,

[3]The own-price elasticities reported by (Fan and Yang, 2020) for the United States market are close to -6.5

2021). Specifically, this article is informed by literature that analyzes the impact of public policy on product offering like (Li, 2017), which studies how policy choice regarding charging standards for electric vehicles affects consumers surplus. Here, the model analyzes how the introduced public policy affects consumers' decisions to opt for an electric car as more charging stations are deployed in the market. My model allows us to quantify the welfare effect of public policy by estimating changes in consumption patterns and by endogenizing a firm's decision to introduce or remove certain products as the best response to the analyzed policy. Other significant contributions to this literature are (Wollmann, 2018) which 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 and (Mohapatra and Chatterjee, 2021) which analyzes price control policies and their effect on drugs availability. These papers show that allowing for endogenous product can be critical when evaluating a public policy. The model presented here follows this literature and, in my model, firms select production locations, which is central to answering my research question of how local manufacturing policy affects welfare.

This article also relates to the literature on entry, exit and endogenous product choices, such as by (Berry, 1994), (Mazzeo, 2002), (Draganska, Mazzeo and Seim, 2009), (Seim, 2006), (Lee and Pakes, 2009), (Fan, 2013), (Eizenberg, 2014), 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 and provides comments regarding identification. Section 4 lays out the analysis framework as well as the results from the estimation. Section 5 describes the counterfactual exercises and presents the results from the analysis. Section 6 concludes.

2 Industry Background

2.1 Context

India presents an attractive market for mobile phone manufacture 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 will approach 1 billion by 2025. In 2019, more than 300 million mobile phones were sold in India of which 150 million were smartphones. This situation makes India the second largest and the fastest-growing market for mobile handsets in the world. The massive size and growth rate of this market combined with India's cheap labor costs motivated the establishment of local manufacturing facilities by pioneers in the industry like Nokia, Motorola, LG, and Samsung between 2005 and 2010.

Even though India's mobile handset industry which includes firms from different origins is well established and has been active for almost 15 years, the local added value contribution has not surpassed 7%. 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. However, the Indian government recognized the industries' potential to incorporate manufacturing of low-end electronics components and accessories into the domestic supply chain in years following 2014. This factor, plus Nokia exiting local manufacturing and Chinese firms increasing popularity, motivated the inclusion of the mobile phone manufacturing industry in the "Make in India" initiative. This set of policies aimed to increase the industries' local added value, which was intended to translate to job creation and lower dependency on imports[4].

2.2 The Make in India Initiative and the Phased Manufacturing Program

Launched in September of 2014 by the Indian government, the "Make in India" initiative (MII) had three objectives: increasing the manufacturing sector's growth rate, creating jobs, and enhancing the manufacturing sector's contribution to the county's GDP. According to its deployment chronology, the sets of policies stipulated in the MII initiative targeting the mobile phone industry comprised two groups. The first group of policies consisted of supply-side tax incentives for new investments in the mobile phone manufacturing industry. The state government offered investors property tax breaks, electricity subsidies, subsidies in CAPEX investment, and local tax exemptions. These first sets of policies encouraged investment in manufacturing units across India by different Original Equipment Manufacturers (OEM).

The second set of policies was launched in 2017. It aimed to increase the industry's local added value and to improve the domestic supply chain by promoting the manufacture of mobile phones, their parts and sub parts, through the implementation of import tariffs on ready-to-use phones. In its initial stage, this program sought to decrease the number of handsets imported as Completely Built Units (CBU)[5] or as Semi Knocked Down (SKD)[6] by introducing import tariffs on these goods. The tariffs were first implemented in July 2017 and 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.

Later, the Indian government introduced a new policy named the Phased Manufacturing Program (PMP), which mandated a tariff schedule for different mobile phone components from 2017 to 2020. The program was designed to establish a tariff each year for another part or component, hoping to encourage local production. The Ministry of Electronics and Information Technology notified firms of the PMP roadmap on April 28th, 2017. For the fiscal year 2016 - 2017, the PMP contemplated a 15% Basic Custom Duty (BCD) on chargers, battery packs, and wired headsets. The following fiscal year, components charged with a 15% BCD included mechanics, die-cut parts, microphones, keypads, and USB cables. Next, in the fiscal year

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

[5] A product is said to be imported as a Completely Build Unit when no additional labor is needed in order to reach its sale shape

[6] A product is said to be imported as a Semi Knocked Down when it needs a manor amount of labor to reach its sale shape

2018-2019, the policy noted implementing a 10% BCD for printed circuit board assemblies (PCBA), camera modules, and connectors. Finally, for the fiscal year 2019-2020, the program set a 10% BCD for display assemblies, touch panels, cover glass assemblies, vibrator motors, and ringers [7].

The results of this policy have been decidedly mixed in terms of improving the industries' domestic supply chain. According to the Internet and Mobile Association of India (IAMAI), the assembly programming testing and packaging operations were successfully integrated into the local production process in 2015. In 2016, the Indian mobile phone manufacturing industry incorporated the production of chargers, adapters and battery packs. During this year, the industry failed to fully integrate the production of wired headsets into its production process given that doing so requires a large investment. By 2017, the PMP policies aimed to incorporate some low value components. In this case, the investment required from the manufacturers to incorporate these components to the local production process exceeded the uptick in costs represented by the tariffs. The same situation replayed in 2018, when local industry managed only to incorporate the production of PCBA. Camera modules and connectors were still imported. The shortcomings of the policy in 2017 and 2018 signaled a low probability of reaching the 2019 goals. As a result, the PMP was halted and later redesigned in 2020[8].

2.3 Firms

As previously mentioned, the Indian mobile phone industry categorizes firms with different backgrounds. Depending on their origin, firms are classified as global brands, Indian brands, or Chinese brands. For the most part, global firms are big players with a presence in all major markets worldwide. Their operations, as well as their supply chain, are distributed across different countries. Firms in this group include Samsung and Apple. Firms characterized as Chinese firms concentrate most or all of their operations in China and most of their supply chain is located 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 are Xiaomi, Huawei, and Oppo. Indian firms are located primarily in Uttar Pradesh, Himachal Pradesh, and Uttarakhand in northern India; Karnatak, Tamil Nadu, Andhra Pradesh, and Telangana in southern India; and West Bengal in eastern India. Their primary businesses focus on catering to the local market. India's flagship firms are Micromax, Intex, Lava, and Kabonn.

The Indian mobile phone market is composed of leading firms facing competitive fringe. Between 2015 and 2018, around 200 firms were present in the Indian mobile market with 20 players comprising more than 80% of the total units sold in the market. Currently, Samsung leads the market and has faced fierce competition from young Chinese firms like Xiaomi, Vivo, and Oppo, and new local firms like LYF, which

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

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

entered the market in 2017. The remaining firms in the market offer products like mid-range smartphones with characteristics similar to those offered by the leading firms, with differences in quality and distribution channels. Also, a range of small firms offers low-end feature phones with a small degree of vertical differentiation. This kind of product has become a commodity in the industry with low technological requirements and standard production process.

All the leading players in the market have some portion of their products produced in India through firm- owned facilities or third-party manufacturers. As already mentioned, most of these facilities perform ensemble and testing procedures, and some may produce essential electronic components like batteries, microphones, cables, and chargers. Most of the investments made by mobile phone manufacturers and third-party firms took place after introducing the “Phased Manufacturing Program”. Such investments only marginally increased the average local value-added and failed to incorporate sophisticated components like microphones and receivers, camera module LCD modules, and touch modules into the production process.

3 Data

Counterpoint Technology Market Research collected the primary data for this study. The data includes sales, prices, and characteristics at the version level of different mobile phone models between January 2015 and May 2018. The uniqueness of these data sets relies on identifying firm origin: local, Chinese or global; and product origin: locally manufactured or imported. The temporal market is defined as a single month; a geographical market consists of the entire Republic of India. A product is defined as a single combination of brand, model, and versions. Data for income and the outside option (i.e., not buying a mobile phone) came from the India Human Development Survey 2011 - 2012 conducted by Data Sharing for Demographic Research. Based on my definition of the market, the sample poses 22,286 product-month observations.

3.1 Market Characteristics

In the original data set, 581 firms were observed across the analysis period. On average, 118 firms were active each month, where 44 firms accounted for about 95% of the total sales in the market. For tractability reasons related to my model, this work considered only the 44 firms with the highest sales across all markets. Across the observed period, there were ten firms whose market share lay above 5%. This group included major worldwide players like Samsung, whose average market share were close to 24%; Xiaomi, with an average market share of 11%; and some local firms like Micromax and LYF Lava and Intex whose market shares lay below 10%. This market was not concentrated in general terms with a Herfindahl Hirschman index close to 0.1 and a C4 index below 64%. Table 1 presents the main features of the market structure by year.

The number of available models in the market diminished since 2016 when 564 different models were

Table 1: India's Mobile Phone Market Structure

Year	Main firms					C4	HHI
	LYF	INTEX	LAVA	MICROMAX	SAMSUNG		
2015	0.0%	12.1%	11.3%	15.7%	23.1%	62.2%	0.10
2016	3.1%	10.2%	9.0%	11.9%	25.1%	56.2%	0.10
2017	7.1%	4.3%	5.4%	8.2%	24.5%	50.5%	0.08
2018	27.8%	1.5%	4.8%	2.7%	17.5%	64.1%	0.11

Note: This table reports the market share for the four firms with the most sales across all analyzed periods; the C4 index, which is the sum of the market shares of the top 4 firms in the market on each year; and the Herfindahl Hirschman Index for each year that is bounded between 1 and 0.

observed on average each month. In 2017 and 2018, the number of available products fell to 421 and 339, respectively. Noteworthy is that the decline in the number of models available in the market occurred when the PMP was introduced. The proportion of smartphones models in the market being around 50% remained relatively constant in the analyzed period. The mean price of feature phones experienced a slight decrease; meanwhile, the mean price for smartphones increased rapidly, especially after 2017. Table 2 presents the mentioned information in detail.

Table 2: India's Mobile Phone Market Products

Year	Avg. num. of product per market	Avg. proportion of smartphones	Avg. price of smartphones (USD)	Avg. price of feature phones (USD)
2015	574	51.1%	173.1	18.8
2016	576	48.1%	190.4	16.4
2017	421	48.7%	231.4	16.0
2018	339	50.7%	258.8	15.0

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.

On average, each of the top 44 firms in the market offered 16 different products. Samsung, the leading firm in the market, offered on average 36 products between smartphones and feature phones. Prices varied quite significantly among products, even within phone categories. It is usual to observe firms offering feature phones with prices ranging from USD 14 to USD 61. For smartphones, the average price is USD 200 and can go as high as USD 1,500. It is common for the top firms in the market to offer top-tier smartphones defined as flagship products. These products possess cutting-edge technology and high-end characteristics that differentiate them from the rest of a firm's product portfolio.

3.2 Firms' Characteristics

Mobile phones in my sample are categorized as either imported (ready-to-use) or produced in India (assembled in India). To be labeled as imported, a product needs to be nationalized as CBU, meaning no additional labor is required to reach its final sale condition. In contrast, produced in India products are nationalized as CKU. In this state, the product needs some additional labor to reach its final sale form. The intensity of work required is lower in SKU products and greater for products in CKU form. Firms, independently of their origin categorization, offer both produced in India or imported products. Table 3 shows that production in India experienced a rapid increase across categories after the application of the first policies of the "Make in India" initiative in 2016 and kept growing by 2017 and 2018 when part of the PMP was deployed. The evolution in the proportion of Indian production is especially significant for global and Chinese firms, reaching 97% and 86%, respectively, by 2018. On the other hand, Indian firms increased the proportion of Indian production after 2015 reaching a maximum of 64% in 2016. However, after that, this group of firms has failed to increase its local production.

Table 3: Evolution of the Proportion of Indian and Abroad Production by Firm Type

Year	Chinese		Global		Indian	
	Indian	Abroad	Indian	Abroad	Indian	Abroad
2015	8%	92%	69%	31%	22%	78%
2016	66%	34%	82%	18%	64%	36%
2017	78%	22%	91%	9%	57%	43%
2018	86%	14%	97%	3%	53%	47%

Note: This table shows the shows the change in the total quantity of mobile phones produced in India and abroad.

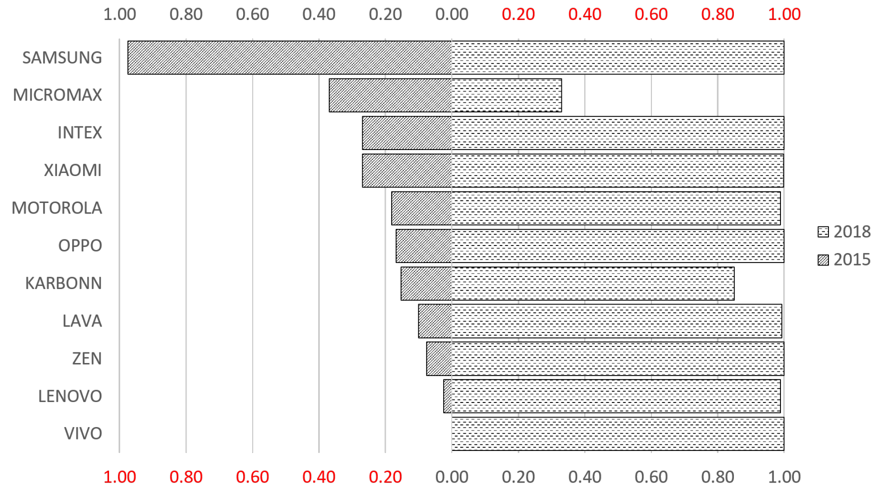
The evolution of the proportion of Indian produced products between 2015 and 2016 suggests that after 2015, firms gradually migrated some of their production to India. This phenomenon is not only visible at the aggregated level, it is also present at the firm level. Figure 3.2 shows the evolution of the proportion of India produced products in 2015 and again in 2018 for the 11 firms with the most sales in the sample. It can be seen that the increase in the proportion of Indian production is significant for all the selected firms except for the Indian firm Micromax. I aim to exploit the variation in production allocation by firm type to identify the marginal cost associated with local and abroad production.

3.3 Product Characteristics

In the sample, 51.5% of products were smartphones; 48.1%, feature phones; and the remaining 0.4%, hybrid phones[9]. The significant participation of feature phones suggests that some consumers in India have a strong

[9] A hybrid mobile phone is defined as an intermediate phone between a feature phone and a smartphone. Most of the time, a hybrid phone allows users to access the internet, lacks a tactile screen, and possesses a basic operative system.

Figure 1: Change of the Proportion of Local Production - Main firms.



Note: This figure plots the percentage of total production which took place in India. The left side panel shows the percentage of the total output that took place locally in 2015. The right side panel shows the same metric for 2018.

preference for cheap and simple phones. Concerning network technology, 29.1% of the mobile phones in the sample were compatible with 4G networks; 17.1% with 3G networks; and the other 53.8%, with 2G networks.

There is significant variation regarding product characteristics, both between and within phone categories. Typically, feature phones have lower features when compared to smartphones. The same is true when comparing non-flagship smartphones and flagship products. Table 4 presents the dispersion of the four main phone characteristics across categories. Most firms offer 2G technology in their feature phones and 4G technology (LTE) in their smartphones. 3G technology is not popular among either of these categories.

For smartphones, an essential source of differentiation is the operating system (OS). Most firms in the sample incorporate different versions of Android as their operating system. On the other hand, leading firms like Apple and LYF have their own operating system. Most of the interaction between user and phone happens through the OS, meaning that consumers invest time learning how to manage it. This situation creates a switching cost for consumers who may want to acquire a phone with a different OS. Also, the applications developed for smartphones are OS-specific. As a result, some applications may be available on some phones but not on others. In this case, the OS can drive the consumer's decision on which phone to purchase.

Camera modules are another essential feature of mobile phones. In the sample, 96% of feature phones had a back camera while only 7% had a front camera. In contrast, 99% of the smartphones in the sample had a back camera, and only 3% did not have a front camera. The technology of the back camera modules of smartphones evolved with basic components in 2015 with an average of 4 megapixels to sophisticated ones in 2018 with 10 megapixels. This evolution is also visible in the different capabilities of the camera like optical and digital zoom, filters, autofocus, among others. In feature phones, the back camera module has a low to medium resolution quality ranging from 0.3 to 3.1 megapixels with minor variations over time.

With the introduction of internet capabilities on mobile phones, screen size, especially of smartphones, has gained special attention from consumers. In the sample, screen size in smartphones varied from 2.8 inches to 6.95 inches. In feature phones, the screen size spanned from 1.3 inches to 5 inches. Other important features in mobile phones are battery size and RAM. Of note, given the type of use of smartphones, consumers value both these characteristics on these devices. In the sample, battery capacity varied from 300 mAH to 8000 mAH on feature phones and 406 mAH to 6050 mAH for smartphones. RAM is another feature that has evolved significantly across time. In 2015, the most powerful phone had a RAM of 4 GB. By 2018 the RAM of the most powerful phone had doubled to 8 GB. Table 4 presents descriptive statistics of phone characteristics in the sample.

Table 4: Descriptive Statistics Mobile Phone Characteristics

	Feature Phone			
	Min	Mean	Median	Max
Back Camera (Megapixels)	0.1	0.6	0.3	8.1
Front Camera (Megapixels)	0.1	0.6	0.3	2.0
Screen Size (Inches)	1.3	2.30	2.4	5.0
Battery Capacity (mAH)	300	1,509	1,400	8,000
RAM (GB)	0.0	0.2	0.0	1.0
	SmartPhone			
	Min	Mean	Median	Max
Back Camera (Megapixels)	0.3	8.6	8.0	40
Front Camera (Megapixels)	0.3	4.2	5.0	25
Screen Size (Inches)	2.8	4.8	5.0	7.0
Battery Capacity (mAH)	406	2,465	2,400	6,020
RAM (GB)	0.1	1.7	1.0	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.

4 The Model

Answering my research question requires a model that represents how firms in the Indian mobile phone manufacturing industry decide between different supply chain alternatives when a tax is applied on imported phone components. For example, if a firm is producing in India, introducing a tariff on imported components implies an increase in marginal cost. Then, the firm would have to decide between keeping the production in India and facing the increase in marginal cost, which could translate to a higher price and consequentially to a lower market share or importing the product as a ready-to-use phone. Additionally, the change in the relative costs of the supply chain due to the tariff could alter the profitability of some products, which could modify the product set offered by each firm in the market. This means that the firm has a third option - stop offering the affected product. Subsequently, the indirect consequence of the policy can, in turn, affect production location decisions.

In this context, the proposed framework should model how firms evaluate their expected variable profit, the sunk cost of switching production locations, and the fixed cost related to product entry and exit. I propose a model that consists of a three-stage game where firms endogenously decide production location and the set of products they offer, given the observed market conditions. At the beginning of each period, demand and the last period's product set are public information. Firms observe a set of sunk costs and decide each product's production location and which products to offer in the market. Then, after demand and marginal cost disturbances are realized, firms set prices for their products. Firms solve the problem by backward induction from the third stage, calculating profits for different combinations of production location, and choosing the location setup that maximizes their profit. Once the location is decided, firms define the set of products that will maximize their profits given the selected location and the demand realization. On what follows, each of these stages will be illustrated in reverse order.

4.1 Demand

I use a random utility discrete choice model to estimate the demand for mobile phones in India. This model incorporates consumer heterogeneity in the valuation of products characteristics observed in the market. A similar approach to estimate the demand for mobile phones can found in (Fan and Yang, 2020) and (Hiller, Savage and Waldman, 2018). Each month is defined as a market. There are N_m consumers, $i = 1, \ldots, N_m$ in each market m. Each consumer chooses a mobile phone from a set of differentiated products available in market m denoted by $j = 0, \ldots, J_m$. If the consumer chooses good $j = 0$, then no mobile phone is purchased. Consumers i in market m will choose a mobile phone j if it maximizes its indirect utility function, represented by:

$$U_{ijm} = X_{jm}\beta + \xi_{jm} + \left[-\exp\left(\alpha + \sigma_p Income_{im}\right)\right] p_{jm} + \sum_k X_{jmk}\sigma_k v_i k + \epsilon_{ijm} \tag{4.1}$$

where X_{jm} is a K-vector of observed product characteristics excluding price and contains a constant term, a dummy for smartphone, and a time trend intended to capture the valuation over time of the outside option. Additionally, I included a firm fixed effect and an interaction between the firm fixed effect and the time trend to capture the fluctuation in the valuation of a brand over time. The term ξ_{jm} captures product characteristics unobserved to the econometrician. 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.

Price is represented by p_{jm}. Consumer specific variables include income denoted by $Income_{im}$ and consumers' attributes v_i. Consumers' income is drawn from an empirical income distribution in India. Consumer attributes v_i are drawn from a standard normal distribution. ϵ_{ijm} denotes the I.I.D. (across consumers and products) consumers i's idiosyncratic taste for good j, and is assumed to follow a Type-I extreme value distribution. My specification allows for that consumer's price sensitivity to vary with income levels. Prince sensitivity follows a log-normal distribution with parameters $(\alpha,\ \sigma_p)$. This means that α captures the mean price sensitivity, and σ_p captures the variation of price sensitivity across consumers depending on income levels. A negative value for σ_p implies that a lower-income consumer will have higher price sensitivity. The utility of the outside option is denoted by:

$$U_{i0m} = \epsilon_{i0m} \tag{4.2}$$

As stated in (Berry, Levinsohn and Pakes, 1995), and (Nevo, 2000) the indirect utility can be divided into two terms:

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

$$\mu_{ijm} = \left[-\exp\left(\alpha + \sigma_p Income_{im}\right)\right] p_{jm} + \sum_k X_{jmk}\sigma_k v_i k + \epsilon_{ijm}$$

This specification resembles the logit choice probabilities. By integrating over the total number of simulated consumers, it is possible to get products j's market shares in market m.

$$s_{ijm} = \int \frac{\exp(\delta_{jm} + \mu_{ijm})}{1 + \sum_{z\in J_m} \exp(\delta_{zm} + \mu_{ijm})} dP_D \tag{4.3}$$

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

Using a random coefficient discrete choice model allows me to exploit the rich substitution patterns between products resulting from this methodology. This feature of the model facilitates evaluating how changes in the cost structure of a subset of products which are assessed a tax on imported components affects prices of all products in the market, which ultimately affects consumers' purchase decisions. Based o consumers behavior, firms can evaluate their expected profit using different supply chain alternatives.

In the model, demand is modeled as static and supply as a three-stage static game. In the case of the demand, unit demand closely approximates consumers' actual purchasing behavior in the market. Most often, consumers buy one cell phone at a time. Even though some consumers may use wireless services from different providers, most phones in the sample allowed for two chipsets. This situation eliminates the need to own more than one phone.

Regarding the nature of the purchasing decision, following (Fan and Yang, 2020), I assume that consumers do not make strategic decisions at the time of purchasing a cell phone. Industry reports[10] suggest that 72% of consumers replace their cell phone within 24 months, with 40% doing so before 12 months. Given the nature of the demand and the fact that most of the products offered in the Indian market are not flagship products, it seems reasonable to assume that Indian consumers do not make inter-temporal decisions when purchasing a cellphone. This allows using a static demand model to represent the consumer behavior of the Indian population.

4.2 Supply

As stated previously, the supply side consists of a three-stage static game, where firms choose the set of products to be offered in the market J_{fm}. In the second stage, firms define the production location scheme represented by L_{fm}. Finally, in the third stage, firms choose retail prices for the product in J_{fm}. In what follows, the three stages will be described in reverse order.

4.2.1 Pricing decision

In the last stage of the model, firms choose retail prices after observing all firms' product set J_m and production location scheme L_m. Each firm f owns a set of products $J_{fm} \subset J_m$ where J_m denotes the set of all the products offered in market m by all firms. For each product in J_{fm}, firm f has defined a production location represented by production scheme vector L_{fm}. The firm's f total variable profit represented by the sum of each product's profit given its production location L_m and the set of products being offered in the market J_m.

$$\Pi_{fm}(\vec{p}, L_m, J_m) = \sum_{k \in J_{fm}} (p_{km} - c_{km}) s_{km}(\vec{p}, L_m, J_m) M \tag{4.4}$$

In the previous expression, c_{km} represents product k's marginal cost which depends on the product's components and production location. s_{km} is product k's corresponding market share which is a function of the J x 1 price vector, the J x 1 production location vector L_m, and the set of products available in market m, J_m. Market m size is represented by M. Assuming an oligopoly competition, the profit-maximizing price or each product $j \in J_{fm}$ should satisfy the following first-order condition:

$$s_{jm}(\vec{p}, L_m, J_m) + \sum_{k \in J_{fm}} (p_{km} - c_{km}) \frac{\partial s_{km}(\vec{p}, L_m, J_m)}{\partial p_{jm}} = 0 \tag{4.5}$$

Let the J x J matrix θ^F be the firm's product ownership matrix, where a one on the ij entry of the matrix denotes that the same firm produces both products j and k. Additionally, let $\vec{s}$ be the endogenous

[10] Please, refer to the following report for more detail https://www.91mobiles.com/hub/91mobiles-smartphone-buyer-insights-study-2019/

vector of market shares and let $\Delta(\vec{p}, J_m, L_m) = \partial s_{km}(\vec{p}, L_m, J_m)/\partial p_{jm}$ be the J x J Jacobean matrix of first derivatives. Finally, let the marginal cost be represented by the J x1 vector $\vec{c}$. By using the operator $\odot$ to represent element-wise multiplication, it is possible to represent the firm's first order condition as follows:

$$\vec{s} + (\theta^F \odot \Delta(\vec{p}, J_m, L_m))(\vec{p} - \vec{c}) = 0 \tag{4.6}$$

After rearranging some terms, I obtain the following expression:

$$\vec{c} = \vec{p} - (\theta^F \odot \Delta(\vec{p}, J_m, L_m))^{-1}\vec{s} \tag{4.7}$$

The logarithm of the marginal cost of product j is modeled as a linear function of observed cost shifters $w_j m$ and a supply shock which is I.I.D across products and markets, ω_{jm}.

$$\log(c_{jm}) = w_j m\gamma + \omega_{jm} \tag{4.8}$$

Cost shifters include product characteristics, and production location fixed effects. Additionally, an interaction between the trade policy and the production location is included in the marginal cost specification to capture the effect of the trade policy on the location decision. The specification also includes the logarithmic of the number of units produced to capture the existence of scale economies. An interaction between the trade policy dummy and the quantity produced is included to address how the trade policy may affect quantity production. Finally, I use time-fixed effects to capture the impact of the production technology across time and brand-fixed effects to capture any cost shifter particular to each firm.

Allowing marginal cost to vary with respect to phone characteristics and production location is essential to identifying how different supply chain alternatives may affect expected profit, which is key to identifying the sunk cost of switching production locations to outside India.

4.2.2 Production allocation decision

In the second stage of the model, firms simultaneously choose production locations, knowing that their actions will affect competitors' pricing and product offering decisions. Here, firms can either import phone components and assemble each product in India or import the phone as ready-to-use (Production takes place outside of India). The decision about the supply chain affects the firm's profit via the marginal and fixed costs that occur every period. Firms are incentivized to allocate production in the country with the lowest marginal cost. Doing this will allow firms to lower prices, gain market share, and obtain higher variable profit. However, moving production location may imply incurring additional fixed costs that affect the firm's total profit. If a specific location offers both lower marginal costs and fixed costs, the firm's production location decision is trivial. Here, the location having a lower cost structure is preferred. If this were not the case, the firm's decision regarding production location could be seen as an investment towards reducing marginal cost. If the reduction in the marginal cost generates an increase in variable profit sufficiently large to offset the upfront sunk cost of switching production location, the firm will make the change.

The model assumes that the outcome observed in the data is a Nash equilibrium. This implies that given the competitor's production allocation, no deviation from the observed firm's equilibrium production allocation should bring a higher expected profit. In this case, a deviation implies switching the observed location to the remaining alternative. Specifically, if a firm produces a mobile phone in India, a deviation means changing production to outside of India. The opposite is true if the observed production takes place outside India. Let L_{fm} represent the observed vector of production allocation for firm f in market m, and L_m the production allocation vector for all products in market m. Let us assume that firm f decides to switch the production location for product j. Let $L_{m|j}$ represent the firm's production allocation vector where production location for product $j \in J_{fm}$ has been switched. In this case, the expected profit for firm f should not increase once the production location for product j has been switched.

$$E(\xi_m, \omega_m)[\pi_{fm}(L_m, \xi_m, \omega_m)] > E(\xi_{m|j}, \omega_{m|j})[\pi_{fm}(L_{m|j}, \xi_{m|j}, \omega_{m|j})] - SC(L_{m|j}) \tag{4.9}$$

In the previous inequality, expectations are taken over demand and marginal cost shocks. $\pi_{fm}(L_m, \xi_m, \omega_m)$ is the equilibrium variable profit for firm f in market m, and $\pi_{fm}(L_{m|j}, \xi_{m|j}, \omega_{m|j})$ is the variable profit if firm f switches production location for product $j \in J_{fm}$. finally, $SC(L_{m|j})$ represents the sunk cost of switching product j production location. By rearranging the previous inequality,I arrive at the following expression:

$$E(\xi_m, \omega_m)[\pi_{fm}(L_m, \xi_m, \omega_m)] - E(\xi_{m|j}, \omega_{m|j})[\pi_{fm}(L_{m|j}, \xi_{m|j}, \omega_{m|j})] > SC(L_{m|j}) \tag{4.10}$$

The term $SC(L_{m|j})$is a vector with zeros in all entries except for the j^{th} entry. The reason is that production locations for all products in J_m except for j remained unchanged. Inequality 4.10 can be used to bound the sunk cost of switching product j's production location.

Whether this expression provides an upper or a lower bound for the switching location sunk cost for product j depends on the nature of the marginal cost. For instance, if marginal cost is non-decreasing with respect to the quantity produced and lower in observed production location compared to alternative locations, then inequality 4.10 provides an upper bound for switching location sunk cost. On the contrary, if the observed locations present a higher marginal cost than the alternative location, then the left side of inequality 4.10 will yield a negative value. In this case, the sign of inequality will switch, providing a lower bound for the switching location sunk cost.

In any case, the lower or upper bound of the sunk cost related to switching production location is identified as inequality 4.10. When the estimation results are presented, I will describe under which circumstances this partial identification is sufficient to form my counterfactual.

It is important to note that the existence of sunk costs can spur strategic behavior. More precisely, it is reasonable to conclude that firms may make current decisions regarding production location by evaluating expected profits originating from different future configurations of the supply chain. However, this option implies computing a significantly large number of expected profits that depend on different states, creating a computational burden that makes this option non-viable.

To address this situation, my model proposes using a repeated static game that converges to the optimal strategy. This modeling decision is based on the assumption that agents do not explicitly compute optimal strategies but instead use a rule of thumb to make decisions regarding production location. Although strong, the behavior in the market suggests that this assumption in accordance with reality. Industry reports[11] have suggested that mobile firms' production location behaviors tend to be conjectural, with managers deciding production location in the short run and employing third-party tolling services to produce in India. Moreover, in the data, it can be observed that firms switch production locations after changes in the legal framework of the market, which further corroborates my assumption.

4.2.3 Product set decision

The decision over alternative supply chains may create changes in a firm's cost structure, further altering the profitability of some products offered by firms in the market. In particular, introducing the tax on import components will affect the marginal cost of a product assembled in India. A higher cost may result in a higher price and a lower market share for such a product. Consequently, the firm may realize that the profit resulting from offering this product may not cover its entry fixed cost.

In this sense, the third stage of the model works as a participation compatibility constrain. Firms simultaneously define the product set to be offered in the market after observing realizations of demand and marginal cost shocks and the production allocation scheme of all players. In this case, the Nash equilibrium implies that the firm has no incentives to deviate from the observed product set given its competitors' product set. A deviation here consists of eliminating or adding a product observed in the data. Let $\mathbb{J}$ be the set of products observed across all markets, such that $J_m \subset \mathbb{J}\ \forall m$. Now, Let $J_{fm} \subset J_m$ be the set of products offered by firm f in market m. Also, let $J_{m-j} \subset J_m$ be the same set of products offered by all firms in the market m excluding product j. At equilibrium, no deviation from the equilibrium set of products $J_{fm} \subset J_m$ should yield a larger profit. This situation can be represented as follows.

$$E(\xi_m, \omega_m)[\pi_{fm}(J_m, L_m, \xi_m, \omega_m)] - F_{jfm}(L_m) > E(\xi_m, \omega_m)[\pi_{fm}(J_{m-j}, L_m, \xi_m, \omega_m)] \tag{4.11}$$

[11] Maximizing Local Value Addition In Indian Mobile Phone Manufacturing: A Practical Phased Approach. Page 21

Here, expectations are taken over the demand and marginal cost shocks. $\pi_{fm}(J_m, L_m, \xi_m, \omega_m)$ represents the variable profit for firm f in market m when its product set includes product j given the production allocation scheme L_m. $F_{jfm}(L_m)$ represents firm's f fixed cost of producing product j, given production allocation. $\pi_{fm}(J_{m-j}, L_m, \xi_m, \omega_m)$ is firms f's marginal profit in market m once product j is removed from the product set. Rearranging some terms, inequality 4.11 gives the upper bound of firm's f fixed cost of producing good j, given by $F_{jfm}(L_m)$.

Now, let $J_{m\cup k}$ be a set of products such that $k \notin J_m$ but $k \in \mathbb{J}$. For tractability reasons, I restrict product k to be observed in the firm's f product set at any market in the data except for m. Specifically, for each product $k \in \mathbb{J}$, I look for the last market where that product was offered, market $\hat{m}$ such that $\hat{m} \neq m$. Now by construction, product $k \in J_{\hat{m}}$ but $k \notin J_m$. To estimate the product's k fixed cost lower bound, I add product k to firms f's product set for market m and calculate the expected variable profit. In equilibrium, firm f adding product k should yield the following result:

$$E(\xi_m, \omega_m)[\pi_{fm}(J_m, L_m, \xi_m, \omega_m)] > E(\xi_m, \omega_m)[\pi_{fm}(J_{m\cup k}, L_m, \xi_m, \omega_m)] - F_{kfm}(L_m) \tag{4.12}$$

where $\pi_{fm}(J_{m\cup k}, L_m, \xi_m, \omega_m)$ is firm's f variable profit after including product k in its product set. $F_{kfm}(L_m)$ represents product k's fixed cost given production allocation L_m. Inequality 4.12 gives a lower bound for product's k fixed cost $F_{kfm}(L_m)$.

Here again, the existence of a fixed cost for product entry and exit can suggest a strategic behavior of the firms in the market. However, accounting for the dynamic nature of firms will require evaluating the expected profits from a significantly large span of possible states generated by all the possible combinations of products offered by all firms in the market at different points in time and, will make the estimation computationally infeasible.

If one considers that most firms in the data operate at a global scale and that most of the products offered in India are not particular to this country but are models being offered in other markets, one can readily see how a product entry or exit decision may be reduced to a firm's decision whether to offer a product in India. In other words, firms are not deciding on whether they should invest in developing a new product, one which may not be currently in production elsewhere. Instead, firms are deciding only if a product currently in their product portfolio should be offered in India. With this in mind, the fixed cost of introducing a product may have more to do with commercialization and logistics matters than with design and development matters. It is worth noticing that similar assumptions are made in (Fan and Yang, 2020) and (Wollmann, 2018).

4.3 Estimation

4.3.1 Demand Estimation Results

The estimation of demand and marginal cost follows (Berry, Levinsohn and Pakes, 1995). Moments are constructed using equations 4.3 and 4.8, and estimated using the Generalized Method of Moments. I use a set of instrumental variables to address the price endogeneity problem. In accordance with the literature, I use competitors' product characteristics as instrumental variables, specifically the sum of competitors' characteristics. Also, following (Hiller, Savage and Waldman, 2018), I use the deviation from the average of the characteristics for all products in the market and products within firms. Instrumental variables also include the number of competitors with similar characteristics. The identification strategy relies on the assumption that firms decide their product characteristics before observing demand and marginal cost shocks. Other instruments are the entry of the JIO Reliance carrier into the Indian Market. This carrier entered the market with its own set of products that compete directly with mobile phone manufacturers. The entry affects prices while remaining uncorrelated with ξ_{jm}.

Along with the results from the BLP model, I present the demand estimates from the logit model. The first column of Table 5 reports estimates from OLS estimations, where I estimate the demand model while ignoring endogeneity. The second column reports 2SLS estimations, where I consider endogeneity and instruments for the price. The last column documents the results from estimation of the full demand model.

In the first two specifications, OLS and 2SLS, the price coefficient is negative and significant, although its magnitude is small compared to the full model. Note that in the full model, the price coefficient takes the form $[-exp(\alpha + \sigma_p * income)]$, where α is the mean price sensitivity, and σ_p captures the heterogeneity in price sensitivity. The estimated mean price coefficient is positive and significant, while the coefficient of income is negative and significant. This result suggests that price sensitivity decreases as consumers' income increases. The estimated own and cross-price elasticities are reported in table 5.

The model suggests that the own-price elasticity for smartphones is significantly larger compared to feature phones. Furthermore, the cross-price elasticity between feature phones and smartphones is lower when compared to the cross-price elasticity within groups. Thus, consumers that prefer feature phones are less sensitive to change in prices. The results also suggest that consumers are sensitive to prices, which suggests that a change in the cost structure of a phone if translated to the price, will result in a significant drop in the product's market share.

Most feature phones in the sample have basic main cameras, no front camera, a small screen, small internal memory, and no RAM. Also, given how consumers use their smartphones, they may have a different perception of the battery size if the observed product is a smartphone. For this reason, hoping to better capture consumers' taste for these characteristics, the proposed specifications include an interaction term between a smartphone dummy and front camera megapixels, RAM, battery size, and internal memory. The results suggest that all these characteristics are positively valued on smartphones.

Consumers' mean taste for main camera megapixels is positive and significant suggesting heterogeneity in taste among consumers. Regarding the front camera, the random coefficient is positive but not significant. The mean coefficient for the smartphone dummy is negative and significant, but smartphones' mean utility is larger overall once interaction of the smartphone dummy and phone characteristics are accounted for. The random coefficient of the constant measures the correlation among inside goods. The estimation indicates that consumers positively value the quality of both cameras' modules.

In terms of network technology, consumers value 4G ready phones more than 2G and 3G ready phones. The coefficient on the 3G technology dummy is positive but not significant. This suggest that consumers strongly prefer 4G phones over all other phones and prefer 3G phones over 2G phones. Regarding Operative Systems (OS), the results suggest that consumers prefer Android OS over other OS. The coefficient on the time since the release of the OS suggests that consumers prefer phones with newer versions on their OS.

4.3.2 Marginal Cost Estimation Results

Using equation 4.8, I estimate the marginal cost of each product. I use instrumental variables to deal with endogeneity. The set of instruments includes competitors' characteristics similar to those used in the demand estimation. Also, I include a year - product origin and firm's origin - product origin fixed effects hoping to capture the effect of the PMP on products of different origins.

The marginal cost specification includes product characteristics, phone network technology, a flagship models dummy, and a time trend variable. In addition, the logarithm of the quantity produced is included to capture possible returns to scale. The specification also has a firm origin - product origin fixed effect and a year -product origin fixed effect. These last variables are set to catch the variation in marginal cost coming from the production allocation decision of firms with different origins and coming from the variation of trade policies applied differentially to local and imported goods across time. Results of the marginal cost estimation are presented in Table 7 .

The result suggests that all things being equal, the marginal cost of producing abroad is slightly smaller for firms in all origin categories. Looking at the year-production location fixed effect, marginal cost decreased for all years in the sample from 2016 to 2018. Moreover, this reduction in marginal cost is accentuated if the product is produced in India. In some way, the results suggest that introducing the "Make in India" initiative reduced the marginal cost for all products in the industry. In contrast, the introduction of tariffs on ready-to-use phones and imported phone components slowed the decrease in marginal cost for both imported and Indian produced phones, but its impact was more substantial on the imported products. Table 8 presents the combination of the firm origin - production location fixed effect and the year - production location fixed effect. Here is shown that in 2015 the marginal cost for products manufactured in India was higher compared to the marginal cost of production abroad while the contrary is true for years 2016 onward.

These results suggest that after 2015, assembling a phone in India represented a smaller marginal cost than importing the prone as ready-to-use regardless of the firm's origin. Notably, this means that firms that opt for an Indian sourced supply chain are trading off a smaller marginal cost which yields a higher variable profit that allows them to cover the upfront sunk cost of moving production to India. Furthermore, this implies that for a firm assembling products in India to move production abroad, the introduction of a tariff on imported components must affect variable profit so that the advantage in the marginal cost of producing in India fails to cover the sunk cost using this supply chain.

Regarding phone characteristics, all the coefficients are positive and significant. This means that higher quality is associated with higher marginal costs. Regarding phone network technology, marginal cost is higher in 4G phones when compared with 3G and 2G phones. The coefficient for the logarithm of the quantity produced is negative and significant which implies the existence of positive returns to scale. As expected, marginal cost increases in the case of flagship phones and smart phones.

The median Lerner Index is 30% in the case of smartphones and 21% for feature phones, while the median markup is 90.71 USD for smartphones and 3.57 USD for feature phones. These values are consistent with industry reports.

4.3.3 Estimation of the Sunk Cost Related to Switching Production

Based on the demand and marginal cost estimates, I obtain the bounds for the sunk cost of switching locations. The estimation considers two possible production locations: India and abroad. As previously mentioned, the direction of inequality 4.10 is given by the nature of the marginal cost function. Estimates of the marginal cost suggest that after introducing the import tariffs on ready-to-use phones and phone components, marginal cost is higher when production takes place abroad. Also, the results from the estimation suggest that marginal cost decreases with the quantity produced, which indicates the existence of economies of scale. In light of these results, if local production is observed for product j, inequality 4.10 provides an upper bound for the sunk cost related to switching production location. On the contrary, I production abroad is observed for product j, inequality 4.10 provides a lower bound for this sunk cost.

I observe either only the upper or lower bound of the sunk cost of switching production locations. I need to introduce an additional assumption to estimate this sunk cost. One can assume that the actual sunk cost for switching locations is equal to 80% of the upper bond or 120% of the lower bound estimated in

4.10. To identify how results may respond to changes stemming from these assumptions, I run a set of robustness checks where I vary the percentage of the sunk cost related to switching production location that is represented by the upper and lower bounds estimated in 4.10. These robustness checks suggest that the results are not significantly sensitive to changes to these percentages. Introducing this assumption allows us to estimate the sunk cost of switching production location using a partial identification model.

Table 9 reports some central tendency statistics for the lower and upper bounds for the sunk cost of switching production location before and after the introduction of local production policies. The statistics are computed across all phone types / month combinations. For feature phones, the median lower and upper bounds for the sunk cost of switching production location were $3,988$ USD and $35,376$ USD, respectively. The same dynamic can be observed for smart phones. The mean lower and upper bounds for the sunk cost of switching production locations were $5,092$ USD and $90,710$ USD, respectively.

4.3.4 Fixed Cost Estimation

Using the demand and marginal cost estimation results, and the production location decision, I obtain firm's participation incentive constraint represented by the bounds of the entry fixed cost for each phone - month combination observed in the data. After choosing the production location, firms will choose the set of products that maximizes their expected profit given demand and marginal cost shocks, the production location scheme, and competitors' product set.

To calculate the upper bound of product's $j \in J_{fm}$ fixed cost, I remove this item from the product set for firm f in market m and recalculate the expected profit, then compare the result with the firm's observed expected profit in the market m. Similarly, to estimate the lower bound for the product's entry fixed cost, I first record the last period when product $j \in J_{fg}$ was observed in the data and name it g. Then product j gets reintroduced in the firm f following period product set, J_{fg+1} and I calculate the firm's expected profit. Finally, I compare the difference between the expected profit after the reintroduction of product j into J_{fg+1} and the observed expected profit in market $g+1$. This procedure allows us to bound product j's entry fixed cost. Table 10 reports the average fixed cost bounds across all phone-types / month combinations after the introduction of the PMP.

Note that all the estimated bounds are higher for the alternative location when compared with the observed location. These results are consistent with the logic that firms will seek to allocate production where fixed costs are the lowest. The results suggest that the median fixed cost of introducing a product in the observed production location after introducing the PMP was between $236,586$ USD and $323,364$ USD in the case of feature phones and between $290,079$ USD and $596,067$ USD for smartphones.

5 Counterfactual Analysis

In this section, I run counterfactual simulations to address the research questions. In particular, I simulate the introduction of a tariff on phone components and evaluate how this policy affects consumer, producer, as well as total welfare. My results highlight how the introduction of this policy affects firms of different origins differentially. Next, I discuss the exercise and my key findings. All details of the counterfactual estimation exercise are provided in Appendix 1.

The counterfactual policy simulates the deferred phase of the PMP and consists of a 10% add-valorem im- port tariff on the display module. I intend to analyze how an increase in the cost structure of producing in India due to the counterfactual policy would determine firms' supply chain decisions and how those decisions would affect total welfare.

As mentioned before, introducing a tax on imported display modules would increase the cost of assembling a phone in India. Due to this increase in production cost, firms could choose to continue offering the affected product at a higher price, switch the production location outside of India to a country with lower production costs, or drop the product from their product set[12]. Modeling this decision-making process requires computing the post-tariff production location and product choice equilibrium. Doing so can be challenging since firms can decide to add or remove any subset of products, either observed or not, in the data set. Also, firms would have to decide the production location of any subset of the product offered in the market. This situation leads to a vast set of possible actions that the firm can take.

In my sample, between 2017 and 2018, there were 665 different models, on average, available in the market. Plus, the top 10 firms offered an average of 21 different products each month. This means that there are 2^{21} possible combinations of product sets for each of the ten leading firms. Additionally, each product can be produced either inside or outside India, extending the number of possible states observed in the market. Considering all the potential outcomes of the market is not computationally viable.

For this reason, to have a tractable model, I introduce two assumptions regarding how the firm's equilibrium product set and production location are computed. First, firms can add only products that have been observed in their product set between June 2017 and July 2018. Introducing this assumption means that the model rules out the possibility that firms introduce new models not observed in the sample. Second, firms can decide production location and add or remove one product at a time following a best-response-based heuristic algorithm, similar to the one proposed by (Fan and Yang, 2020) and (Lee and Pakes, 2009). This

[12]Since 2016 when the PMP was first introduced, the indigenous industry production process has included only components like chargers, adapters, wired handsets, and some die-cut parts in its production process. Initiatives to produce more complicated elements like mics and receivers, keypads, USB cables, and some internal mechanisms have failed, resulting in local firms importing the whole part and paying the tariff applied to such elements. Therefore, local manufacturing of sophisticated products may not be viable in the short run, leaving firms with the mentioned alternatives

procedure simulates the firm's decision-making process by allowing each firm to decide production location and the set of products offered to the market while considering its competitors' actions. The algorithm runs until no deviation from the last attained state implies an increase in the profit of any firm in the market.

The counterfactual policy could have a first-order effect on consumer surplus through an increase in the prices of products affected by the policy that results from either an increase in the production cost of Indian-produced products, an increase in production cost associated with switching production locations, or by the removal of products from the market. A second-order effect of the counterfactual policy involving consumer surplus happens through the increase in prices of products not affected by the policy, which results from the decay of competitive pressure due to either a removal of substitute products from the market or an increase in prices of substitute products affected by the policy. This means that assessing firms production decisions is key to understanding how the counterfactual policy may affect consumer surplus.

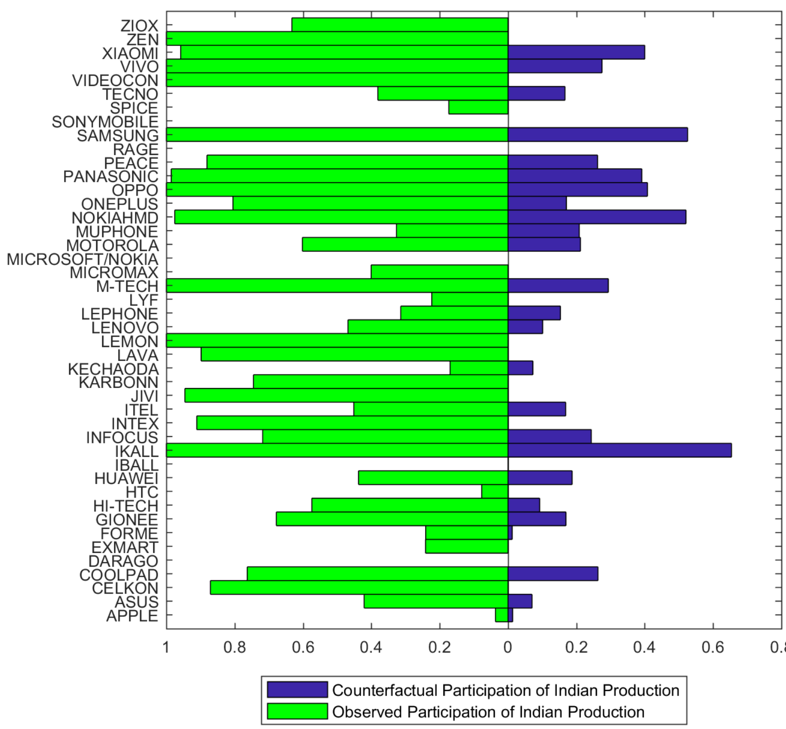
The results suggest that firms opt to relocate production of Indian-produced products outside of India, which implies a marked decrease in the proportion of products that are manufactured in India. If the ad-valorem tariff applies to the import of display modules, the proportion of products assembled in India falls from 62.2% to 15.1%. Firms would also opt to remove products that are no longer profitable due to the introduction of the import tariff on the display module. If the counterfactual policy were introduced, 139 feature phones models and 111 smartphone models would exit the market in the twelve months analyzed in the counterfactual.

In response to the policy, the firms would also decide whether to keep the production in India or switch production to locations outside India. My results suggest that the average marginal cost of products affected by the policy would increase by 1.7%. The increase in marginal cost for products that would switch production location from India to another country would be 1.9% while the increase for products for which production locatio would remain in India would be 1.1%. The marginal cost of imported ready-to-use phones would remain unchanged since the counterfactual policy does not affect these products.

As a consequence of the increase in marginal costs, the average price for all products in the sample in the mentioned period would increase on average by 0.91% and the number of phones sold in the market would decrease by 0.94%. As a consequence of the increase in prices and the exit of some products from the market, total consumer surplus would decrease by 54.2 million USD while producer surplus would increase by 2.8 million USD, which suggests that the counterfactual policy would decrease total welfare by 51.4 million USD. Table 11 presents the results from the counterfactual exercise in terms of total welfare.

Since the counterfactual policy aims to incentivize investment in the Indian phone manufacturing industry, assessing how firms from different origins react to the policy is of great value. In the observed data, 72% of Indian firms' products were assembled in India, with the remaining 28% imported as ready-to-use, which is the largest proportion of Indian-produced products across all firms' origin categories. Global firms followed, with 66% of their products being assembled in India. Finally, China assembled 52% of the products in India and imported the rest. The simulation results suggest that due to the introduction of the tariff on imported display modules, most firms in the market decided to change production location from India to outside India. Figure 5 shows the comparison between the observed and counterfactual proportion of Indian produced phones for each firm.

Figure 2: Change in the proportion of products produced in India. Observed versus Counterfactual Scenario.

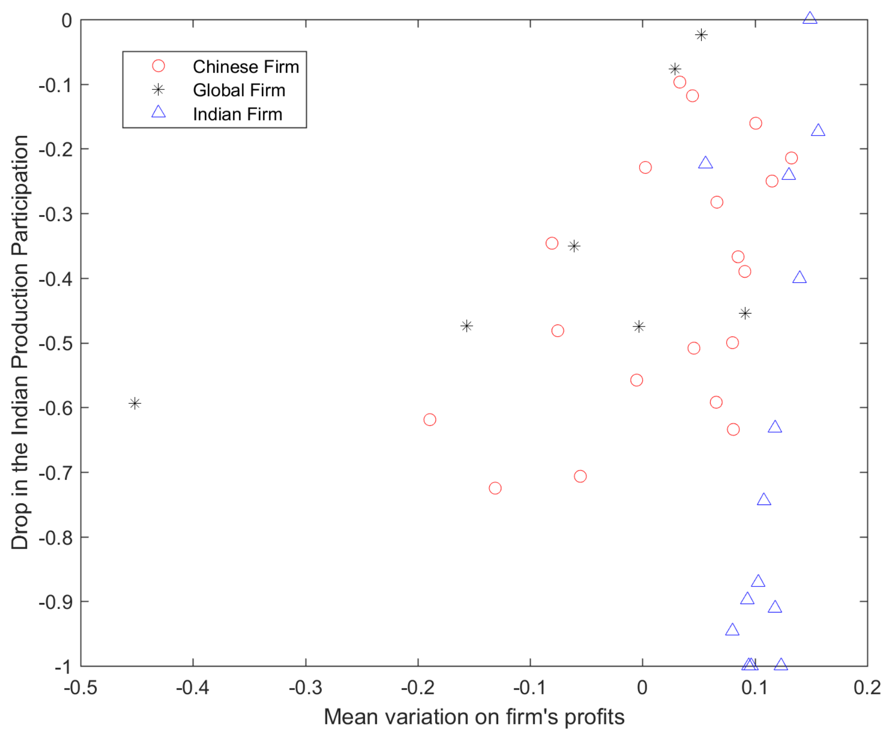


Note: This figure plots the observed and simulated mean proportion of Indian produced products for all firms in the sample.

This strategy is especially salient in the case of Indian firms, where the proportion of Indian-produced phones dropped to almost 0%. In the case of global firms, the proportion of products produced in India dropped from 66% to 32%, and for Chinese firms, from 52% to 20%. Figure 5 depicts that for Chinese and global firms, there is a positive correlation between the proportion of Indian produced phones that were dropped and changes in profits. Specifically, firms in these two groups that significantly switched production locations from India to abroad experienced a drop in their profit. This correlation is not present in the case of Indian firms, which suggests that these firms were less affected by the change in production location.

Specifically, firms in these two groups that significantly switched production locations from India to abroad experienced a drop in their profit. This correlation is not present in the case of Indian firms, which suggests that these firms were less affected by the change in production location.

Figure 3: Comparison of firm's drop in the proportion of products produced in India versus firm's mean market share and firm's origin.

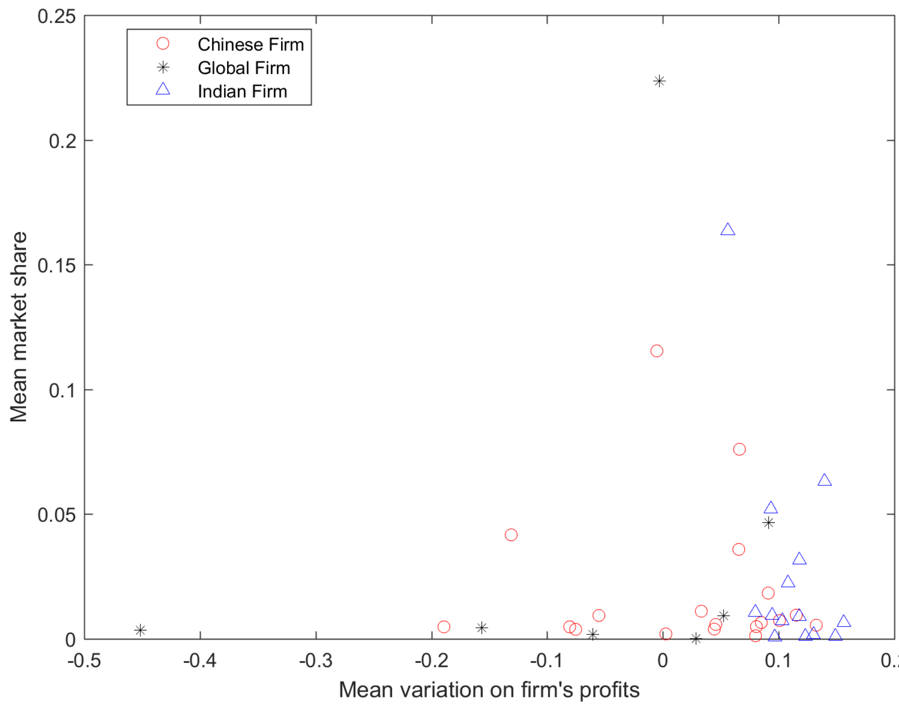


Note: This figure plots the mean variation on firm's profit against the drop on the firm's proportion of Indian produced products. Different types of markers and colors represents different firms' origins.

Figure 5 also suggests that, although profits across firms remain mostly unchanged, Chinese and global firms would have been at a disadvantage if the last stage of the PMP had not been postponed. With this postponement, the profit for these firms would have remained unchanged. In contrast, the policy would have benefited Indian firms whose profit would have increased by 8%. It is important to mention that the effect of the policy seems not to be correlated with a firm's size. Figure 5 presents the relationship between firms' origins, firms' variation in profits, and firms' market shares.

These results are consequential with the cost structure coming to form the supply estimation. On the

Figure 4: Comparison of Firm's Mean Variation in Profit versus Firm's Mean Market Share and Firm's Origin.



Note: This figure plots the mean variation on firm's profit against the firm's market share. Different types of markers and color represents different firm's origins.

one hand, the difference in the marginal cost of producing a phone in India or abroad is slim for firms of all origins. On the other hand, the median upper bound for the sunk cost of switching production locations is less than one hundred thousand dollars for smartphones and forty thousand dollars for feature phones. This situation implies that switching locations will not mean a considerable increase in the cost structure for the firms in the market. This reality led firms to mostly change production location to avoid the harmful effects of the import tariff imputed to phone components without this implying significant changes in the market.

Another option available to firms facing the import tariff on display modules is to stop producing phones whose cost increased due to the tariff and would be no longer profitable. The results from the counterfactual exercise suggest that out of the 250 products that would exit the market in the 12 months analyzed, Chinese firms would contribute 133 products; global, 111 products; and Indian firms only six. It is worth mentioning that the mean characteristics of the products that would exit the market as a consequence of the domestic industrial policy have different characteristics from the mean characteristics of products observed in the sample. For instance, the mean price of the group of smartphones that would leave the market is 50 USD lower than the mean price for smartphones observed in the sample. However, smartphones leaving the market have better features that the sample's average smartphone. In the case of feature phones, the results are different. The feature phones that would exit the market are 2 USD cheaper and present lower characteristics than the average feature phone. This situation suggests that the products that would leave the market are high-quality cheap smartphones and low-quality cheap feature phones.

That cheap and high-quality smartphones would exit the market could further affect consumer surplus since it may make access to smartphones difficult for low-income consumers. Table 12 presents a comparison between the characteristics of the average smartphone and feature phone and the average smartphone and feature phone that would exit the market due to the taxation of imported display modules.

Firms could use a third strategy to continue offering the affected product at a higher price. Chinese firms use this strategy in the 43% of the products affected by the policy; global firms in 58% of the affected products; and Indian firms in less than 1% of its affected products. These results suggest that the increase in prices of Indian firms' products originated in a cost increase due to a change of production location. In contrast, the increase in prices of products offered by Chinese and global firms has its origins in the cost increase of producing in India due to the import tariff and the cost increase due to switching production location.

6 Conclusion

Boosting local production of manufactured goods has recently become a popular policy for both developed and developing countries. Policymakers have justified instituting these policies by arguing that relying on a foreign supply chain may distort local markets. Also, domestic industrial policies can potentially generate high-paying local jobs, improve local added value, increase exports, and increase domestic capital investment. While these positive effects of a domestic manufacturing policy are easily identifiable and measurable, their application can lead to short-run costs, especially if considering introducing import tariffs. This document seeks to quantify the costs associated with the loss in total welfare resulting from implementing a domestic industry that aims to improve the local supply chain. Specifically, the paper analyzes a natural experiment in the Indian Mobile Phone Industry where import tariffs were applied to ready-to-use phones in a first instance and to phone components in a second instance. This last policy, named the Phased Manufacturing Program, seeks to incentivize the development of the domestic supply. To this end, I propose a three-stage static demand and supply model that aims to represent firms' decision-making process regarding alternative supply chains. Mainly, the proposed framework allows firms to endogenously choose their product set, production location, and prices.

After estimating the model, I conducted counterfactual simulations that aimed to mimic the deterred phase of the PMP that was supposed to come into effect in 2018 and 2019. Here, the display module of locally manufactured products will include an ad-valorem tariff of 10%. My counterfactual shows that if the last phase of the PMP had not been halted, production in India would have fallen significantly, prices of mobile phones would have increased slightly, the number of available products would have decreased, and consumers' surplus would have dropped. It is essential to mention that the model assumes that, in the short run, local firms may not be able to invest in developing their production process to incorporate the production of sophisticated parts like camera modules and displays.

The results of the counterfactual exercise suggest that, in the context of a rigid short-run production process, a domestic industrial policy based on imposing import tariffs on phone components not only fails to contribute to the local supply chain but, to the contrary, will undermine local production. This unintended consequence occurs because the increase in production costs due to the introduction of the tax on imported components causes that importing ready-to-use phones becomes profitable to firms compared to assembling them in India. Consequently, the policy will decrease manufacturing jobs in the local industry resulting in a decrease in total welfare.

In addition, the costs of introducing the domestic industrial policy described in the PMP would imply a decrease in the number of products available in the market and an increase in the prices faced by consumers. However, given the high degree of substitutability among products and the competitiveness in the market, the cost associated with the reduction in consumer welfare is not significantly high. Finally, noteworthy is that the smartphone products exiting the market would present higher quality than the average smartphone in the sample, further affecting consumer surplus.

Table 5: Demand Estimates

	OLS	2SLS	BLP
Random Coefficients			
Price X Income			-2.31**
			(0.05)
Constant			3.81**
			(0.60)
Main Camera			0.05**
			(0.02)
Front Camera X Smartphone			0
			(0.02)
Mean Coefficients			
Price Sensitivity	-0.00**	-0.00**	11.27**
	(0.00)	(0.00)	(0.36)
Constant	-3.13**	-3.01**	7.68**
	(0.24)	(0.29)	(1.06)
Main Camera	-0.03**	-0.03**	0.13**
	(0.01)	(0.01)	(0.02)
Front Camera X Smartphone	0.04**	0.04**	0.06**
	(0.01)	(0.01)	(0.02)
Screen Size	-0.25**	-0.24**	0.98**
	(0.03)	(0.03)	(0.13)
Internal Memory X Smartphone	-0.00**	-0.00	-0.01**
	(0.00)	(0.00)	(0.00)
RAM X Smartphone	-0.12**	-0.11**	0.55**
	(0.03)	(0.03)	(0.07)
Battery Size X Smartphone	0.24**	0.24**	0.33**
	(0.07)	(0.07)	(0.13)
Age of Operating System	-0.03**	-0.03**	-0.02**
	(0.00)	(0.00)	(0.00)
Smartphone Dummy	-4.26**	-4.29**	-3.56**
	(0.51)	(0.52)	(1.02)
Android F.E.	1.36**	1.36**	1.81**
	(0.14)	(0.14)	(0.25)
Three G F.E.	-0.16**	-0.17**	0.65**
	(0.07)	(0.07)	(0.11)
Four G F.E.	0.21**	0.21**	1.77**
	(0.08)	(0.08)	(0.18)
No. of Markets	41	41	41
No. of Observations	22,318	22,318	22,318
Objective function			434

Notes: Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6: Estimated demand elasticities for top 10 products

	LF 2403*	F90*	F120*	Y71	5A	105DS	NOTE	A83*	J6	LF 240*
Own Price Elasticity	-4.41	-4.43	-4.73	-6.78	-7.03	-5.10	-4.77	-6.41	-4.86	-5.014

Note: All elasticities correspond to the last month in the data, May 2018. Product shown correspond to the top 10 most sold products
* represents feature phones

Table 7: Supply Estimates

Variable	Coefficients	Variable	Coefficients
Log Front Camera	0.05**	Log Quantity	-0.04**
	(0.01)		(0.01)
Log Main Camera	0.09**	Chinese firm - abroad	2.99**
	(0.01)		(0.08)
Log Screen Size	0.83**	Chinese firm - India	3.00**
	(0.02)		(0.08)
Log Battery	0.06**	Indian firm - abroad	3.19**
	(0.01)		(0.13)
Log Ram X Smartphone	0.39**	Indian firm - India	3.22**
	(0.02)		(0.13)
Log Internal Memory	0.11**	Global firm - abroad	3.02**
	(0.01)		(0.07)
Age of Operating System	0.00**	Global firm - India	3.03**
	(0.00)		(0.07)
3G tech	0.12**	Indian product - 2016	-1.19**
	(0.01)		(0.10)
4G tech	0.22**	Indian product - 2017	-1.04**
	(0.02)		(0.10)
Feature phone Dummy	-0.33**	Indian product - 2018	-1.01**
	(0.02)		(0.11)
Hybrid phone Dummy	-0.24**	Imported product - 2016	-1.16**
	(0.04)		(0.10)
Flagship Model	0.17**	Imported product - 2017	-1.00**
	(0.01)		(0.10)
Time Trend	-0.01**	Imported product - 2018	-0.96**
	(0.00)		(0.11)
No. of Markets		41	
No. of Observations		22,318	
Objective function		434	

Notes: Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{**}p < 0.1$.

Table 8: Variation of marginal cost explained by firm and product origin by year.

Firm origin	Production location	2015	2016	2017	2018
Chinese	India	3.00	1.80	1.96	1.99
	Imported	2.99	1.82	1.99	2.03
Global	India	3.03	1.83	1.99	2.01
	Imported	3.02	1.86	2.02	2.06
Indian	India	3.22	2.03	2.19	2.21
	Imported	3.19	2.03	2.19	2.23

Note: This table presents the summation of the firm origin - production location fixed effects and the production location - year fixed effects. Note that 2015 is omitted in the production location - year fixed effects; therefore, the first column shows only the coefficients for firm origin - product origin fixed effects.

Table 9: Estimated bounds for switching production location sunk cost (Thousands of USD)

	Min	Median	Mean	Max	Std. Dev.
LB Feature Phones	0.55	3.99	13.12	257.37	35.17
UB Feature Phones	0.12	35.38	92.86	2,785.22	190.34
LB Smartphones	0.58	5.10	32.61	684.49	95.04
UB Smartphones	397.86	90.71	252.36	3,874.84	356.12

Note: This table shows the summary statistics for the sunk cost of switching production locations' upper and lower bounds. It considers all the observations after March 2017 when the PMP was introduced.

Table 10: Bounds for fixed cost in different locations

Observed production location (Millions of USD)			
		Mean	Median
Feature Phone	Lower Bound	0.64	0.24
	Upper Bound	1.07	0.32
Smart Phone	Lower Bound	2.89	0.29
	Upper Bound	2,90	0.60
Alternative production location			
		Mean	Median
Feature Phone	Lower Bound	0.64	0.35
	Upper Bound	1.05	0.31
Smart Phone	Lower Bound	3.30	0.67
	Upper Bound	2.81	0.60

Note: This table presents the upper and the lower bound of the fixed cost related to introducing a new product into the market. Observed and Alternative locations can refer to India and production abroad, depending on where production is observed in the data.

Table 11: Welfare effect of a 10% tax on imported display modules

Percentage change					**Level change Millions of USD**	
Marginal Cost	Price	Quantity	Indian Produced Proportion	Ready-to-use Proportion	Total Consumer Surplus	Total Producer Surplus
0.96%	0.91%	-0.94%	-47.1%	47.0%	54.2	2.8

Note: This table shows the average variation in marginal cost, prices, proportion of products produced in Indian and ready-to-use phone imports. Also shown is the level increase in total consumer surplus and total producer surplus. The simulation considers a 10% ad-valorem import tariff on the display module. The counterfactual scenario assumes a sunk cost of switching locations equal to 1.2 times its lower bound and 0.8 times its upper bound. All simulations correspond to the last 12 months of the data.

Table 12: Comparison of the Mean Characteristics Between Observed Products and Discontinued Products

	Price USD	Front Camera Megapixels	Main Camera Megapixels	Screen Size Inches	Battery Size Thousand mAh	Ram GB
Smartphone						
Observed Products	230.5	6.2	9.7	5.1	2.8	2.4
Removed 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
Removed Products	13.1	0.0	0.3	2.0	1.3	NA

Note: This table shows the comparison of the mean characteristics of observed products and products that exited the market due to the domestic industrial policy. The top panel makes the comparison among smartphones, while the bottom panel compares feature phones.

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7 Appendix 1: Counterfactual Estimation

This appendix presents a detailed description of each of the steps used in the counterfactual estimation.

7.1 New price equilibrium

To introduce the tariff in the cost structure of a specific cellphone model, I identify the contribution of the camera component to the marginal cost using the supply estimation. Given the logarithmic shape of the marginal cost, the marginal contribution to each component is easy to compute. Having calculated the marginal contribution of the display module to the marginal cost, a 10% increase is applied to simulate the rise in the component's price due to the introduced tariffs.

$$\frac{\delta MC_{jm}}{\delta k} = MC_{jm} \frac{\gamma_k}{\sum_{g \in \omega_{jm}} \gamma_g} \quad \text{where} \quad k \in \omega_{jm}+ \tag{7.1}$$

Using the specification for marginal cost presented in equation 4.10, it is possible to compute each product feature's contribution to its marginal cost by taking the derivative of the marginal cost with respect to each product feature. Equation 7.1 shows the marginal contribution of the characteristic k of product j to its marginal cost measured in USD. This expression suggests that the coefficients vector γ work as weights for the contribution of each characteristic to the marginal cost. This functional form allows us to compute the counterfactual marginal cost for the firms affected by the simulated tariff. This can be achieved by multiplying the variation of the camera module cost by the marginal contribution of this feature to the marginal cost represented in equation 7.1.

I calculate a new equilibrium price vector using a fixed point algorithm with the counterfactual marginal costs at hand. Then, I set the initial price vector equal to the marginal cost and iterate over market shares and prices until a fixed point is reached where market shares and prices are in equilibrium.

7.2 Production location scheme

Each firm production location scheme depends on the new equilibrium price vector, which is a function of competitors' production allocation. After observing the counterfactual marginal cost and the new equilibrium price vector, firm f computes the variable profit for both possible production locations for product j. Suppose the difference in the expected variable profit from the alternative location and the observed location is greater than the upper bound for the sunk cost of switching the production location. In that case, the production will move from the observed location to the alternative site.

In this exercise I assume that the new tariff on camera modules applies only to devices assembled in India. In the case of imported devices, the marginal cost does not suffer any change. Note that if a firm decides to produce a specific product abroad, its decisions will not change once the counterfactual tariff on imported components of phones assembled in India is implemented. This affirmation is based on the fact that if firm f decides to import product j given the observed local cost structure, it will continue to import good j once the cost structure of producing in India increases due to the tariff. Under these circumstances, the only possible change in production allocation will have to be from production in India to production abroad. In this case, firm f will produce product j abroad if:

$$[\pi_f(L_j^A(\vec{p}_{cf}), \xi, \omega)] - [\pi_f(L_j^L(\vec{p}_{cf}), \xi, \omega)] > SC(L_j^L) \tag{7.2}$$

In the last expression, for simplicity I drop the market subscript. Here, $L_j^A(\vec{p}_{cf})$ is the location scheme for all products observed in the market with product $j \in J_f$ is produced abroad and L_j^L is the location scheme where $j \in J_f$ being produced locally. Here, the location scheme depends on the equilibrium price vector. Note that $L_j^A(\vec{p}_{cf})$ and $L_j^L(\vec{p}_{cf})$ are identical, except for location j which represents product j's production location. Equation 7.2 suggests that firm f will prefer to produce product j abroad if the difference between the two locations' variable profit is greater than the sunk cost related to switching production.

7.3 Product set

The algorithm proposed to compute the counterfactual product set can be divided into two different steps, the first where firms decide production location, and the second where firms choose their product set. To illustrate how this procedure works let's take firm f which operates in market m. I will define $\hat{J}_f$ as firm f's set of potential products. As a starting point I use firm's f observed product set which depends on the production allocation scheme such that $J_{fm}(L_{fm}) \subseteq \hat{J}_f$.

In the first step, firm f will define its product allocation scheme for each product. Let's use product $j \in \hat{J}_f$ as an example. First, I compute the counterfactual profits for firm f in market m using the observed product set and production allocation. Then I calculate the counterfactual profit $\pi_{fm}^c(L_m)$ and $\pi_{fm}^c(L_{m|j})$

which uses the observed product set and a new production allocation where product j switched production location. If the difference between the two counterfactual profits is greater than the estimated sunk cost for switching the production location of product j, then the production allocation for j is switched. This operation is repeated for all products $j \in \hat{J}_f$.

In the second step, I use the counterfactual production allocation for firm f denoted by (L_f^*) and compute the baseline counterfactual profit $\pi_{fm}^c(L_m^*)$. I start by assuming that the baseline profit is the highest possible profit that firm f can reach by deviating from the observed set of products, then $\pi_{fm}^c(L_m^*) = \pi_{fm}^{*c}$. Now I take one-step deviations from the observed product set J_{fm} such that the new product set J_{fm}^c results from either adding or deleting one product at a time. I then compute firm f's profit resulting from the deviation denoted by π_{fm}^d. If $\pi_{fm}^d < \pi_{fm}^{*c}$ the process stop, and I am back to π_{fm}^{*c} as the highest possible profit. If to the contrary, $\pi_{fm}^d > \pi_{fm}^{*c}$ then J_{fm}^c is the new baseline product set and the highest possible profit for firm f is updated to be equal to π_{fm}^d. The next step is to take one-step deviations from the current product set J_{fm}^c and repeat the loop until no deviation yields a higher payoff. Once no deviation has been observed for firm f, I move to the next firm and repeat this procedure. Finally, the procedure keeps looping over firms until there is no deviation of neither the firms' product set or production allocation schemes.

8 Appendix 2: Counterfactual robustness check

This section shows results from the three counterfactual exercises described in Section 5, assuming that the actual sunk cost of switching production locations equals 90% of the upper bound and 110% of the lower bound. The welfare measures presented in table 13 suggest that there is no significant difference in using different assumptions for the estimation of switching production sunk cost. However, the results concerning the proportion of phones that would be manufactured in India presented in table 13 do change. The main reason is that if the sunk cost of moving production to India is high, more firms will find it more profitable to produce abroad. This means that, in general, my estimation may be conservative given that the counterfactual presented in Section 5 considered a smaller sunk cost of moving production to India, but the main result holds: not deferring the last phase of the PMP would have resulted in a decrease in the proportion of phones manufactured in India.

Table 13: Counterfactual Results: Welfare

Tariff on	Marginal Cost	Average Price	Avg. Consumer Surplus	Total Consumer Surplus	Total Producer Surplus
	Percentage change				
Front Back Camera	0.17%	0.4%	-0.4%	-0.7%	-0.3%
Display	1.26%	1.2%	-0.4%	-1.6%	1.2%
Front Back Camera + Display	1.39%	1.3%	-0.4%	-1.6%	1.3%

Note: This table shows the average variation in marginal cost, prices, consumer surplus, total consumer surplus, and total producer surplus for three different simulations. The first simulation considers a 10% ad-valorem import tariff on the back and front camera module. The second simulations consider a 10% ad-valorem import tariff on the display module. The last simulation consists of a 10% ad-valorem import tariff on the camera and display modules. All the counterfactual scenarios assume a sunk cost of switching locations equal to 1.1 times its lower bound and 0.9 times its upper bound. All simulations correspond to the last 12 months of the data.

Table 14: Counterfactual Results: Production in India

	Percentage change		**Number of Removed Products**	
Tariff on	Quantity	Indian Produced Proportion	Feature Phone	Smart-Phone
Front Back Camera	-0.3%	-19.3%	25	124
Display	-1.2%	-57.1%	194	182
Front Back Camera + Display	-1.2%	-59.9%	213	196

Note: This table presents the average variation in the number of units sold in the market, the proportion of local production, and the number of feature phones and smart phones that exit the market in each scenario. The first simulation considers a 10% ad-valorem import tariff on the back and front camera module. The second simulations consider a 10% ad-valorem import tariff on the display module. The last simulation consists of a 10% ad-valorem import tariff on the camera and display modules. All the counterfactual scenarios assume a sunk cost of switching locations equal to 1.1 times its lower bound and 0.9 times its upper bound. All simulations correspond to the last 12 months of the data.