Who Bears the Costs of Technology Sanctions? Evidence from Global Smartphone Markets*

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Abstract

U.S.–China trade tensions have led to sanctions on major Chinese firms, with potential spillovers to third-country markets. We study the effects of U.S. restrictions on Huawei's access to key U.S. technologies in smartphone markets in the United States and Europe. Using product-level data, we show that the sanctions substantially reduced Huawei's sales and prices, consistent with a negative demand shock. To quantify equilibrium effects, we develop a differentiated-products oligopoly model in which the sanctions degrade two key Huawei product attributes: access to Google Mobile Services and 5G chipsets. We find that the sanctions were effective in reducing Huawei's profits, despite its divestiture of Honor to mitigate losses. While U.S. consumers are largely unaffected, European consumers experience considerable welfare losses. These findings indicate that firm-targeted sanctions can shift welfare losses away from the sanctioning country and onto third-country consumers.

Keywords: Trade Shocks, Smartphone Industry, Demand Estimation

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1 Introduction

Trade tensions between the United States and China have become a defining feature of the global economic landscape. Beginning in 2018, the U.S. government imposed a series of tariff and non-tariff measures on Chinese goods and firms, motivated by concerns over intellectual property and unfair trade practices. A growing literature has documented the direct impact of tariffs on U.S. industries; see for example Cavallo, Gopinath, Neiman, and Tang (2021). In contrast, much less is understood about the consequences of firm-targeted non-tariff sanctions—particularly their indirect effects on third-country markets through global supply chain disruptions and competitive interactions. To address this gap, we study U.S. blacklisting sanctions imposed on Huawei, a major firm in the global smartphone industry. Specifically, we ask whether these sanctions were effective in reducing Huawei's profits, and whether they hurt U.S. consumers or instead shifted the costs onto consumers in other countries.

The telecommunications industry has been one of the primary targets in the U.S.-China trade conflict, alongside industries such as steel, solar panels, energy, and soybeans. In May 2019, as the trade war intensified, the Chinese telecommunications corporation Huawei and its 68 affiliates were added to the U.S. Entity List. The U.S. Entity List identifies foreign entities and individuals deemed to pose a national security or foreign policy risk, thereby prohibiting U.S. companies from exporting or transferring sensitive technologies to them without a specific license. As a result of these sanctions, Huawei and its sub-brand Honor faced significant restrictions. First, their ability to use the Android operating system (denoted hereafter as OS) was curtailed, preventing newly released Huawei smartphones from pre-installing Google Mobile Services (hereafter GMS). Second, Huawei and Honor were denied access to 5G chipsets, which rely heavily on U.S. technology and materials. Beyond the immediate supply disruptions, the sanctions triggered a broader strategic reorientation within Huawei. Huawei accelerated the development of its own operating system (HarmonyOS) and app ecosystem, while simultaneously attempting to reconfigure its access to advanced chipsets under tightening export controls *[The Economist (2019), Reuters (2024)]*.[1] These efforts aimed to mitigate long-run dependence on U.S. technologies, but also fundamentally altered consumer perceptions of product quality and ecosystem compatibility. As a result, the U.S. restrictions are likely to affect firms and consumers beyond the directly involved countries, influencing not only competition between smartphone manufacturers but also consumer welfare.

To evaluate the effects of the U.S. trade sanctions, we focus not only on the U.S. smartphone market, but also on a large number of European countries, where Huawei was particularly prominent and still growing when the sanctions were initiated. Using product-level data at the quarterly level during 2010–2020, we

[1] References to media and industry sources are shown in square brackets and presented in Appendix's Table A.19.

proceed in several steps. In a first step, we provide reduced-form evidence by comparing Huawei's sales and prices before and after its placement on the U.S. Entity List to those of other Chinese firms. We find that Huawei's sales and prices declined by 74.1% and 19.5%, respectively, relative to other Chinese firms, such as OPPO, Vivo, and Xiaomi. These findings indicate that the sanctions primarily operated through a negative demand shock, likely reflecting Huawei's lost access to GMS and the anticipated disruption in access to 5G chipsets.

In a second step, we estimate a demand system with differentiated products, combined with an oligopolistic supply side. The model incorporates the main smartphone characteristics as determinants of consumer utility and marginal costs, including the key components affected by the sanctions: the availability of GMS and 5G. Our estimates indicate that consumers have high average valuations for Android OS (typically bundled with GMS) and 5G. Indeed, the estimated average consumer's willingness-to-pay for GMS is $55.9, and the estimated average willingness-to-pay for 5G compatibility is $275.7, highlighting the importance of the technological attributes targeted by the sanctions.

In the third step, we use the model to evaluate the effects of the U.S. sanctions on firms and consumers. We first confront the model predictions with the estimated changes around the event, and find that they are broadly consistent. We then consider several counterfactual scenarios: (i) Huawei loses access to GMS for all its existing products; (ii) Huawei additionally loses access to 5G chipsets for all its products; (iii and iv) Huawei divests Honor to partly circumvent the ban;[2] and (v) Huawei exits altogether, whereas Honor remains active.

We obtain the following findings. First, the sanctions imply substantial sales and profit losses for Huawei and its sub-brand Honor, indicating that the targeted sanctions are highly effective. Divesting Honor mitigates profit losses, but this effect is limited because of the competition Honor creates for Huawei. Second, Huawei's lost sales are mainly captured by other Android-based handsets and/or Chinese brands, notably Samsung and Xiaomi. The U.S. firm Apple benefits only modestly, suggesting that there is no immediate "industrial policy" motivation for the U.S. sanctions. Third, U.S. consumers experience negligible losses. In sharp contrast, consumers in European countries experience substantial losses, estimated at $1.31 billion when Huawei loses access to GMS and 5G for all its existing products; $0.75 billion if Huawei divests Honor; and $3.12 billion in a long-run scenario where Huawei entirely exits the market.

These findings show that the U.S. non-tariff trade sanctions were highly effective in reducing Huawei's sales and profits, while leaving U.S. consumers essentially unaffected. Instead, the economic costs are borne primarily by consumers in third-country markets, particularly in Europe, highlighting the international

[2] Scenario (iii) assumes Huawei and Honor continue to behave as a multiproduct firm after the divestiture, whereas scenario (iv) assumes they become competitors. These separate scenarios enable a decomposition of the divestiture effects into the benefits from regained access to Honor and the costs of competition.

incidence of firm-targeted technology sanctions.

Related literature Our paper relates to several strands of literature. First and foremost, a large literature examines the effects of trade tensions, with a recent wave focusing on the 2018–2019 U.S.-China tariff war. Most of this work documents its impact on the countries directly involved. A central finding is that the U.S. tariffs on Chinese imports were fully passed through to domestic prices and led to a sharp decline in Chinese imports into the United States, implying substantial losses for U.S. consumers (Amiti, Redding, and Weinstein, 2020; Cavallo et al., 2021; Fajgelbaum, Goldberg, Kennedy, and Khandelwal, 2020; Flaaen, Hortaçsu, and Tintelnot, 2020; Handley, Kamal, and Monarch, 2025). In contrast, much less attention has been paid to the consequences of trade tensions for uninvolved third-party countries. Existing contributions primarily analyze trade diversion across destinations following the introduction of tariffs, focusing on adjustments in trade flows and indicating the presence of positive spillovers (Jiang, Lu, Song, and Zhang, 2023; Benguria and Saffie, 2024). However, little is known about how trade tensions spill over to third countries through industry-specific competitive channels that shape the international incidence of trade policy. Our paper provides evidence on this mechanism by studying how firm-targeted technology sanctions affect competition and shift consumer welfare across countries.[3]

A limited but growing literature examines the industry-level consequences of trade policies, thereby shedding light on spillovers in globally integrated industries. Flaaen et al. (2020) study the U.S. washing machine market and show that large Asian firms could initially avoid anti-dumping duties by relocating their production to third countries. Miao (2024) analyzes dynamic competition in the global semiconductor industry under the risk of trade disruptions. Closer to our setting, Elsas-Nicolle (2025) examines the impact of the U.S.-China Trade War on the European smartphone market, using a reduced-form approach and focusing on the short-term effects of Huawei's blacklisting on prices. Our paper contributes to this literature by developing a structural model that explicitly incorporates the technological channels targeted by the sanctions (GMS and 5G chipsets), allowing us to quantify their effects on firm profits, market structure, and consumer welfare across third-party countries.

Second, several recent studies examine consumer and firm responses to product-related scandals and safety crises, providing useful benchmarks for understanding the impact of major adverse shocks. For example, Ferrer and Perrone (2023) study the costly impact of the French mad cow crisis when consumers have limited substitution possibilities. Other studies show how product-level demand shocks can spill over to other products and even other firms; see Freedman, Kearney, and Lederman (2012) on the 2007 wave

[3]There is also a growing literature on the impact of targeted, non-tariff sanctions, which typically focuses on various aspects of their effectiveness (e.g., Ahn and Ludema, 2020; Draca, Garred, Stickland, and Warrinnier, 2023) or on innovation responses by the targeted firms (Anwar, Hu, Luan, and Wang, 2024). This work also largely abstracts from how such sanctions spill over to competition and consumer welfare in third-country markets.

of toy recalls in the United States, and Bachmann, Ehrlich, Fan, Ruzic, and Leard (2023) on the 2015 Volkswagen emissions scandal. Overall, this literature emphasizes that adverse demand shocks, whether stemming from safety scandals or regulatory actions, can reshape market outcomes well beyond the directly affected products or firms. Our paper contributes to this strand by studying a trade-policy-induced shock that operates through both demand and supply channels, showing how policy shocks can affect not only the targeted firm but also its competitors and consumers in other markets through competitive interactions and global supply chain linkages.

Third, our paper relates to the recent literature on differentiated-product demand and competition in smartphone markets. Several papers estimate demand and markups to study the impact of patent infringements (Hiller, Savage, and Waldman, 2018), or the role of product variety (Fan and Yang, 2020) and the operating system (Grzybowski and Nicolle, 2021). More closely related to our study, Chatterjee, Fan, and Mohapatra (2024) develop a structural model of the Indian cell phone market that incorporates spillover effects from the roll-out of 4G networks to quantify the impact of various policies, including a ban on low-cost Chinese phones. Relying on a similar model and setting, Callejas, Chatterjee, and Mohapatra (2024) show how government tariff policies have promoted domestic mobile handset production in India. We contribute to this literature by evaluating the impact of actual trade restrictions that reshape competition and welfare across multiple countries in a global oligopoly.

The rest of the paper is organized as follows. Section 2 describes the industry background, as well as the U.S.-China trade conflict and the U.S. sanctions on Huawei. Section 3 describes the dataset, presents descriptive statistics, and provides preliminary reduced-form evidence on the impact of the sanctions on sales and prices. Section 4 develops our structural framework to obtain the demand and cost parameter estimates. Finally, section 5 presents the results from our counterfactual analysis. We conclude in Section 6.

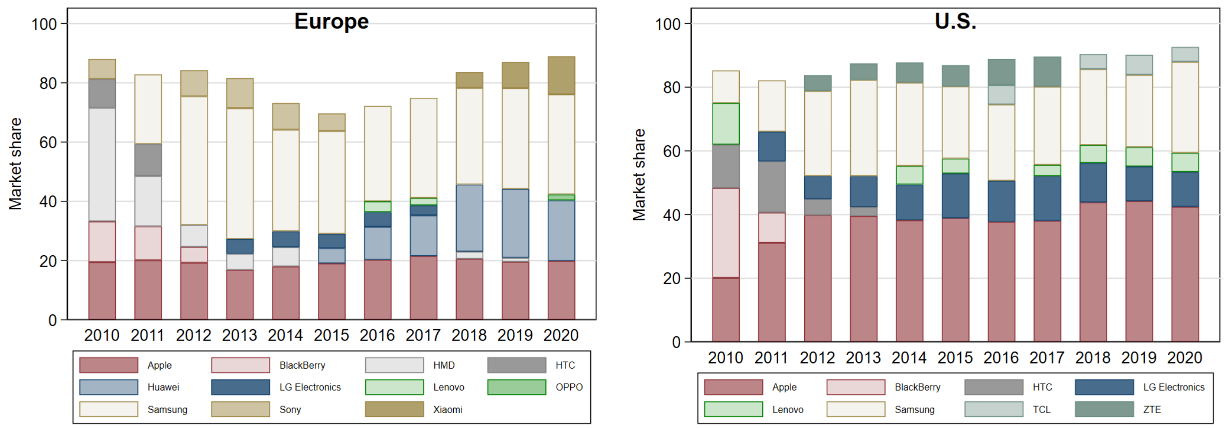
2 Industry background

We first discuss several key features of the global smartphone market, including the reliance of manufacturers on imported (often U.S.-based) technology. Next, we describe the trade sanctions imposed by the U.S. government on Huawei, with a focus on its smartphone business.

2.1 Global Smartphone Market

Leading players and rising competition from China The smartphone market is characterized by rapid technological change and intense competition. Figure 1 presents the evolution of the Top 5 manufacturers' market share in the U.S. and in Europe between 2010 and 2020, based on IDC's *Worldwide Quarterly*

Figure 1: Market Share of the Top 5 Smartphone Brands in Europe and the U.S.



Note: Data cover the period from 2010 to 2020.

Mobile Phone Tracker (described further in the data section). In both regions, Apple and Samsung have been leading players. In the U.S., their average annual market shares were 37.6% and 23.3%, respectively. In Europe, Samsung's market share was even larger, while Apple's share was considerably lower. Both companies benefit from strong brand reputation, innovation, and diverse product portfolios.

A notable recent trend in European markets has been the rise of Chinese manufacturers, in particular Huawei, whose market share rose from about 5.1% in 2015 to a peak of 23.2% in 2019. This growth was driven by Huawei's competitive pricing, strong marketing strategies, and advanced technology. Europe quickly became Huawei's second-largest market, especially in Central and Eastern Europe, as shown in Figure A.1 of the Appendix. In contrast, Huawei had a small presence in the U.S. market, with an average market share of just 1.2%. Its European market share still shows notable variation across European countries, as illustrated in Figure A.2 of the Appendix. In China, both Apple and especially Samsung have been relatively small during the period 2010 to 2020. In contrast, Huawei showed a strong increase in its market share, from about 14.6% in 2015 to 44.1% in 2020 (see Figure A.7, also presented in the Appendix).

These market shares highlight Huawei's considerable exposure to the risk of U.S. trade sanctions in its European markets, in contrast to its limited exposure in the U.S. Exposure is also limited in China, where Google services are already partially blocked and therefore cannot be targeted by trade sanctions.

Reliance on imported (U.S.) technology Smartphones rely on several crucial components. While some are produced "in-house" by manufacturers, others are sourced from a global network of suppliers. Figure A.4, in the Appendix, presents an overview of the interdependencies between these components.

Regarding software, smartphones rely on a mobile operating system (OS). Apple uses its proprietary OS, named iOS, while most other manufacturers rely on Google's open-source Android OS. Operating systems are closely connected to their app stores: iOS users download apps from the App Store, while Android users use Google Play. To access Google Mobile Services (GMS), such as Google Play, YouTube, Google Maps, and Gmail, manufacturers must sign agreements with Android – the Mobile Application Distribution Agreements.[4] These agreements provide a license to pre-install Google apps. In return, manufacturers must meet certain requirements, such as the placement of these apps on the devices and the default status of Google Search and Chrome. For a detailed institutional description of the contractual framework, see Etro and Caffarra (2017).

Regarding hardware, various essential components, such as memory and wireless communication chips, image sensors, or chemicals to strengthen the screen glass, are typically sourced from a few companies, including Qualcomm, MediaTek, Broadcom, and TSMC *[Counterpoint Research, 2025]*. Smartphone manufacturers are highly dependent on these suppliers due to the complexity and technical specificity of these parts. Although alternative suppliers are available, their products often fall short in quality, which poses challenges in a highly competitive market. Trade tensions thus clearly have the potential to weaken firms relying on these technologies. We discuss these elements further in the next section.

2.2 U.S. – China Trade Conflict and Sanctions on Huawei

Already during the 2016 presidential campaign, Donald Trump criticized several existing trade agreements and promised to restore U.S. manufacturing jobs that had been lost to countries like China and India. One year into his first term, he intensified these efforts, particularly toward China, by threatening substantial fines for alleged intellectual property theft and imposing substantial tariffs. In response, China imposed a 25% tax on more than 100 American goods.

Against this background of trade tensions, the U.S. government expressed increasing concerns about Huawei's activities in telecommunications, arguing that they posed threats to national security and foreign policy interests. In May 2019, the U.S. Bureau of Industry and Security put Huawei and its 68 non-U.S. affiliates on its Entity List, thereby restricting U.S. companies from supplying hardware or software to Huawei without a special license. Figure A.3 presents a timeline of the main events.

The restrictions cut off Huawei's access to U.S. technology, affecting multiple parts of its business (such as 5G infrastructure), but particularly its global smartphone business. On the software side, as soon as the restrictions took place, Google was prohibited from collaborating with Huawei on new device models. As a result, Huawei lost access to the above-discussed GMS, preventing the pre-installation of Google apps on its

[4] Manufacturers that do not sign these agreements can still use the *bare* version of Android - potentially developing a forked version.

new Android phone models.[5] Models launched before May 2019 continued to operate as usual and receive updates. In response to the ban, Huawei developed its own ecosystem, Huawei Mobile Services, but also launched HarmonyOS, its proprietary operating system, to reduce reliance on Android *[Bloomberg, 2019; Reuters, 2019a]*. Yet, many Android apps that require Google's support are incompatible with the newly developed platform, diminishing its attractiveness to consumers.

On the hardware side, Huawei faced a disruption in the supply of System-on-Chips (SoCs).[6] Press coverage at the time highlighted widespread uncertainty about whether Huawei could regain access to cutting-edge 5G chipsets, given its dependence on U.S.-controlled manufacturing equipment and design software *[Reuters, 2019b, 2020]*. Indeed, Qualcomm and other U.S. chip manufacturers could no longer supply SoCs to Huawei. In addition, the Taiwanese company TSMC and the Chinese company SMIC had to refuse new orders from Huawei due to their reliance on U.S. equipment and raw materials. The Dutch company ASML was also pressured to cancel its sales to SMIC. The hardware restrictions did not affect Huawei immediately and abruptly, as it continued to produce 4G smartphones.[7] For 5G devices, Huawei has been more severely affected. It could initially rely on existing inventories of compatible modems, but was unable to continue supplying 5G smartphone devices afterwards. As a result, the latest models from Huawei, including the Mate 50 series launched in September 2022, the Nova 10 series from July 2022, and the newly released P60 series in March 2023, lack the capability to connect to 5G networks *[Huawei, 2023]*. In the longer run, Huawei reoriented its semiconductor strategy, intensifying collaboration with domestic partners and exploring constrained production pathways to mitigate its loss of access to U.S.-linked technologies *[Financial Times, 2023]*.

Honor, a brand of Huawei, was also affected by the restrictions, despite having some autonomy. To keep Honor's smartphone business alive and allow it to access U.S. suppliers and components, Huawei sold Honor to Shenzhen Zhixin New Information Technology in November 2020 *[Huawei, 2020]*. This released Honor from restrictions imposed by the U.S. sanctions. Some of Honor's models have been confirmed to ship with GMS since 2021.[8]

Overall, these developments likely led to a significant deterioration in Huawei's reputation in Europe. The sudden loss of access to key U.S. technologies (most notably GMS and 5G chipsets) raised concerns

[5]For new models launched after the ban, users could not simply install the Google Play Store themselves, because GMS requires Google certification at the system level. Without the Google Play Store, users also lost access to the full suite of official Google applications.

[6]A SoC is a crucial smartphone component that combines a CPU, GPU, modem, and other chips to interact with standard hardware components such as the screen, battery, camera, and microphone.

[7]From September 2020 to April 2021, about 69% of export licenses to Huawei were permitted, and Qualcomm was allowed to sell 4G mobile phone chips to Huawei. Intel, AMD, and Nvidia were also allowed to sell PC chips to Huawei.

[8]The models are the following: Honor 50 (2021 June), Honor 50 Lite (2021 Oct), Honor Magic4 Pro (2022 Feb), Honor X7 (2022 Mar), Honor X8 (2022 Mar), Honor X9 (2022 Mar), and so on. See *[Honor, 2024]*. As a result, Honor has begun to regain market share in Europe, after a significant decline from 7% in Q1 2019 to just 0.5% in Q3 2021. By Q1 2024, its share had recovered to 4% *[Statista, 2025]*

among European consumers about the usability and future viability of Huawei devices. At the same time, the intensification of U.S.-China trade tensions and the framing of Huawei as a national security risk increased political and regulatory pressure on European governments and telecom operators, many of which subsequently excluded Huawei from 5G network deployments *[The Economist, 2019; The Guardian, 2020]*.

3 Data and Reduced-Form Evidence

We first introduce our main dataset and provide descriptive statistics. We then present reduced-form evidence on how Huawei's placement on the U.S. Entity List affected its prices and quantities sold. This analysis offers initial insights into whether the event primarily constituted a demand shock, a supply shock, or a combination of both.

3.1 Data

Our main dataset, obtained from International Data Corporation (IDC), contains quarterly mobile phone sales per country at the manufacturer-brand-model level, along with product attributes such as operating system, processor vendor, processor cores, processor speed, screen size, storage capacity, and other technical attributes.

The dataset covers the U.S. and 26 European countries over 42 quarters from Q1 2010 to Q2 2020.[9] It consists of 180,330 observations on sales value, sales volume, and characteristics at the level of the market (quarter-country) and product (brand-model), amounting to about 169 products per market. We exclude products whose corresponding model names are "Others". Our measure of smartphone price is the average sales price, expressed in 2015 US dollars.[10] We exclude models priced below $90 or above $2,000. The final dataset consists of 141,805 observations, with on average 135 products per quarter-country. The number of unique products across quarters and countries in the entire sample is 11,030. On average, about 253 distinct products are available per country in a given year, with heterogeneity both across countries and over time. Product variety differs across markets: for example, in 2015, only 88 products were sold simultaneously in both Russia and France, despite each country offering over 400 products. Also, within countries, product entry and exit imply limited overlap across consecutive years (e.g., in France, only 162 products were sold in both 2015 and 2016).

[9] The European countries are: Austria (AT), Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Ireland (IE), Italy (IT), Kazakhstan (KZ), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Russia (RU), Serbia (RS), Slovakia (SK), Spain (ES), Sweden (SE), Switzerland (CH), U.S., Ukraine (UA), and United Kingdom (UK).

[10] To deflate prices, we use CPI data from the Federal Reserve Bank of St Louis. See *[Federal Reserve Bank of St Louis, 2025]*.

The 183 brands in our data together provide 13 unique operating systems. Android is used by the vast majority of manufacturers. Several other operating systems are adopted by only a single brand (and are hence effectively proprietary): iOS (Apple), BlackBerry OS (BlackBerry), Palm OS (Palm), Sailfish (Jolla), MeeGo and Fremantle (Nokia), Firefox OS (Alcatel), and Tizen (Samsung). Other operating systems are used by a small number of brands: Windows, Symbian, Linux, and WebOS. As a result, brand and operating system do not generally coincide (except for Apple and iOS), implying our regressions separately identify operating-system effects after controlling for a full set of brand fixed effects.

One of the core variables, which indicates whether an Android smartphone can use GMS, is obtained from comparing the Google support devices list *[Google Play, 2025]* with the model's name in the IDC data. Since May 2019, there have been a total of 29 Huawei and Honor models that cannot pre-install GMS.[11] Consistent with the timing we described in Section 2, all of them are released after the "Entity List" shock.

Table 1 presents summary statistics on the quantity sold, price, and product characteristics across products and markets (quarter and country). *Screen Size* is the diagonal measure of the smartphone's display area (inches), *Megapixels* is the main camera's resolution (MP), and *Storage* is the storage capacity (GB). *Age* is the number of quarters since the product's first introduction on the market. *Android GMS* is a dummy variable indicating whether the smartphone uses Android OS and has access to GMS. *Android No GMS* is a dummy variable indicating whether the smartphone uses Android OS but without access to GMS. *iOS*, *Windows*, *Symbian*, and *Blackberry* are dummy variables for the other major OSs. *Cores* is the number of processor cores. We also observe the cellular network generation supported by each product, classified as 2.5G (GPRS/EDGE), 3G (UMTS/HSPA/HSPA+), 4G (LTE), or 5G (NR).

The average quantity sold per handset and per market is around 20 thousand. The average price per handset is $361, with a standard deviation of 245. During the studied period, Android OS accounted for over 80% of the observations. Only a negligible fraction corresponds to Android versions without GMS (0.2%), although this share naturally increased after the trade sanction shock. Apple's smartphones (running on iOS) constituted 11% of the observations. Windows, Symbian, and BlackBerry's operating systems accounted for approximately 4%, 3%, and 2% of the observations, respectively. On average, the screen size is 5 inches: regular smartphones typically have a screen size between 4 and 5.5 inches; phablets have a larger screen size, usually between 5.5 and 7 inches, and represent about one third of the market. The average storage capacity is 48 GB, and the camera resolution is 13.7 MP.[12] The average number of quarters since the product's release date is 4.38. The average number of processors in the CPU is 5. About 74% of phones have 4G capability,

[11] Furthermore, the Chinese brand ZTE can also not pre-install GMS because of U.S. sanctions for exporting U.S.-origin goods to Iran between 2010-2016, violating U.S. export control and sanction laws.

[12] For 11 products, the data do not report a camera. We obtained this information directly from the third-party phone-comparison website GSM Arena. See *[GSM Arena, 2025]*

Table 1: Summary Statistics

	Mean	SD	Min	Max
Quantity (in thousands)	20.32	98.96	0.00	4.84
Price (in hundreds USD)	3.61	2.45	0.92	19.65
Screen Size (inches)	5.04	0.98	2	7.2
Megapixels	13.71	11.93	0	108
Storage (in tens of GB)	4.81	7.61	0.8	102.4
NFC	0.55	0.5	0	1
Age (in quarters)	4.38	2.83	1	29
Android GMS	0.8	0.4	0	1
Android No GMS	0.002	0.05	0	1
iOS	0.11	0.31	0	1
Windows	0.04	0.19	0	1
Symbian	0.03	0.16	0	1
BlackBerry	0.02	0.14	0	1
Cores	5.02	2.73	1	10
Cellular Network: 2.5G	0.007	0.08	0	1
Cellular Network: 3G	0.25	0.43	0	1
Cellular Network: 4G	0.74	0.44	0	1
Cellular Network: 5G	0.007	0.08	0	1

Note: Based on 141,805 observations at the quarter-country-brand-model level as discussed in the text.

and 25% of the phones have 3G capability. The 2.5G and 5G handsets account for 0.7% and 0.7% of the observations, respectively.

There is substantial variation in prices and characteristics across products and markets. For example, screen size ranges from 2 to 7.2 inches, camera megapixels range from 0 to 108 MP, and storage capacity ranges from 8 GB to 1,024 GB. This variation highlights the high degree of differentiation observed for these products: manufacturers design their products to appeal to customers who do not perceive smartphones as perfect substitutes.

3.2 Reduced-Form Evidence

We begin with a reduced-form analysis to assess the impact of the U.S. trade sanctions on Huawei's prices and quantities sold, compared with those of Xiaomi and other Chinese brands not directly targeted by the sanctions. This analysis serves two purposes. First, it provides an initial indication of whether trade sanctions primarily affected Huawei through a demand shift (e.g., due to the loss of GMS) or a supply shift (due to increased costs). With a pure demand shock, one would expect both Huawei's quantities sold and prices to decline. With a pure supply shock, one would expect quantities sold to decline and prices to rise. The precise impact depends on the slopes of the demand and supply curves. Our structural model will incorporate these elements through a differentiated-products demand model and an imperfectly competitive supply model. Second, a reduced-form analysis can reveal whether the trade sanctions had an immediate effect or a delayed effect, given the various adjustments discussed in the previous section. This can provide guidance for conducting appropriate counterfactual scenarios following our structural estimations.

A first look at the price and sales evolution of Huawei (including Honor) and other Chinese brands reveals the following. After Huawei's placement on the U.S. Entity List on May 16, 2019, Huawei's quarterly sales volume declined from 10.6 million units in Q2 2019 to 7.4 million units in Q2 2020, while its average price fell from $337 to $216 over the same period. In contrast, Xiaomi's sales volume and average price increased over this period, in line with its pre-existing trend. These patterns suggest that the trade sanctions resulted in significant losses for Huawei through reductions in both sales and prices, and potentially some gains for its close competitors, such as Xiaomi. Figure A.5 and Figure A.6 in the Appendix provide additional detail.

Empirical approach To explore these evolutions further, we use a Difference-in-Differences (DiD) research design. Specifically, we compare the quantities and prices of our two treated brands (Huawei and Honor) before and after their placement on the U.S. Entity List, using Xiaomi and other Chinese brands as a control group not directly affected by the sanctions. We caution that the control group may be contaminated through equilibrium price and quantity responses. Our structural framework will account for this, at the cost of making more specific assumptions on demand and imperfect competition.

To conduct our analysis, we aggregate the data to the quarter-country-brand level to obtain quantities and sales-weighted prices for our 26 European countries and the U.S. We focus on the period from Q1 2017 to Q2 2020, which includes 9 quarters before and 5 quarters after the event. As previously mentioned, the treated group consists of products from Huawei and Honor, and the control group includes products from Xiaomi and all other Chinese brands. We estimate the following regression specification:

$$y_{bct} = \beta_0 + \beta_1 * \mathbb{1}(H_b * W_t) + \delta_{bc} + \delta_t + \varepsilon_{bct} \tag{1}$$

where the outcome variable y_{bct} is either the logarithm of price or the logarithm of quantity of brand b in country c at quarter t. W_t is a dummy variable equal to 1 if quarter t is after Huawei's placement on the U.S. Entity List, and 0 otherwise. H_b is a dummy variable equal to 1 if brand b is Huawei or Honor, and 0 otherwise. The parameter β_1 captures the impact of the event on the treated group, relative to the control group (Xiaomi and other Chinese companies). We also consider a more flexible specification that accounts for the separate impact on Huawei and Honor relative to the control group. The brand-country fixed effects, δ_{bc}, account for unobserved country-brand specific characteristics that are constant over time, and the year-quarter fixed effects, δ_t, control for seasonal changes in demand and cost conditions, common across brands.

Table 2: Estimated Effects on Smartphone Prices and Quantities

	Price	Units
$\mathbb{1}(H_b * W_t)$	-0.195*	-0.741***
	(0.103)	(0.151)
R-squared	0.798	0.822
$\mathbb{1}(Huawei_b * W_t)$	-0.138***	-0.700***
	(0.035)	(0.052)
$\mathbb{1}(Honor_b * W_t)$	-0.251***	-0.779***
	(0.019)	(0.051)
R-squared	0.783	0.823
Brand Country FE	Yes	Yes
Year Quarter FE	Yes	Yes
N	2,314	2,314

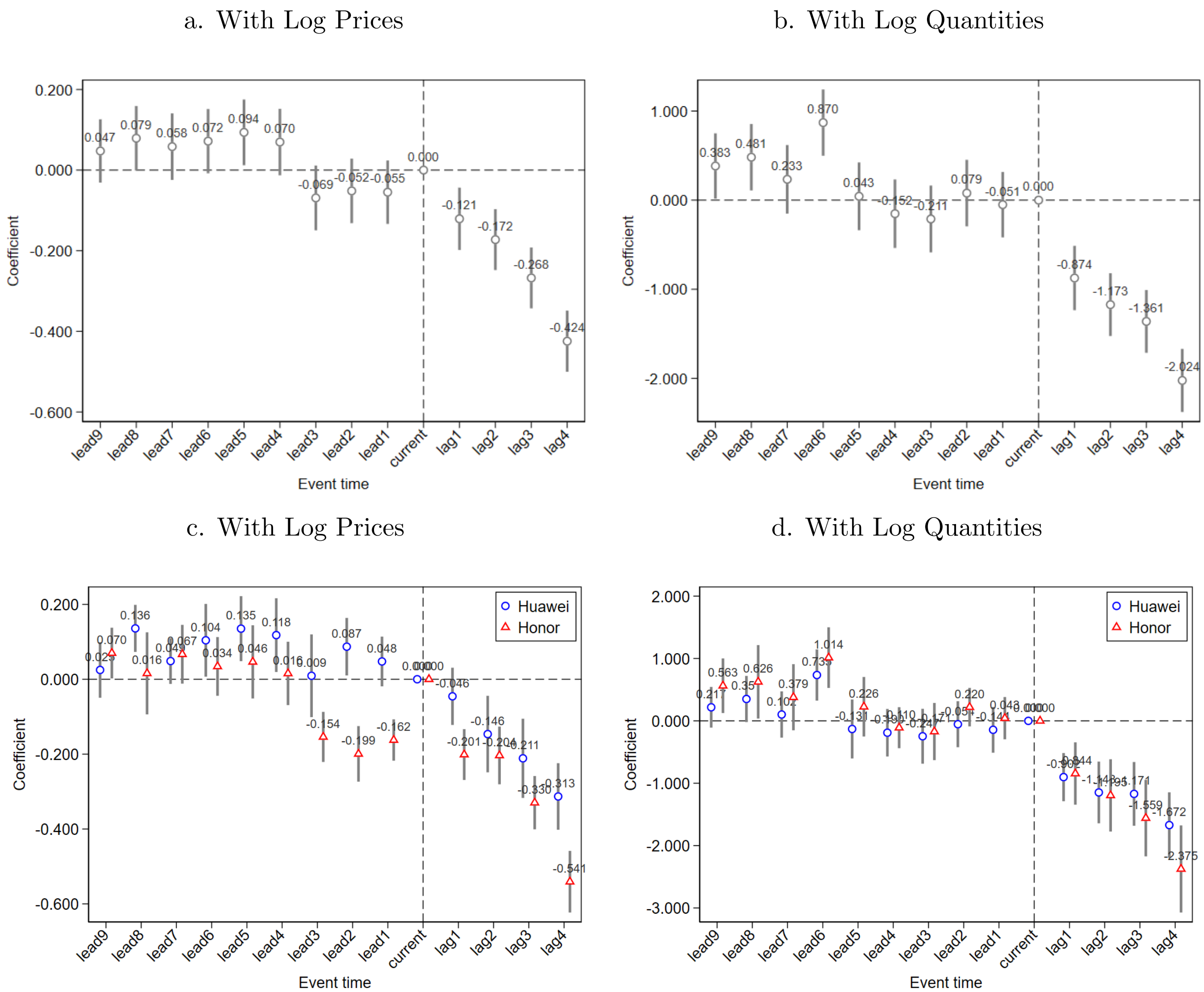
Notes: Estimates based on 2,314 brand-level observations in 27 countries during 2017Q1-2020Q2 (9 quarters before and 5 quarters after the event). Standard errors are robust and clustered at the country and brand level (* p <.1, ** p <.05, *** p <.01.). The percentage quantity and price effects are calculated as β_1 using $\exp(\beta_1) - 1$, with standard errors adjusted accordingly, using the delta method.

Estimation results Table 2 presents the results. We estimate that Huawei's average price declined by 19.5% and its quantity sold declined by 74.1% after the sanctions. Distinguishing between the brands Huawei and Honor shows that Huawei's average price decreased by less (-13.8%) than Honor's price (-25.1%), and its quantity sold also declined by less.

These findings suggest that the trade sanctions had a significant impact on Huawei and Honor, as compared to other Chinese companies. Furthermore, the fact that both prices and sales dropped indicates that the sanctions largely consisted of a demand shift rather than a supply shift (as the latter would have led to an increase in Huawei's average price). The observed demand shift may reflect the loss of access to GMS, as well as a deterioration in brand reputation stemming from espionage-related accusations against the firm and, to a lesser extent, from the anticipated unavailability of 5G chipsets. Finally, the comparatively larger drop in quantity than price suggests a relatively elastic supply curve.

To assess the validity of the parallel trends assumption before Huawei's placement on the Entity List and the dynamic path afterwards, we conduct an event study. We construct nine lead indicators representing the quarters prior to treatment (which took place in Q2 2019) and five lag indicators for the quarters following the treatment. We estimate the model specified in Equation (2), using the logarithm of quantity and average price again as the two outcome variables:

Figure 2: Event Study Estimates



Note: The figures present coefficients and 95% confidence intervals.

$$y_{bct} = \beta_0 + \sum_{\tau=-9}^{-1} \lambda_\tau \mathbb{1}_{b\tau} + \sum_{\tau=1}^{5} \gamma_\tau \mathbb{1}_{b\tau} + \delta_{bc} + \delta_t + \varepsilon_{bct} \tag{2}$$

The results are presented in Figure 2. The coefficients on the lead terms are usually not statistically different from zero, indicating no significant difference in the pre-treatment trends of prices and sales quantities between Huawei and the control group. The significant lags point again to a significant decline in the average price and especially quantity sold for Huawei's smartphones. This strongly suggests that the targeted firms have been mainly affected through a demand shock. Interestingly, the post-treatment effects become stronger over time. This suggests that the demand shock took some time to materialize.

4 Structural Framework

The reduced-form evidence presented in the previous section indicates that the trade sanctions had a considerable impact on Huawei (and its other brand, Honor), especially through a demand shift. To analyze this further, we now develop a structural framework. This framework incorporates several key dimensions along which Huawei faced disruptions: the loss of access to GMS on the software side, and restricted access to crucial hardware components for 5G on the hardware side. These disruptions may, in principle, affect both demand and supply (cost). Furthermore, the structural framework can account for Honor's response to divest its brand Honor.

To model the demand for smartphones, we develop a random coefficients logit model, which incorporates consumer heterogeneity in the valuation of several product characteristics, including those affected by the sanctions. We add an oligopolistic supply side with price-setting smartphone producers, where marginal costs also depend on product characteristics. We estimate the demand and supply model using our rich dataset. In the next section, we use the estimated model to perform policy counterfactuals to examine the effects of the sanctions on consumers and producers.

4.1 Demand side

4.1.1 Consumer demand model

Assume that the number of potential consumers in country c and quarter t is L_{ct}. The utility of consumer i purchasing product j in country c at quarter t is:

$$u_{ijct} = x_j \beta_i - \alpha_i p_{jct} + \lambda_b + \kappa_c + \gamma_t + \xi_{jct} + \varepsilon_{ijct}, \tag{3}$$

where x_j is a vector of observed product characteristics and p_{jct} is the price. The random coefficient vector β_i captures heterogeneous consumer valuations for the product characteristics, assumed to be normally distributed with mean β and variance σ^2. Similarly, α_i is a normally distributed random coefficient for the valuation of price with mean α and variance σ_α^2. The brand fixed effects λ_b capture consumers' average taste for brands b. The country (κ_c) and a year-quarter fixed effects (γ_t) capture regional and seasonal differences in demand. The term ξ_{jct} represents the remaining unobserved quality for product j in country c at time t, and ε_{ijct} captures consumers' idiosyncratic taste, assumed to be i.i.d. and follow a type-I extreme value distribution. Finally, the utility of the outside option (net of $= \varepsilon_{i0ct}$) is normalized to 0, such that $u_{i0ct} = \varepsilon_{i0ct}$.

Assuming that consumers choose the product that maximizes utility, the predicted market share of product j at time t in country c is the integral of the individual choice probability over the distribution of consumer heterogeneity:

$$s_{jct} = \int \frac{exp(x_j\beta_i - \alpha_i p_{jct} + \lambda_b + \kappa_c + \gamma_t + \xi_{jct})}{1 + \sum_{k=1}^{J} exp(x_k\beta_i - \alpha_i p_{kct} + \lambda_b + \kappa_c + \gamma_t + \xi_{kct})} dF(\alpha, \beta) \tag{4}$$

where $F(\alpha, \beta)$ represents the distribution of the random coefficient α_i and β_i. We calculate the market share as $s_{jct} = q_{jct}/L_{ct}$, where q_{jct} is the quantity sold of product j. We define the mean utility derived from product j in country c at time t as:

$$\delta_{jct} = x_j\beta - \alpha p_{jct} + \lambda_b + \kappa_c + \gamma_t + \xi_{jct} \tag{5}$$

and we obtain δ_{jct} from inverting Equation (4) following Berry, Levinsohn, and Pakes (1995). We approximate the market size L_{ct} at 20% of the population in 2020 (based on information obtained from the World Bank).[13]

Our specification of the product characteristics in x_j includes indicators for Android OS with GMS (*Android GMS*), Android OS without GMS (*Android No GMS*), iOS, Windows OS, Symbian OS, and Blackberry OS. The base category consists of other, more marginal operating systems such as Firefox, Fremantle, MeeGo, Palm, Sailfish, Tizen, and webOS. In addition, we include the following technical attributes: screen size, camera resolution (megapixels), storage capacity, NFC capability, product age, number of processor cores, and cellular network generation (e.g., 3G, 4G, 5G). We estimate mean valuations for all these characteristics, and allow for heterogeneity for several key variables: price, screen size, age, and iOS.

Following the literature, we assume that ξ_{jct} is uncorrelated with the product characteristics x_{jct}, but it may be correlated with prices and market shares. Hence, instrumental variables should be used to consistently estimate the parameters. As in Berry et al. (1995), we use the following instruments: (i) the own product characteristics; (ii) sums of characteristics of the other products produced by the same firm, and (iii) sums of characteristics of products produced by the other firms. Since we include a constant, this also includes the counts of other products by the same firm and by other firms. The F-statistic from a first-stage regression of price on the excluded instruments exceeds 20, rejecting the null hypothesis that these instruments do not explain any variation in prices, confirming the relevance of the instruments. See Table A.1 in the Appendix for details.

[13] We obtain similar results with a potential market size of 30% of the population, which is comparable to the potential market size of 10% in Fan and Yang (2020), who use monthly instead of quarterly data.

4.1.2 Estimation results

Table 3 presents the estimated demand parameters. The columns associated with Model I show the 2SLS regression results from the logit demand model without random coefficients. The columns associated with Model II present the GMM results for the full random-coefficients logit model. The latter allows for unobserved consumer heterogeneity in the valuation of price and several key characteristics: screen size, model age, and iOS. We also considered specifications with consumer heterogeneity for additional characteristics, but it proved difficult to obtain precise estimates. Nevertheless, our main findings remain robust in such alternative specifications.

First consider the estimated price sensitivity. The mean price sensitivity (α) is significant and of the expected sign in the logit model (0.586), but it is more than twice as large (1.235) in the full random coefficients logit model. Furthermore, the standard deviation of the price sensitivity (σ_α) is sizable (0.310), implying considerable heterogeneity in consumers' price sensitivity. These estimates translate into a more than doubling of the average price elasticity ($\bar{\eta}_{jj}$) in the full model (with a change from -2.11 to -4.36). These magnitudes are comparable to the estimates obtained by Hiller et al. (2018) and Fan and Yang (2020).

Now consider the estimated valuations of other product characteristics, focusing on the full model. Unsurprisingly, consumers are estimated to have a significantly positive valuation for GMS, implying an average willingness-to-pay (WTP) for these services of \$55.9. Consumers also place a significantly higher value on products with larger screen sizes, higher camera resolution, and greater storage capacity. The average WTP is \$92.7 for a one-inch increase in screen size, \$1.2 for an additional megapixel of camera resolution, \$8.3 for an additional GB of storage, \$113.7 for 3G compatibility, \$175.8 for 4G, and \$275.7 for 5G. Note that Fan and Yang (2020) estimate a comparable WTP for 3G (\$102) and 4G compatibility (\$150), while Hiller et al. (2018) estimate a much lower WTP for 4G compatibility (\$7.93).

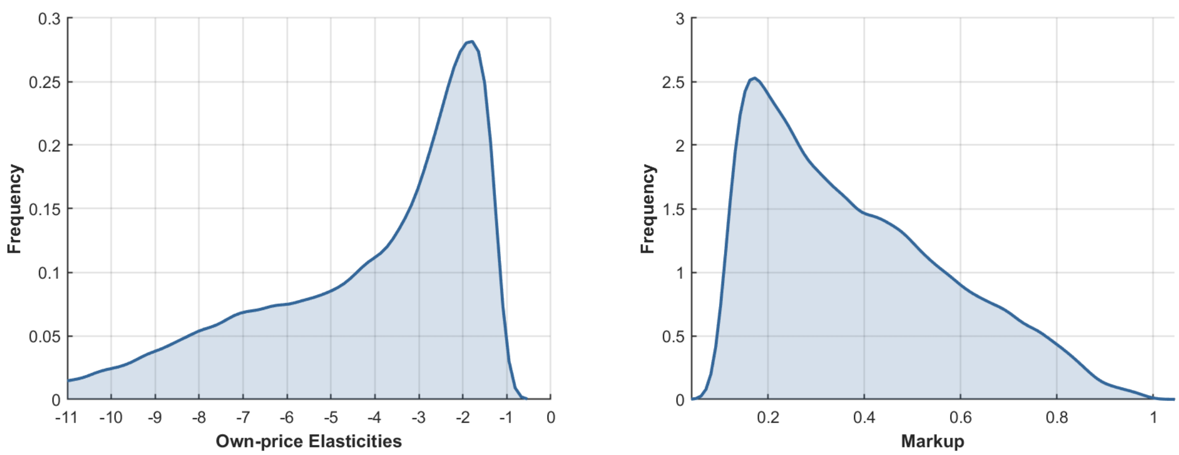
Figure 3 presents the distribution of the estimated price elasticities and the implied markups, calculated under the assumption of multi-product Bertrand competition. The median own-price elasticity is -3.2, and the 1st and 99th percentiles are, respectively, -13 and -1.7. Markups are on average 40.8%, with a median of 35.9%, and the 1st and 99th percentiles are 11% and 102.8% (see Table A.2). To obtain an idea of the substitution patterns implied by the estimates, we calculate the own-price and cross-price elasticities for the Top 10 products in France in Q2 2020. The cross-price elasticities indicate that consumers are more likely to substitute among products from the same brand and OS, indicating brand and OS loyalty. For further detail, see Table A.3 in the Appendix.

Table 3: Estimation Results from Discrete Choice Models of Smartphone Demand

	Model I Logit-GMM		Model II RCL			
	Mean	s.e.	Mean	s.e.	Std. Dev.	s.e.
Price	0.586	0.039	1.235	0.119	0.310	0.099
Screen Size	0.542	0.048	1.145	0.094	0.014	0.559
Megapixels	0.012	0.001	0.015	0.002		
Storage	0.057	0.005	0.103	0.013		
NFC	0.418	0.029	0.825	0.070		
Age	-0.176	0.002	-1.051	0.080	0.661	0.046
Android GMS	0.879	0.062	0.690	0.080		
Android No GMS	0.129	0.117	-0.033	0.190		
iOS	5.466	0.257	4.882	0.443	3.150	0.431
Windows	0.648	0.068	0.797	0.089		
Symbian	1.288	0.074	1.660	0.100		
BlackBerry	2.015	0.090	1.935	0.135		
Cores	0.113	0.008	0.229	0.018		
Cellular Network: 3G	0.911	0.075	1.404	0.108		
Cellular Network: 4G	1.379	0.094	2.171	0.148		
Cellular Network: 5G	2.241	0.186	3.405	0.368		
$\bar{\eta}_{jj}$	-2.11		-4.36			
$\#\eta_{jj} > -1$	35,149		53			
$mc(\$)$	183.2		258.0			

Notes: Estimates based on 141,805 product-level observations in 27 countries during 2010Q1-2020Q2. Country, brand, and year-quarter fixed effects are included. The base category for operating systems includes other, more marginal operating systems, as discussed in the text. The estimation procedure uses 1,000 modified Latin hypercube sampling (MLHS) draws and takes 10 different starting values for the nonlinear coefficients.

Figure 3: Distribution of Estimated Price Elasticities and Markups



4.2 Supply side

4.2.1 Oligopoly model

To uncover marginal costs and perform policy counterfactuals, we adopt a multi-product price-setting oligopoly model. This approach aligns closely with prior structural analyses of smartphone markets, including Hiller et al. (2018), Fan and Yang (2020), and Yang (2020). As discussed in Duch-Brown, Grzybowski, Romahn, and Verboven (2023), this approach can be justified under a competitive retail sector or, more generally, under an imperfectly competitive retail sector with efficient contracting between producers and retailers (no double marginalization effects). The estimated markups then reflect a combination of market power of manufacturers and retailers, while marginal cost captures both the production cost and the distribution cost incurred by local retailers.

To simplify notation, remove the market subscripts for country c and time t. Each firm f has a portfolio of products F_f and maximizes the sum of profits over its products $k \in F_f$:

$$\Pi_f(\mathbf{p}) = \sum_{k \in F_f} (p_k - c_k) q_k(\mathbf{p}), \tag{6}$$

where c_k is the marginal cost for product k and $q_k(\mathbf{p}) = s_k(\mathbf{p})L$ is demand as a function of the price vector. The first-order condition of the profit-maximizing price of each product $j = 1, \ldots, J$ is given by Equation (7):

$$q_j(\mathbf{p}) + \sum_{k \in F_f} (p_k - c_k) \frac{\partial q_k(\mathbf{p})}{\partial p_j} = 0. \tag{7}$$

A Bertrand-Nash equilibrium obtains if Equation (7) holds for all products $j = 1, \ldots, J$. To write the system of J first-order conditions in vector notation, define the $J \times J$ matrix $\boldsymbol{\theta}$ as the firms' product ownership matrix, a block-diagonal matrix with a typical element $\theta(j,k)$ equal to 1 if products j and k belong to the same firm, and 0 otherwise. Let $\mathbf{q}(\mathbf{p})$ be the $J \times 1$ demand vector, and $\boldsymbol{\Delta}(\mathbf{p}) \equiv \partial \mathbf{q}(\mathbf{p}) / \partial \mathbf{p}'$ be the corresponding $J \times J$ Jacobian matrix of first derivatives. Let $\mathbf{c}$ be the $J \times 1$ marginal cost vector. Using the operator $\odot$ to denote element-by-element multiplication, we have:

$$\mathbf{q}(\mathbf{p})(\boldsymbol{\theta} \odot \boldsymbol{\Delta}(\mathbf{p}))(\mathbf{p} - \mathbf{c}) = 0, \tag{8}$$

which can be inverted to give:

$$\mathbf{p} = \mathbf{c} - (\boldsymbol{\theta} \odot \boldsymbol{\Delta}(\mathbf{p}))^{-1} \mathbf{q}(\mathbf{p}). \tag{9}$$

This decomposes the price of each product into its marginal cost and a markup that depends on the own-and cross-price elasticities of demand.

Equation (9) can be rewritten to recover the marginal cost vector **c**. Adding market subscripts, we take the following specification for the marginal cost of product j in country c at quarter t:

$$\ln(c_{jct}) = \ln(Q_{jt})\eta + w_j\phi + \bar{\xi}_{jt}\tau + \lambda_b + \kappa_c + \gamma_t + \omega_{jct}, \tag{10}$$

where $Q_{jt} = \sum_c q_{jct}$ is a measure of total output of product j at time t; w_j includes smartphone attributes (screen size, camera megapixels, storage, cellular network generation, and OS dummies); and $\bar{\xi}_{jt} = \sum_c \xi_{jct}/N_{jt}$ is unobserved average product quality for product j across all countries in quarter t, following Barwick, Cao, and Li (2021). We include six OS categories of main interest: iOS, Android with GMS, Android without GMS, Windows OS, Symbian OS, and BlackBerry OS. The base category consists of the marginal operating systems. Brand, country, and year-quarter fixed effects are also included. Finally, ω_{jct} denotes unobserved cost shocks to product j in country c at time t. We are primarily interested in the coefficients of the OS-type and cellular network generation dummies, which capture relative cost differences across operating systems and smartphone generations.

Finally, note that Equation (9) can also be used to conduct new counterfactual equilibria in response to the trade sanctions, in particular, Huawei's loss of access to GMS and 5G chipsets. We discuss our approach in more detail in Section 5.

4.2.2 Estimation results

Using the estimates from the full random-coefficients logit model, as presented in Table 3, we can back out the marginal cost of each product. We then project these marginal costs on product characteristics, following Equation (10).

Table 4 reports the marginal cost parameter estimates. Model I assumes constant returns to scale, while Models II and III allow for *decreasing returns to scale* through the total quantity variable Q_{jt} in specification (10). This quantity may be correlated with the error term ω_{jct}. Intuitively, a low country-specific unobserved marginal cost shock ω_{jct} may induce the firm to produce a higher quantity q_{jct} and therefore a higher total quantity Q_{jt}, resulting in a downward bias of the quantity coefficient. Model II ignores this endogeneity issue (assuming country-level sales are small relative to total sales) and performs estimation using OLS. Model III accounts for it, using an instrumental variable strategy. Following Goldberg and Verboven (2001), we use as an instrument the difference between the total sales and country-specific sales, $\ln(Z_{jmt}) = \ln(Q_{jt} - q_{jmt})$. Models II and III indicate the presence of significant returns to scale, with estimated scale elasticities of -0.106 and -0.06 under OLS and IV estimation, respectively.

Table 4: Estimation Results from Supply-Side Models of Smartphone Marginal Costs

	Model I OLS		**Model II** OLS		**Model III** 2SLS	
	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
$\ln(Q_{jt})$			-0.106	0.001	-0.060	0.001
Screen Size	0.706	0.004	0.738	0.004	0.724	0.004
Megapixels	0.018	0.000	0.021	0.000	0.019	0.000
Storage	0.044	0.000	0.042	0.000	0.043	0.000
Android GMS	-0.134	0.022	0.005	0.021	-0.055	0.021
Android No GMS	-0.245	0.041	-0.184	0.040	-0.210	0.040
iOS	1.508	0.059	2.071	0.057	1.827	0.057
Windows	0.095	0.023	0.162	0.023	0.133	0.023
Symbian	0.228	0.024	0.333	0.024	0.287	0.024
BlackBerry	-0.379	0.032	-0.095	0.031	-0.218	0.031
Cellular Network: 3G	0.567	0.021	0.627	0.021	0.601	0.021
Cellular Network: 4G	1.138	0.022	1.283	0.022	1.220	0.022
Cellular Network: 5G	1.374	0.031	1.413	0.030	1.396	0.030
$\hat{\xi}_{jt}$	0.125	0.001	0.169	0.001	0.150	0.001
Year-Quarter FE	Yes		Yes		Yes	
Country FE	Yes		Yes		Yes	
Brand FE	Yes		Yes		Yes	

Notes: Estimates based on 140,541 product-level observations in 27 countries during 2010Q1-2020Q2. The base category for operating systems includes other, more marginal operating systems, as discussed in the text.

The signs and magnitudes of the estimated coefficients on smartphone attributes are generally intuitive and comparable across the three models. Marginal costs are higher for handsets with larger screens, better camera resolution, greater storage capacity, and support for the latest cellular network generations. According to the estimates of Model III, Android phones without GMS have a 14.4% lower marginal cost (0.155 log points) than those with GMS. Furthermore, 4G phones exhibit a cost advantage over 5G phones of 16.2% (0.176 log points). In absolute terms, shifting smartphone production from Android with GMS to Android without GMS implies a cost reduction of on average \$37 per device, while switching from 5G to 4G technology reduces costs by about \$42 per device.

4.3 Accounting for brand reputation effects

We also considered a demand specification that explicitly accounts for the reputation loss incurred by Huawei following its placement on the Entity List and the resulting media coverage (see *[The Economist, 2019; The Financial Times, 2023]*). To that end, we include dummy variables for Huawei interacted with the post-2017 and post-2019 periods. The former captures the perceived brand value before the firm's placement on the Entity List, whereas the latter captures the potential reputational loss afterward. Overall, the demand parameter estimates mirror the estimation results reported earlier in Tables 3 and 4. Notably, we estimate a significant negative coefficient for Huawei after 2019. In monetary terms, this coefficient translates into a sizeable reduction in WTP for Huawei's brand of $15.2 in the full model, consistent with a loss in brand value in the aftermath of Huawei's placement on the U.S. Entity List. For more detail, we refer to Tables A.4, A.5, and A.6 in the Appendix.

5 Policy Counterfactuals

We now use our structural model to conduct a series of policy counterfactuals. The first objective is to assess the effectiveness of the U.S. trade sanctions in reducing Huawei's profits. The second is to evaluate their distributional effects, i.e., which producers benefited and which consumers bore the costs. This analysis also allows us to uncover potential protectionist motives (if the U.S. firm Apple benefits significantly) and the international incidence of consumer losses (if they primarily fall on non-U.S. markets).

5.1 Overview

To conduct the policy counterfactuals, we rely on the demand and marginal cost estimates presented in Table 3 and Table 4. To solve for the new price equilibrium of a given counterfactual, we use fixed-point iteration on Equation (9).[14] Note that in our setting, all countries within a given period are interdependent because marginal costs depend on total output across countries. Hence, we cannot solve the new price equilibrium on a country by country basis, and instead solve it for all 27 countries together.

The first set of counterfactuals focuses on the direct impact of trade sanctions, which stems from Huawei's loss of access to GMS and to 5G chipsets, as outlined in Section 2. Implementing these counterfactuals amounts to adjusting the relevant product characteristics entering the demand equation (x_{jct}) and the marginal cost equation (w_{jct}). The first counterfactual (denoted CF1) removes only GMS from Huawei's product characteristics, whereas the second counterfactual (CF2) additionally removes 5G to account for the supply-chain restrictions.[15] We present the results in Section 5.2.

The second set of counterfactuals incorporates responses of Huawei on the extensive margin: a divestiture of its brand Honor to regain access to GMS for that brand, and a full exit of Huawei. Divestiture not only raises profits from regained access to GMS for Honor, but also reduces profits from new competition. To decompose both effects, our first divestiture scenario assumes that Honor continues to coordinate its pricing decisions with Huawei as before the divestiture (CF3), whereas our second divestiture scenario assumes that

[14] We use the safe Anderson Acceleration type 1 (Zhang, O'Donoghue, and Boyd, 2020) to invert the first-order condition. This approach performs better in terms of the required number of iterations and its ability to obtain a solution.

[15] As discussed in Section 2.2, Huawei did not completely stop producing smartphones with 5G chips after the shock, thanks to its inventory, at least over the period we observe.

Honor becomes an independent price competitor (CF4). Finally, our exit scenario considers a situation in which Huawei completely exits the market, while Honor continues to operate internationally (CF5). This scenario corresponds to a *de facto* complete ban on the firm's devices. While such an outcome has not been implemented globally, it is not unrealistic in the long run. In particular, a comparable regulatory regime was introduced in the U.S. in 2022, when U.S. regulators prohibited the authorization and sale of new Huawei telecommunications equipment and devices on national security grounds *[BBC News, 2022; Reuters, 2023]*. Although these measures did not require the withdrawal of existing devices, they eliminated Huawei's ability to compete in new device sales. In this sense, CF5 can be interpreted as a "worst-case" outcome for Huawei, in which no viable alternative suppliers are found for either the operating system or 5G chipsets, leading to the firm's gradual disappearance from the market. For reference, Huawei's market share in Europe and the U.S. had reached 2.43% and 2.74%, respectively, in March 2025. Honor has begun to regain market share in Europe, after a significant decline from 7% in Q1 2019 to just 0.5% in Q3 2021. By Q1 2024, its share had recovered to 4%. We present the results in Section 5.3.

All counterfactual changes are measured relative to the predicted equilibrium in the absence of sanctions, where all Huawei products retain access to, and can pre-install, GMS (denoted as CF0). Technically, this prediction is obtained using a model in which GMS is reinstated on Huawei products that are otherwise unable to pre-install it. This corresponds to a "business-as-usual" scenario without trade sanctions or supply disruptions.

5.2 Direct effects of the sanctions

5.2.1 Lost access to GMS (CF1)

We begin with the most immediate consequence of Huawei's placement on the U.S. Entity List in May 2019: its loss of access to GMS. Recall that this also affected its Honor brand.

Impact on Huawei and its competitors Table 5 presents the counterfactual effects of Huawei's lost access to GMS on its own and the main competing firms' performance (typically selling just one brand, with the exception of Huawei). Our results indicate that lost access to GMS would lead to a 25.6% decline in sales volume for Huawei and a 35.5% decline for its sub-brand Honor over the period from Q2 2019 to Q2 2020. In addition, sales-weighted average prices—computed using fixed weights—decline by 11% for Huawei and 9.1% for Honor. By contrast, average selling prices computed with time-varying sales weights *increase* by 8.5% for Huawei and decrease by 3.6% for Honor (not reported in the table). This reflects a shift toward higher-priced models for Huawei (a sales-mix effect).

Table 5: Impact of Huawei's Lost Access to GMS on Main Brands (Q2 2019 - Q2 2020)

		No Sanction (CF0)		**GMS Removal (CF1−CF0)**			
Origin	**Brand**	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	9.04	3.03	-0.87	-28.8	-25.6	-11.0
China	**Honor**	2.03	1.06	-0.41	-39.1	-35.5	-9.1
China	Xiaomi	4.14	1.73	0.09	5.4	4.5	0.2
China	OPPO	0.81	0.23	0.01	4.7	4.6	-0.1
China	Others	5.79	2.07	0.04	1.9	1.8	-0.1
Korea	Samsung	43.02	11.49	0.34	3.0	2.0	0.2
U.S.	Apple	95.32	32.55	0.20	0.6	0.5	0.0
	Others	8.15	2.57	0.05	2.1	2.0	0.0
	Total	168.30	54.73	-0.55	-1.0	-2.0	-0.6

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Together, these effects imply profit losses of 28.8% for Huawei and 39.1% for Honor. In monetary terms, this amounts to losses of $875 million for Huawei, and $413 million for Honor ($1.29 billion, for the two brands combined). Overall, these findings suggest that the sanctions were highly "effective" in the sense that they generated a substantial direct adverse impact on the targeted brands.

Other smartphone companies benefit from the sanctions because of consumer substitution. First, the U.S.-based company Apple would experience a modest 0.5% increase in sales volume and no change in average prices. This reflects its relatively distant competitive position, mainly due to its distinct operating system. Nevertheless, given Apple's scale, this translates into a sizable profit increase of $199 million. Second, the largest Android-powered firm, Samsung, emerges as the biggest winner with a 2% increase in sales and a 3% increase in profits, amounting to over $340 million. This favorable outcome reflects both the scale of the Android ecosystem and the closer substitutability among devices sharing the same operating system. Third, other Chinese brands also benefit considerably, despite their smaller size. Most notably, Xiaomi's profits would increase by 5.4%, or up to $93 million, while the remaining Chinese brands' profits would increase by $38 million. These comparatively stronger gains reflect their closer substitutability with Huawei's products. Indeed, our demand estimates highlight significant consumer heterogeneity in the valuation of operating systems and price, and Chinese brands tend to rely on the same operating system while competing in similar lower-priced market segments.

Interestingly, the model predicts that Huawei's sales volume decline is substantially larger than its price decline, consistent with the reduced-form results. This confirms that the trade sanctions reflect more a demand than a supply shock – although the model incorporates both possibilities. Nevertheless, the predicted magnitudes are smaller than the reduced-form estimates. One possible reason is that, in addition to losing

Table 6: Impact of Huawei's Lost Access to GMS on Consumers by Geographic Region

	No Sanction (CF0)	GMS Removal (CF1−CF0)		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.23	-0.39	-2.2	-1.0
East	9.80	-0.40	-6.9	-1.4
South	13.95	-0.26	-3.4	-1.8
Central-East	9.32	-0.20	-4.0	-1.8
North	6.40	-0.04	-1.4	-0.7
USA	85.61	-0.01	0.0	0.0
Total	168.30	-1.31	-2.0	-0.6

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.
[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

access to GMS and 5G, Huawei may have experienced a decline in its brand reputation, which is not captured by the model. We discuss this additional scenario in Section 5.5.

Impact on consumers in the U.S. and Europe Table 6 presents the counterfactual results for the main focal markets: the U.S. and five broad European regions.

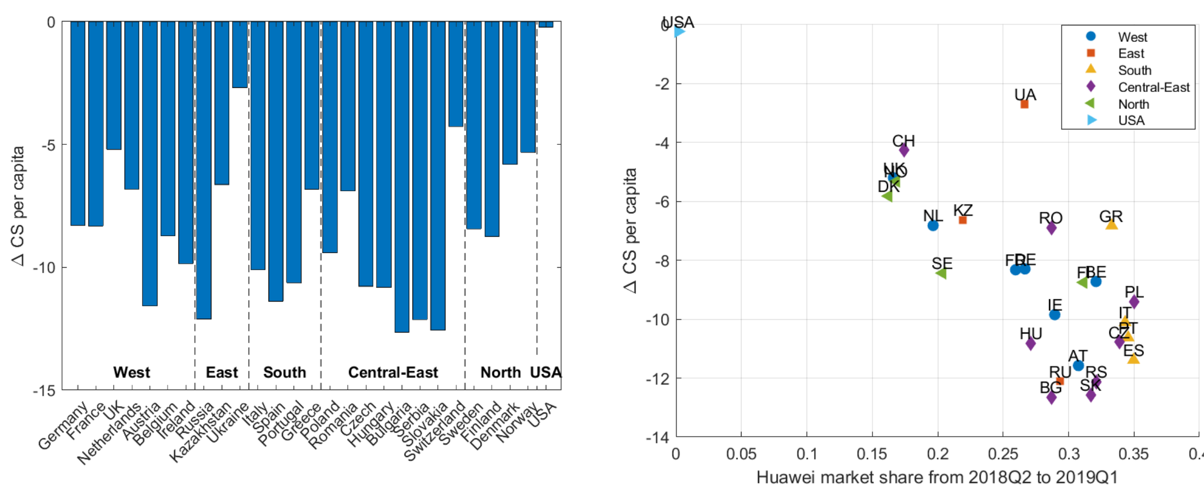
We find that Huawei's lost access to GMS has virtually no adverse effects on smartphone consumers in the U.S. market. Aggregate sales volumes and price levels remain essentially unchanged, and consumer surplus declines by only \$15 million, a negligible amount relative to the overall U.S. smartphone sales of approximately \$86 billion. In contrast, consumers were substantially affected in most European markets. Reduced competitive pressure implies price increases across all European countries, ranging from 0.7% in the North to 1.8% in the South and Central-East. Furthermore, total sales volumes decrease across all regions, in particular in the East (i.e., by 6.9%). These changes translate into substantial consumer surplus losses of \$1.29 billion across Europe, particularly in the West (a loss of \$394 million) and in the East (a loss of \$397 million). Figure A.8 presents a detailed breakdown of total changes in consumer welfare at the country level, highlighting considerable heterogeneity.

The large differences in losses across regions broadly reflect their variation in potential market size, which is the largest in Western Europe (52.1 million potential consumers), followed by Eastern Europe (41.4 million) and Southern Europe (25.6 million). By contrast, the cross-country differences in consumer losses do not match well with the differences in sales revenues (or expenditures). For example, consumer expenditures are much larger in Western Europe (\$43.2 billion) than in Eastern Europe (\$9.7 billion), while consumer losses

Figure 4: Changes in Consumer Surplus per Capita Across Countries

(a) Change in CS per capita

(b) Change in CS per capita as a function of Huawei's pre-shock market share



Note: Huawei's market share is calculated using sales unit data from the year preceding the shock.

are even slightly larger in Eastern Europe. This reflects the different composition of expenditures across the regions, to which we return next.

Figure 4 presents country-level changes in per-capita consumer surplus. According to panel (a), there is significant cross-country heterogeneity, with per capita losses being largest in several Central and Eastern European countries (e.g., Bulgaria and Slovakia) as well as in parts of Western Europe (e.g., Austria). According to panel (b), there is a clear correlation between per-capita consumer welfare losses and Huawei's pre-shock market presence. For example, in Bulgaria, Slovakia, and Austria, Huawei's pre-shock market presence was strong. At the same time, the negative relationship between per capita consumer surplus losses and Huawei's market share is not perfect, indicating that additional factors contribute to the observed cross-country differences in welfare effects. To illustrate this point, Figure A.9 plots per capita consumer surplus losses against Huawei's share of popular products. The resulting pattern differs somewhat, suggesting that variation in product variety and product positioning across countries also plays an important role.

5.2.2 Lost access to GMS and 5G chipsets (CF2)

We also extend the previous counterfactual to account for Huawei's loss of access to 5G technology in addition to GMS. The results indicate (modestly) larger losses for both Huawei and Honor, alongside correspondingly greater gains for competing firms. Nevertheless, the incremental effect of the 5G restriction remains relatively limited, reflecting the fact that the 5G segment was still small at the time of the trade shock. Over the long term, however, this channel is likely to become more consequential, as analyzed below. Consumer surplus losses are again larger than in the baseline counterfactual, though only marginally so. For more details, see Table A.7 and Table A.8 in the Appendix.

5.3 Divestiture and exit

5.3.1 Honor divestiture (CF3 and CF4)

As discussed in Section 2.2, Huawei sold its sub-brand approximately six months after the sanctions, enabling Honor to resume selling new smartphones equipped with GMS. To assess the effects of this divestiture, we consider two counterfactual scenarios in which GMS remains unavailable to Huawei but becomes available to Honor. In the first scenario, Huawei and Honor continue to coordinate their pricing decisions as if they were still multi-product firms (CF3). In the second scenario, they compete in prices, so that the divestiture would raise joint profits only if the value of GMS offsets the losses from intensified competition (CF4).

We find that a divestiture of Honor can mitigate the impact of the sanctions by up to $417 million if Huawei and Honor would continue to coordinate their pricing decisions, as the combined profit loss for Huawei and Honor would amount to $871 million (CF3), instead of 1.29 billion without divestiture (CF1). The divestiture would remain almost equally profitable ($415 million) if we take into account the newly introduced price competition between Huawei and Honor (CF4). Consistent with these findings, profit gains for competing firms are correspondingly smaller. Furthermore, consumer surplus losses become more moderate under divestiture. Losses to European consumers fall from $1.29 billion without divestiture (CF1) to $0.89 billion under divestiture and unchanged price competition (CF3) and $0.75 billion if we additionally account for the induced price competition between Huawei and Honor (CF4). For further details, see Table A.9 and Table A.10 in the Appendix.

5.3.2 Huawei exit (CF5)

The sanctions not only restricted Huawei's access to GMS but also to 5G-enabling equipment. As discussed above, the additional impact of the 5G restriction was limited at the time of implementation, reflecting the fact that the 5G market was still relatively small when the sanctions were introduced.[16] Over the longer term, however, an increasing share of handsets is expected to be equipped with 5G capabilities. The GSMA predicts that, "by 2030, 5G will make up 57% of all mobile connections and become the dominant mobile technology" *[European Commission, 2024]*. As reliance on 5G intensifies, access to advanced 5G components

[16] Most European operators launched their 5G services in 2020. According to data published by the European Commission (see *[European Commission, 2025]*), about 14% of the EU population was covered by 5G in 2020, rising to almost 95% by the end of 2024. In terms of adoption, take-up remained limited: 22% in 2023 and 36% in 2024. Hence, in 2019 and 2020, the technology was not yet "mature".

and compatible technologies will become increasingly critical for Huawei's competitiveness, implying that trade sanctions may impose more severe constraints if alternative suppliers cannot be secured.

To gauge potential losses, we conduct a policy counterfactual in which Huawei fully exits the market, while Honor remains active with continued access to both GMS and 5G technology. We find substantial gains for all Chinese competitors, particularly Xiaomi and OPPO, whose profits increase by 13.3% and 11.1%, respectively, alongside higher prices for Xiaomi and Samsung. Honor also benefits, with profits rising by 10.4%, although this increase is combined with an average price decrease of approximately 3.4%. This scenario, however, proves costly for consumers in Europe: their aggregate consumer surplus declines by $3.12 billion, compared with losses of $1.29 billion in the benchmark scenario in which Huawei "simply" loses access to GMS. For further details on the effects, we refer to Table A.11 and Table A.12 in the Appendix.

5.4 Comparison of total effects across various scenarios

Table 7 compares the total effects of various variables across the various counterfactual scenarios. To put the predicted changes in consumer surplus, producer surplus, total welfare, and sales volume in perspective, it is useful to first look at several relevant variables before the sanctions. Total observed revenues across the 27 countries over the focal period amounted to $167.3 billion, and estimated total variable profits amounted to $54.7 billion. Finally, total observed sales reached 348 million units between Q2 2019 and Q2 2020.

Table 7: Overall Impact of Sanctions on Market Outcomes

			Π	W	Q	
No Sanction (CF0)			54.73	122.58	0.35	
	ΔCS	ΔCS Eur.	$\Delta\Pi$	ΔW	$\Delta Q(\%)$	$\Delta P(\%)$
GMS Removal (CF1)	-1.31	-1.29	-0.55	-1.86	-2.0	-0.6
GMS & 5G Removal (CF2)	-1.33	-1.31	-0.55	-1.88	-2.0	-0.6
Sell Honor (coordinate) (CF3)	-0.89	-0.89	-0.34	-1.23	-1.3	-0.5
Sell Honor (compete) (CF4)	-0.75	-0.75	-0.42	-1.17	-1.1	-0.6
Huawei Removal (CF5)	-3.15	-3.12	-0.77	-3.92	-4.7	-5.1

Notes: Changes in consumer surplus, profits, total welfare, and quantity are measured in billion. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

As mentioned earlier, removing Android GMS from all Huawei phones is equivalent to a $1.31 billion loss in consumer welfare. At the same time, manufacturers experience a significant decline in total profits (of about $554 million), primarily driven by reduced consumer demand. Both consumers and firms are substantially worse off when product quality deteriorates in the market. The largest losses in total welfare arise under the "worst-case" scenario in which Huawei exits the market entirely, primarily driven by a substantial decline in consumer surplus. Relative to the benchmark scenario (CF1), the divestiture scenarios appear less harmful for both consumers and manufacturers, with total welfare losses of approximately $1.2 billion.

Overall, our counterfactual analyses indicate that the trade shock examined in this paper affected a substantial number of firms and consumers in the European market, resulting in economically meaningful welfare losses. Consistent with the existing literature, our findings further suggest that sanctions can generate welfare reductions within the targeted industry.

5.5 Sensitivity to assumptions

In this section, we discuss additional counterfactuals conducted under alternative assumptions on both the demand and supply sides. Specifically, we re-evaluate scenarios CF1–CF5 using an alternative demand specification that accounts for brand reputation effects (as discussed in Section 4.3) and an alternative supply-side specification assuming constant returns to scale.

Counterfactual analyses accounting for brand reputation effects To account for a possible brand reputation loss, we extend the demand model by including a dummy variable for Huawei after the sanctions, and we estimate a sizable coefficient. The updated counterfactuals indicate that losses for both consumers and manufacturers are substantially larger when reputation effects are taken into account, compared with the baseline specification that abstracts from reputation loss. For example, under the earlier benchmark scenario CF1, consumer surplus losses are estimated at $1.31 billion, industry profit losses at $0.55 billion, and total welfare losses at $1.86 billion. Once reputation effects are incorporated, the losses are estimated to be almost twice as large: consumer surplus declines by $2.44 billion, industry profits fall by $1.01 billion, and total welfare losses reach $3.45 billion. These large losses are driven by a perceived quality shock affecting a substantial share of consumers choosing Huawei smartphones. Tables A.4 and A.5 in Appendix A.3.2 present the model estimates after accounting for reputation effects. Table A.13 presents the updated counterfactual changes in consumer surplus, profits, and total welfare. Figure A.10 and Tables A.14 and A.15 provide further breakdowns by brand, region, and country.

Counterfactual analyses with constant returns to scale Our main specification allowed for non-constant returns to scale, where the marginal cost of product j depends on its total sales across all countries in quarter t (Model III in Table 4). We also considered a more restrictive specification in which marginal costs do not depend on quantity (Model I). Relative to our baseline specification, the estimated effects remain broadly similar in magnitude but become somewhat more pronounced, with larger losses for both consumers and producers across all scenarios. For further details, we refer to Appendix A.5.2. Table A.16 summarizes the overall estimated changes in market outcomes, whereas Figure A.11 and Tables A.17 and A.18 report corresponding breakdowns by brand, region, and country.

6 Conclusion

This paper studies the economic incidence of technology sanctions in global product markets. We analyze the effects of U.S. restrictions on Huawei's access to key technologies in the smartphone industry, focusing on outcomes in both the United States and Europe. We first document that the sanctions led to large declines in Huawei's prices and sales volumes, consistent with a negative demand shock following the firm's loss of access to Google Mobile Services and 5G chipsets.

To quantify the effectiveness of the sanctions and their market implications, we develop and estimate a differentiated-products oligopoly model of smartphone demand and supply. The estimates indicate that consumers place substantial value on the attributes targeted by the sanctions, particularly GMS and 5G connectivity. Consistent with this, our counterfactual analysis shows that the sanctions were highly effective in reducing Huawei's profits, while shifting demand towards competing manufacturers such as Samsung and Xiaomi. Apple benefits only modestly from the reallocation of demand, suggesting that there may be no immediate industrial policy motive for the U.S. sanctions.

A central finding of the paper concerns the international incidence of the sanctions. While the restrictions have negligible effects on U.S. consumers, they imply considerable losses for European consumers, particularly in Western and Eastern regions. Consumer losses amount to \$1.31 billion from Huawei's lost access to GMS and 5G, and up to \$3.12 billion in a long-run scenario where Huawei entirely exits the market.

These findings highlight an important feature of technology sanctions in global industries: in contrast to tariff sanctions, their economic costs need not fall primarily on consumers in the sanctioning country. Instead, they can be transmitted through international product markets and be borne by consumers in third countries. This mechanism is particularly relevant in industries with globally shared technology ecosystems.

Our analysis focuses on the short-run effects in the smartphone industry and includes a simplifying long-run scenario in which Huawei entirely exits. Future research could benefit from access to more recent data to explore longer-run adjustments to the sanctions in more detail, including changes in product innovation and entry and exit. Such adjustments may further shape the incidence of the restrictions on consumers. It would also be valuable to collect data on the upstream segment of the supply chain—specifically the chipset manufacturing industry—to investigate potential spillover effects of the sanctions on chip producers. Although U.S. brands do not experience direct negative impacts from the ban on Huawei, the major chip manufacturers— primarily U.S. firms such as TSMC, Qualcomm, and Intel—may be affected as Huawei has shifted away from U.S. chip suppliers and has accelerated the development of its own in-house chipsets. As a result, trade sanctions may also have side effects on U.S. upstream firms.

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Appendix

A.1 Industry Background

Figure A.1: Share of Huawei's Global Annual Smartphone Sales Attributed to Europe (2010–2020)

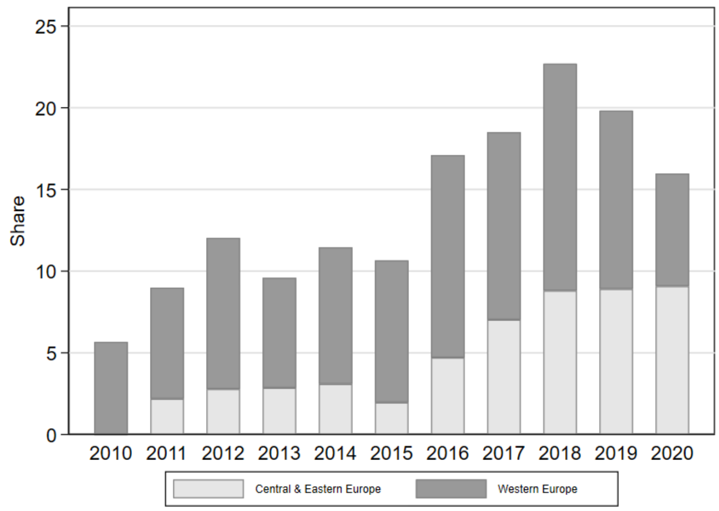


Figure A.2: Huawei's Smartphone Market Share in the U.S., China, and 26 European Countries

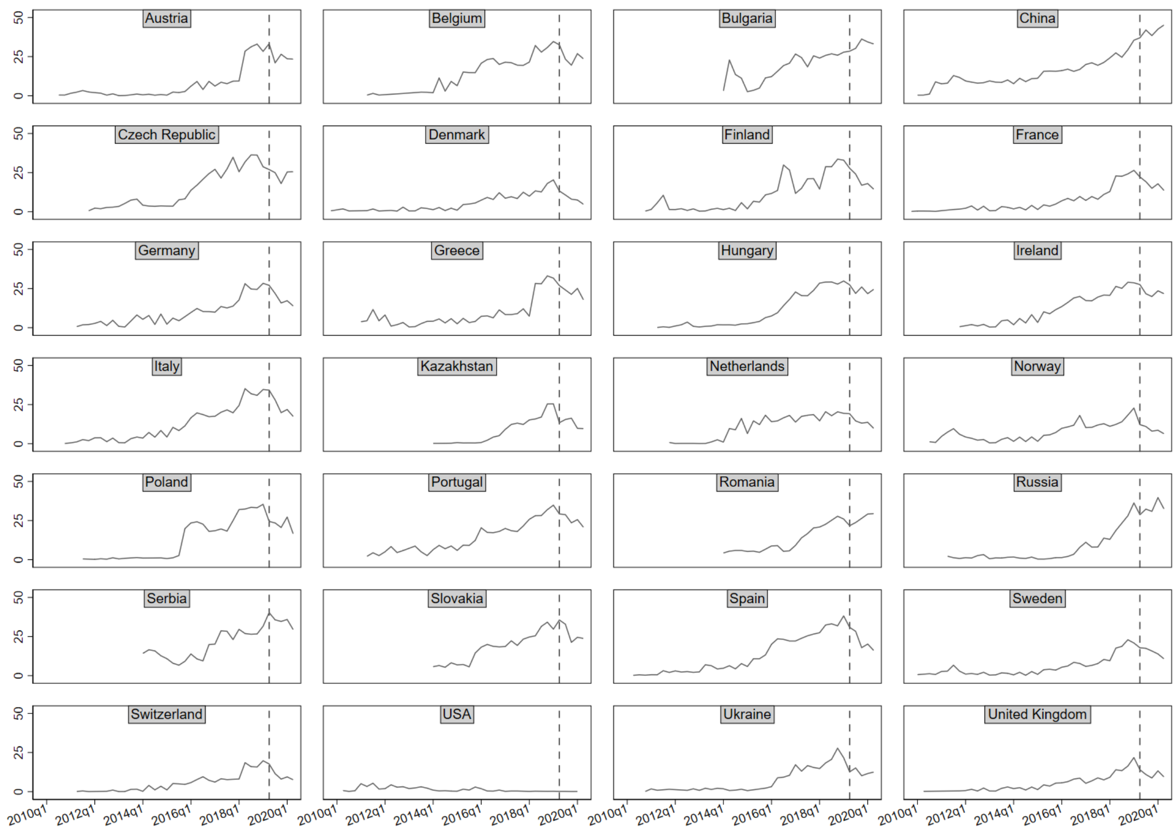


Figure A.3: Timeline of Key Policy Actions and Trade Restrictions Affecting Huawei

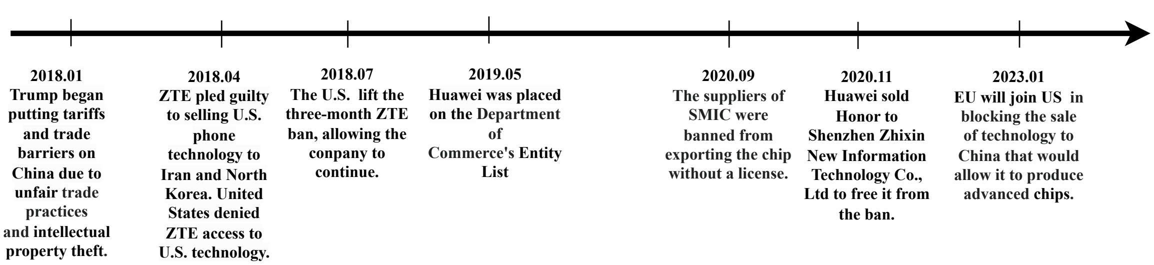


Figure A.4: Key Hardware and Software Components of a Smartphone

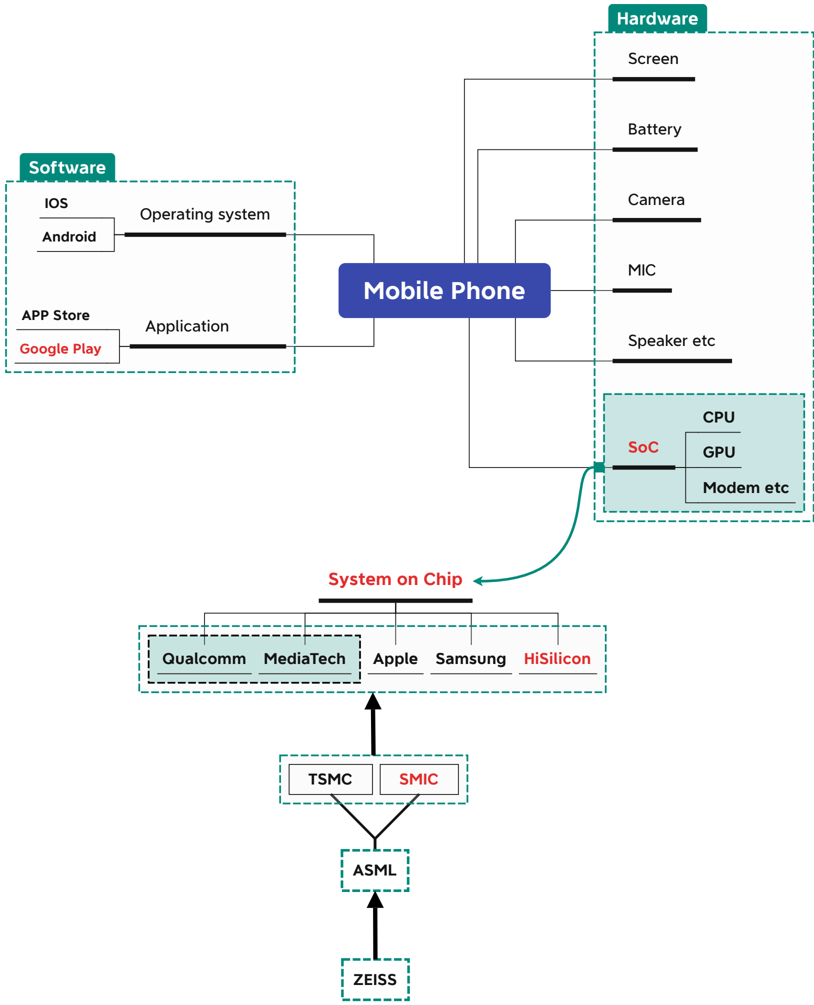


Figure A.4 illustrates the relationships among the components of smartphones. SoC is crucial because it integrates a mobile application processor (a CPU), GPU, modem, and other chips (Yang, 2020). Standard hardware components, such as the screen, battery, camera, and microphone, are included. Most OEMs (original equipment manufacturers) buy SoCs from Qualcomm and MediaTek. In 2014, Huawei developed the Kirin and subsequently applied it to its flagship smartphones. Samsung developed its own SoCs (Exynos) and supplied Samsung and Meizu phones. Apple is unusual among handset OEMs because it uses thin modems (from Qualcomm), in conjunction with its own proprietary application processor.

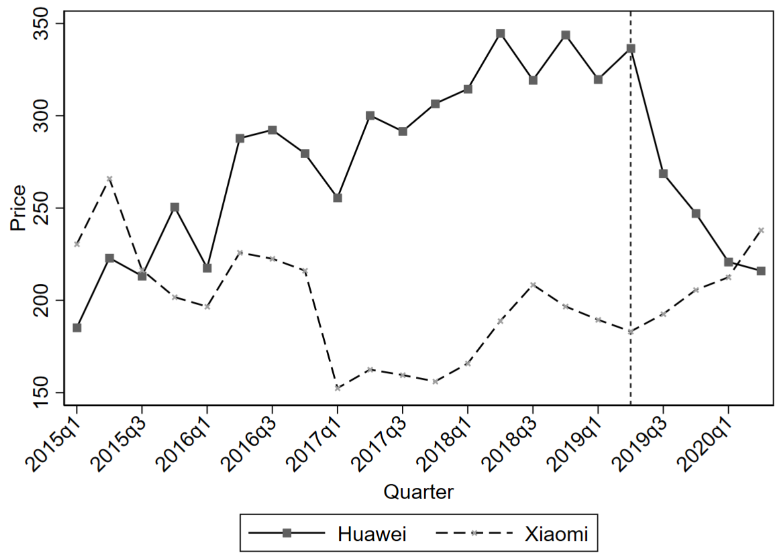
Among chip manufacturers, Taiwan Semiconductor Manufacturing Corporation (TSMC), the world's largest contract chipmaker and a key supplier to Huawei, must halt new orders from Huawei following the ban. The largest contract chipmaker in mainland China, Semiconductor Manufacturing International Corporation (SMIC), cannot produce chips for Huawei because the firms' production relies heavily on U.S.

equipment and raw materials. In 2019, the Trump administration pressed Dutch officials to cancel the sale of an Extreme ultraviolet lithography (EUVL) machine to SMIC. At that time, Advanced Semiconductor Materials Lithography (ASML) was required to cease renewing the license required to ship the tool. SMIC, as Huawei's alternative manufacturer, has also been severely impacted by the trade conflict.[17]

[17] ASML is the only company in the world that owns the technology and makes the machinery to make physical chips out of silicon wafers. Chipmakers such as TSMC, NVIDIA, and Intel won't be able to manufacture chips without ASML's EUV technology.

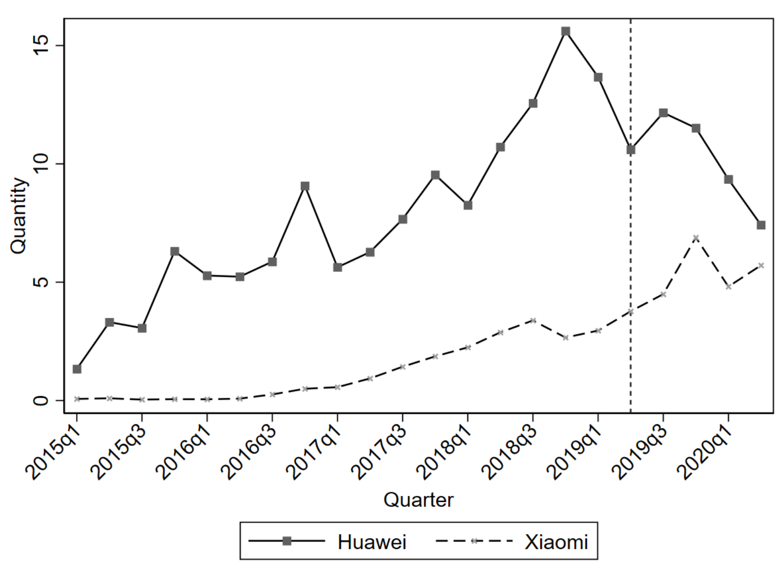
A.2 Additional Descriptive Statistics

Figure A.5: Quarterly Average Smartphone Prices for Huawei (and Honor) and Xiaomi in Europe (in USD)



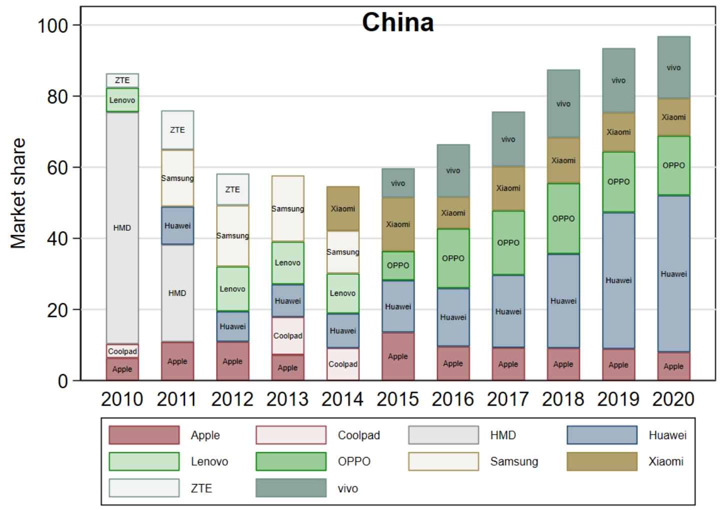
Notes: Vertical line indicates Huawei's placement on the U.S. Entity List. Here, the line for "Huawei" combines sales for Huawei and Honor's smartphones.

Figure A.6: Quarterly Smartphone Sales for Huawei (and Honor) and Xiaomi in Europe (in Million Units)



Notes: Vertical line indicates Huawei's placement on the U.S. Entity List. Here, the line for "Huawei" combines sales for Huawei and Honor's smartphones.

Figure A.7: Market Share of the Top 5 Smartphone Brands in China (2010–2020)



A.3 Additional Estimation Results

A.3.1 Main demand model: First stages and elasticities

Table A.1: First-Stage Regressions

	(1)	(2)	(3)	(4)
$Z_{num,all}$	0.067***	0.064***	0.050***	-0.004**
	(0.001)	(0.001)	(0.001)	(0.001)
$Z_{num,same}$	0.178***	0.115***	0.134***	0.093***
	(0.005)	(0.004)	(0.004)	(0.004)
$Z_{ScreenSize,same}$	-0.061***	-0.044***	-0.044***	-0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
$Z_{Megapixels,same}$	-0.000***	0.000	0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{NFC,same}$	0.023***	-0.040***	-0.047***	-0.011***
	(0.001)	(0.001)	(0.001)	(0.001)
$Z_{Storage,same}$	0.002***	0.001***	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{Cores,same}$	0.010***	0.011***	0.011***	0.009***
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{ScreenSize,other}$	-0.013***	-0.012***	-0.009***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{Megapixels,other}$	-0.000***	-0.000***	-0.000***	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{NFC,other}$	-0.008***	-0.004***	-0.013***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{Storage,other}$	0.001***	0.001***	0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
$Z_{Cores,other}$	0.000***	-0.000	-0.000*	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Brand FE	No	Yes	Yes	Yes
Country FE	No	No	Yes	Yes
Year-Quarter FE	No	No	No	Yes
R^2	0.651	0.729	0.740	0.778
F-statistic	2,125.5	2,317.0	2,727.6	120.3

Notes: Estimates based on 141,805 product-level observations in 27 countries during 2010Q1-2020Q2. Standard errors are shown in parentheses. Observed characteristics are included in all regressions. The F-statistic is computed for the subset of excluded instruments.

Table A.2: Model-Implied Own-Price Elasticity and Markup Distributions of All Local Minima

	1^{st}	25^{th}	Median	75^{th}	99^{th}
Elasticities	**-13.00**	**-5.79**	**-3.23**	**-2.01**	**-1.67**
	[-13.68, -12.23]	[-6.13, -5.39]	[-3.43, -3.01]	[-2.13, -1.87]	[-1.24, -1.09]
Markup	**11.0%**	**22.2%**	**35.9%**	**55.0%**	**102.8%**
	[10.3%, 11.8%]	[20.9%, 23.8%]	[33.8%, 38.5%]	[51.7%, 58.9%]	[96.7%, 110.3%]

Notes: The bold numbers represent the average value of the own-price elasticity. The numbers in brackets are the corresponding minimum and maximum values.

Table A.3: Demand Elasticities with Respect to Price: Top 10 Products in Q2 2020 in France

Brand	**Product**	A51	A20e	A41	A21s	A10	iPhone 11 128GB	A71	iPhone 11 256GB	iPhone 11 64GB	P Smart
Samsung	Galaxy A51	-3.63	0.06	0.05	0.03	0.02	0.07	0.06	0.07	0.06	0.02
Samsung	Galaxy A20e	0.15	-1.66	0.03	0.02	0.05	0.06	0.04	0.05	0.05	0.05
Samsung	Galaxy A41	0.09	0.02	-3.44	0.03	0.01	0.05	0.05	0.05	0.04	0.00
Samsung	Galaxy A21s	0.08	0.03	0.04	-2.15	0.01	0.04	0.04	0.04	0.03	0.01
Samsung	Galaxy A10	0.14	0.12	0.03	0.02	-1.51	0.05	0.04	0.05	0.05	0.05
Apple	iPhone 11-128GB	0.08	0.03	0.03	0.01	0.01	-8.34	0.03	0.61	0.49	0.01
Samsung	Galaxy A71	0.13	0.04	0.05	0.03	0.01	0.07	-4.73	0.07	0.05	0.01
Apple	iPhone 11-256GB	0.08	0.02	0.03	0.01	0.01	0.65	0.03	-8.87	0.49	0.01
Apple	iPhone 11-64GB	0.08	0.03	0.03	0.01	0.01	0.63	0.03	0.58	-7.50	0.01
Huawei	P Smart (2019)	0.13	0.15	0.02	0.01	0.06	0.05	0.03	0.04	0.04	-1.59

A.3.2 Accounting for brand reputation effects

Table A.4: Estimation Results from Discrete Choice Models of Smartphone Demand (with Reputation Loss)

	Model I Logit-GMM		**Model II** RCL			
	Mean	s.e.	Mean	s.e.	Std. Dev.	s.e.
Price	0.702	0.042	1.392	0.117	0.301	0.098
Screen Size	0.682	0.052	1.349	0.104	0.017	0.558
Megapixels	0.011	0.001	0.014	0.002		
Storage	0.073	0.006	0.127	0.015		
NFC	0.494	0.031	0.930	0.071		
Age	-0.181	0.002	-1.150	0.087	0.716	0.049
Android GMS	0.922	0.063	0.733	0.084		
Android No GMS	0.039	0.121	-0.205	0.213		
iOS	6.071	0.274	5.330	0.457	3.510	0.434
Windows	0.711	0.070	0.882	0.097		
Symbian	1.360	0.076	1.765	0.110		
BlackBerry	1.983	0.093	1.905	0.143		
Cores	0.135	0.009	0.260	0.019		
Cellular Network: 3G	1.018	0.079	1.559	0.118		
Cellular Network: 4G	1.535	0.099	2.394	0.161		
Cellular Network: 5G	2.715	0.200	4.076	0.428		
HuaweiPost	-0.296	0.041	-0.212	0.067		
$\bar{\eta}_{jj}$	-2.52		-4.91			
$\#\eta_{jj} > -1$	21,446		39			
$mc(\$)$	212.5		267.9			

Notes: Estimates based on 141,805 product-level observations in 27 countries during 2010Q1-2020Q2. Country, brand, and year-quarter fixed effects are included. The base category for operating systems includes other, more marginal operating systems, as discussed in the text. The estimation procedure uses 1,000 modified Latin hypercube sampling (MLHS) draws and takes 10 different starting values for the nonlinear coefficients. $HuaweiPost$ is a binary variable equal to one for observations after May 2019. To capture Huawei's growth phase after 2017, we also include an indicator for the post-2017 period.

Table A.5: Estimation Results from Supply-Side Models of Smartphone Marginal Costs (with Reputation Loss)

	Model I OLS		**Model II** OLS		**Model III** 2SLS	
	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
$\ln(Q_{jt})$			-0.093	0.001	-0.055	0.001
Screen Size	0.665	0.003	0.692	0.003	0.681	0.003
Megapixels	0.016	0.000	0.018	0.000	0.017	0.000
Storage	0.041	0.000	0.040	0.000	0.041	0.000
Android GMS	-0.120	0.019	0.001	0.019	-0.049	0.019
Android No GMS	-0.203	0.036	-0.151	0.035	-0.173	0.035
iOS	1.415	0.052	1.909	0.050	1.705	0.051
Windows	0.096	0.021	0.153	0.020	0.129	0.020
Symbian	0.214	0.022	0.304	0.021	0.267	0.021
BlackBerry	-0.341	0.028	-0.093	0.027	-0.195	0.028
Cellular Network: 3G	0.528	0.019	0.580	0.018	0.559	0.018
Cellular Network: 4G	1.053	0.020	1.180	0.019	1.128	0.019
Cellular Network: 5G	1.303	0.028	1.338	0.027	1.324	0.027
$\hat{\xi}_{jt}$	0.122	0.001	0.154	0.001	0.141	0.001
Year-Quarter FE	Yes		Yes		Yes	
Country FE	Yes		Yes		Yes	
Brand FE	Yes		Yes		Yes	

Notes: Estimates based on 140,978 product-level observations in 27 countries during 2010Q1-2020Q2. The base category for operating systems includes other, more marginal operating systems, as discussed in the text.

Table A.6: Model-Implied Own-Price Elasticity and Markup Distributions of All Local Minima (with Reputation Loss)

	1^{st}	25^{th}	Median	75^{th}	99^{th}
Elasticities	**-14.89**	**-6.63**	**-3.71**	**-2.30**	**-1.34**
	[-15.34, -14.15]	[-6.85, -6.23]	[-3.83, -3.48]	[-2.38, -2.16]	[-1.38, -1.26]
Markup	**9.5%**	**19.6%**	**31.7%**	**48.2%**	**92.3%**
	[9.2%, 10.2%]	[18.9%, 20.8%]	[30.6%, 33.7%]	[46.6% 51.3%]	[89.2%, 98.3%]

Notes: The bold numbers represent the average value of the own-price elasticity. The numbers in brackets are the corresponding minimum and maximum values.

A.4 Additional Results from the Counterfactuals

A.4.1 Results from Counterfactual 1

Figure A.8: Total Consumer Welfare Changes by Country (CF1)

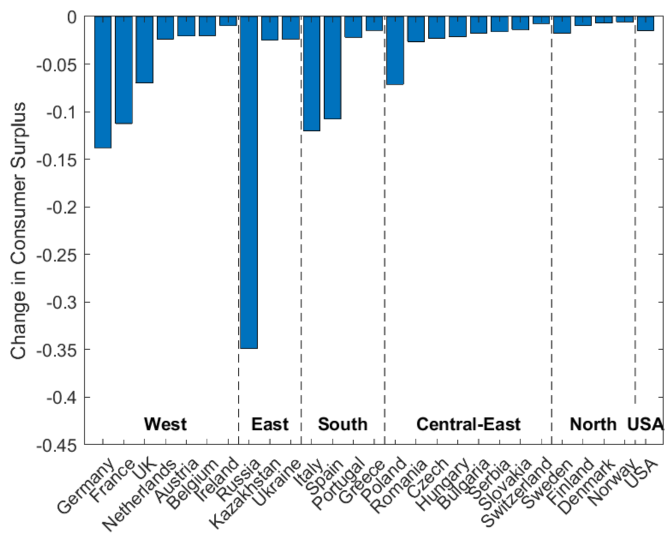
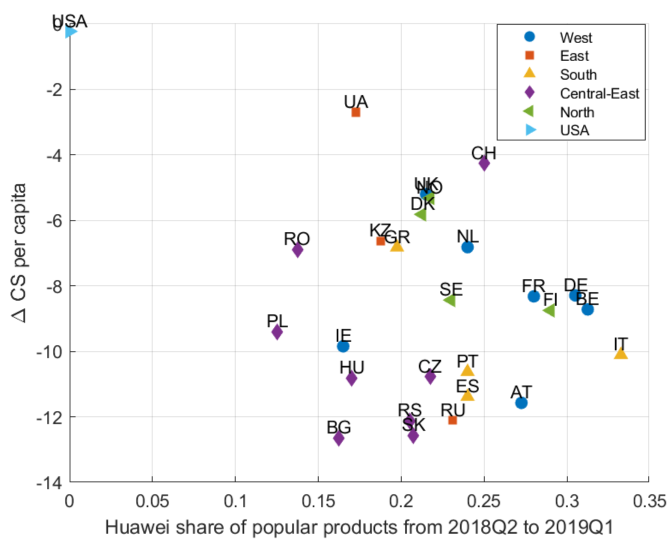


Figure A.9: Change in Consumer Surplus and Share of Popular Huawei Products by Country (CF1)



Note: Change in consumer surplus per capita. Popular products are defined as the top 100 models by sales volume within each country-quarter. On average, these products accounted for approximately 60% of total market share at the country-quarter level between Q2 2018 and Q1 2019.

A.4.2 Results from Counterfactual 2

Table A.7: Impact of Huawei's Lost Access to GMS and 5G on Main Brands (CF2)

		No Sanction (CF0)		**GMS & 5G Removal (CF2−CF0)**			
Origin	**Brand**	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	9.04	3.03	-0.89	-29.5	-26.2	-10.8
China	**Honor**	2.03	1.06	-0.41	-39.2	-35.7	-9.1
China	Xiaomi	4.14	1.73	0.09	5.5	4.6	0.2
China	OPPO	0.81	0.23	0.01	4.9	4.8	-0.2
China	Others	5.79	2.07	0.04	1.9	1.9	-0.1
Korea	Samsung	43.02	11.49	0.35	3.0	2.0	0.2
U.S.	Apple	95.32	32.55	0.21	0.6	0.5	0.1
	Others	8.15	2.57	0.05	2.1	2.1	-0.1
	Total	168.30	54.73	-0.55	-1.0	-2.0	-0.6

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Table A.8: Impact of Huawei's Lost Access to GMS and 5G on Consumers by Geographic Region (CF2)

	No Sanction (CF0)	**GMS & 5G Removal (CF2−CF0)**		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.23	-0.41	-2.2	-1.0
East	9.80	-0.40	-7.0	-1.4
South	13.95	-0.27	-3.5	-1.8
Central-East	9.32	-0.20	-4.1	-1.8
North	6.40	-0.04	-1.5	-0.7
USA	85.61	-0.01	0.0	0.0
Total	168.30	-1.33	-2.0	-0.6

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

A.4.3 Results from Counterfactuals 3 and 4

Table A.9: Impact of Honor's Divestiture on Main Brands (CF3 & CF4)

		No Sanction (CF0)		**Sell Honor (coordinate) (CF3−CF0)**				**Sell Honor (compete) (CF4−CF0)**			
Origin	**Brand**	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	9.04	3.03	-0.90	-29.7	-27.0	-10.6	-0.91	-29.9	-25.3	-11.6
China	**Honor**	2.03	1.06	0.03	3.0	4.7	-1.0	0.03	3.1	10.5	-3.6
China	Xiaomi	4.14	1.73	0.07	3.8	3.1	0.1	0.06	3.3	2.7	0.1
China	OPPO	0.81	0.23	0.01	3.1	3.0	-0.1	0.01	2.7	2.6	-0.1
China	Others	5.79	2.07	0.03	1.4	1.3	0.0	0.02	1.1	1.1	0.0
Korea	Samsung	43.02	11.49	0.25	2.1	1.4	0.2	0.21	1.8	1.2	0.1
U.S.	Apple	95.32	32.55	0.14	0.4	0.4	0.0	0.12	0.4	0.3	0.0
	Others	8.15	2.57	0.04	1.6	1.6	0.0	0.03	1.4	1.3	0.0
	Total	168.30	54.73	-0.34	-0.6	-1.3	-0.5	-0.42	-0.8	-1.1	-0.6

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Table A.10: Impact of Honor's Divestiture on Consumers by Geographic Region (CF3 & CF4)

	No Sanction (CF0)	**Sell Honor (coordinate) (CF3−CF0)**			**Sell Honor (compete) (CF4−CF0)**		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.23	-0.33	-1.8	-0.9	-0.28	-1.6	-1.0
East	9.80	-0.10	-1.8	-0.5	-0.06	-1.2	-1.0
South	13.95	-0.24	-3.2	-1.7	-0.22	-2.9	-1.9
Central-East	9.32	-0.18	-3.7	-1.7	-0.16	-3.5	-1.8
North	6.40	-0.03	-1.1	-0.6	-0.02	-0.8	-0.7
USA	85.61	-0.01	0.0	0.0	-0.01	0.0	0.0
Total	168.30	-0.89	-1.3	-0.5	-0.75	-1.1	-0.6

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.
[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

A.4.4 Results from Counterfactual 5

Table A.11: Impact of Huawei's Exit on Main Brands (CF5)

		No Sanction (CF0)		**Huawei Removal (CF5−CF0)**			
Origin	**Brand**	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	9.04	3.03	-	-	-	-
China	**Honor**	2.03	1.06	0.11	10.4	17.7	-3.4
China	Xiaomi	4.14	1.73	0.23	13.3	10.7	0.5
China	OPPO	0.81	0.23	0.03	11.1	10.7	-0.4
China	Others	5.79	2.07	0.12	5.6	5.5	-0.2
Korea	Samsung	43.02	11.49	1.00	8.7	5.0	0.7
U.S.	Apple	95.32	32.55	0.61	1.9	1.4	0.2
	Others	8.15	2.57	0.17	6.8	6.6	-0.2
	Total	168.30	54.73	-0.77	-1.4	-4.7	-5.1

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Table A.12: Impact of Huawei's exit on Consumers by Geographic Region (CF5)

	No Sanction (CF0)	**Huawei Removal (CF5−CF0)**		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.23	-1.31	-7.7	-8.6
East	9.80	-0.23	-4.4	-6.4
South	13.95	-0.83	-11.6	-16.6
Central-East	9.32	-0.60	-12.7	-16.6
North	6.40	-0.15	-5.7	-5.9
USA	85.61	-0.03	0.0	0.0
Total	168.30	-3.15	-4.7	-5.1

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

A.5 Sensitivity to assumptions

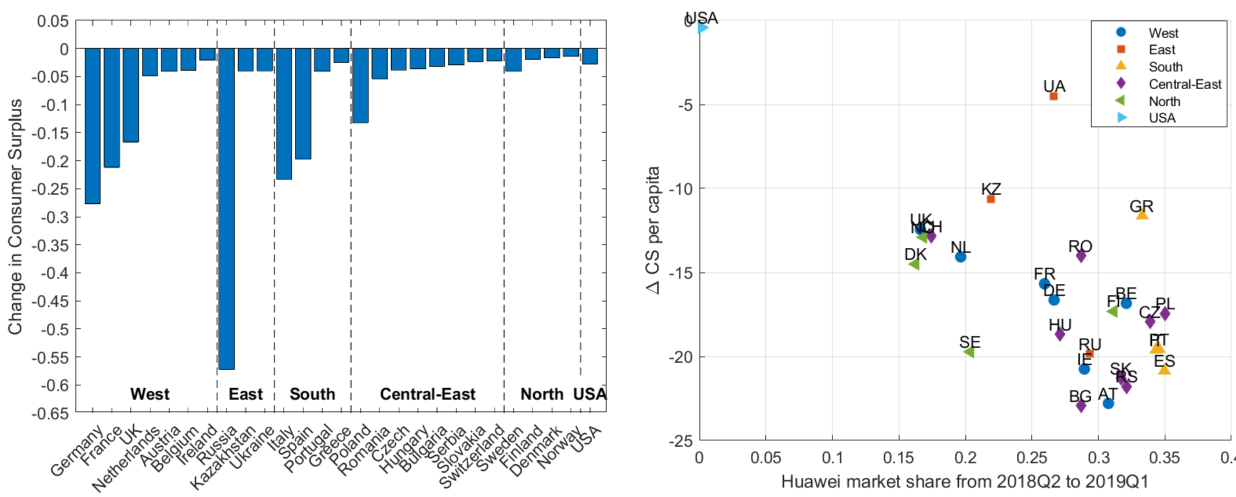
A.5.1 Counterfactuals accounting for brand reputation effects

Table A.13: Overall Impact of Sanctions on Market Outcomes (with Reputation Loss)

			Π	W	Q	
No Sanction (CF0)			51.26	115.82	0.35	
	ΔCS	ΔCS Eur.	$\Delta\Pi$	ΔW	$\Delta Q(\%)$	$\Delta P(\%)$
GMS Removal (CF1)	-2.44	-2.41	-1.01	-3.45	-4.1	-0.5
GMS & 5G Removal (CF2)	-2.46	-2.43	-1.01	-3.47	-4.2	-0.5
Sell Honor (coordinate) (CF3)	-1.93	-1.91	-0.76	-2.69	-3.2	-0.4
Sell Honor (compete) (CF4)	-1.81	-1.79	-0.84	-2.65	-3.0	-0.5
Huawei Removal (CF5)	-3.59	-3.56	-1.01	-4.60	-5.9	-5.1

Notes: Changes in consumer surplus, profits, total welfare, and quantity are measured in billion. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Figure A.10: Change in Consumer Surplus and Share of Popular Huawei Products by Country (with Reputation Loss)



Note: Huawei's market share is calculated using sales unit data from the year preceding the shock.

Table A.14: Impact of Huawei's Lost Access to GMS on Main Brands (with Reputation Loss)

		CF0: No Sanction		CF1: GMS Removal				CF2: GMS & 5G Removal				CF3: Sell Honor (coordinate)				CF4: Sell Honor (compete)				CF5: Huawei Removal			
Oringin	Brand	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	11.05	3.39	-1.79	-52.9	-48.2	-9.5	-1.81	-53.4	-48.7	-9.2	-1.82	-53.9	-49.8	-9.0	-1.83	-53.9	-48.3	-10.0	-	-	-	-
China	**Honor**	2.46	1.20	-0.69	-57.5	-52.7	-9.7	-0.69	-57.7	-52.9	-9.6	-0.14	-11.9	-7.3	-2.5	-0.14	-11.9	-2.7	-4.6	-0.08	-6.3	2.9	-4.3
China	Xiaomi	4.00	1.48	0.17	11.5	9.7	0.3	0.17	11.6	9.8	0.3	0.13	9.1	7.6	0.2	0.13	8.6	7.1	0.2	0.27	18.0	14.6	0.5
China	OPPO	0.78	0.20	0.02	10.5	10.2	-0.4	0.02	10.8	10.5	-0.4	0.02	8.0	7.8	-0.3	0.02	7.6	7.3	-0.3	0.03	15.5	15.0	-0.6
China	Others	5.68	1.81	0.08	4.2	4.2	-0.1	0.08	4.3	4.3	-0.2	0.06	3.5	3.5	-0.1	0.06	3.3	3.2	-0.1	0.13	7.4	7.3	-0.3
Korea	Samsung	42.30	10.08	0.69	6.8	4.4	0.4	0.70	6.9	4.5	0.4	0.57	5.6	3.6	0.4	0.53	5.3	3.4	0.3	1.15	11.4	6.6	0.8
U.S.	Apple	94.86	30.86	0.40	1.3	1.1	0.1	0.41	1.3	1.1	0.1	0.33	1.1	0.9	0.1	0.31	1.0	0.8	0.1	0.67	2.2	1.7	0.2
	Others	8.01	2.25	0.11	4.7	4.7	-0.1	0.11	4.8	4.7	-0.1	0.09	4.1	4.0	-0.1	0.08	3.8	3.7	-0.1	0.20	8.8	8.6	-0.2
	Total	169.15	51.26	-1.01	-2.0	-4.1	-0.5	-1.01	-2.0	-4.2	-0.5	-0.76	-1.5	-3.2	-0.4	-0.84	-1.6	-3.0	-0.5	-1.01	-2.0	-5.9	-5.1

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Table A.15: Impact of Huawei's Lost Access to GMS on Consumers by Geographic Region (with Reputation Loss)

	CF0: No Sanction	CF1: GMS Removal			CF2: GMS & 5G Removal			CF3: Sell Honor(coordinate)			CF4: Sell Honor (compete)			CF5: Huawei Removal		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.55	-0.80	-5.1	-0.7	-0.82	-5.1	-0.6	-0.73	-4.6	-0.6	-0.69	-4.3	-0.7	-1.43	-9.2	-8.6
East	10.02	-0.65	-12.0	-1.5	-0.65	-12.0	-1.5	-0.29	-5.5	-0.6	-0.25	-4.9	-1.1	-0.39	-7.6	-6.7
South	14.18	-0.50	-7.1	-1.5	-0.50	-7.2	-1.4	-0.47	-6.8	-1.4	-0.44	-6.5	-1.6	-0.91	-13.4	-16.7
Central-East	9.50	-0.37	-8.2	-1.4	-0.37	-8.3	-1.3	-0.35	-7.8	-1.2	-0.33	-7.6	-1.4	-0.67	-15.0	-16.6
North	6.42	-0.09	-3.8	-0.3	-0.09	-3.9	-0.3	-0.08	-3.3	-0.3	-0.07	-3.1	-0.4	-0.16	-6.9	-5.9
USA	85.49	-0.03	0.0	0.0	-0.03	0.0	0.0	-0.02	0.0	0.0	-0.02	0.0	0.0	-0.03	0.0	0.0
Total	169.15	-2.44	-4.1	-0.5	-2.46	-4.2	-0.5	-1.93	-3.2	-0.4	-1.81	-3.0	-0.5	-3.59	-5.9	-5.1

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

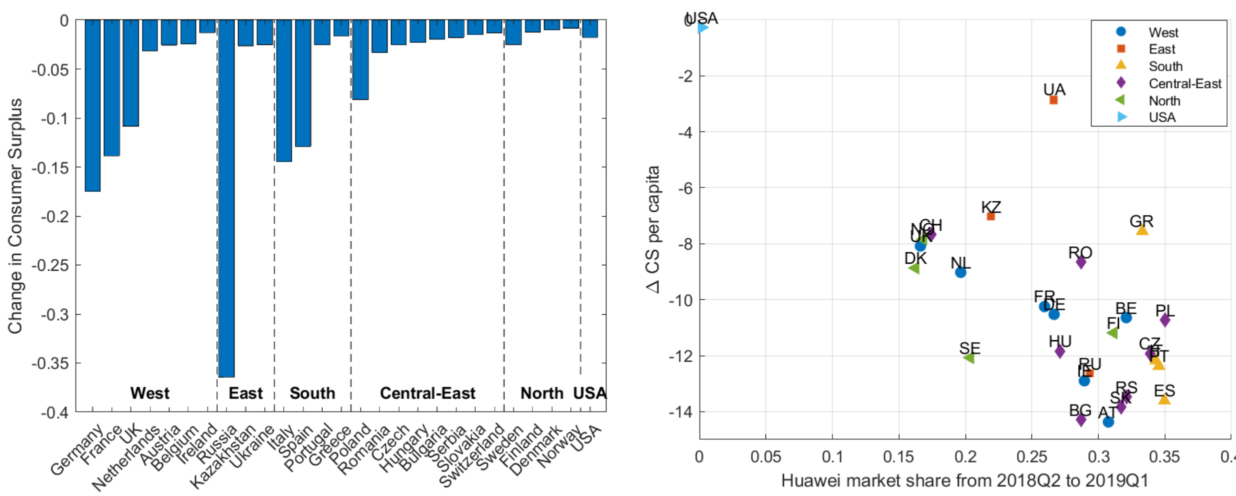
A.5.2 Counterfactuals with constant returns to scale

Table A.16: Overall Impact of Sanctions on Market Outcomes (with Constant Returns to Scale)

			Π	W	Q	
No Sanction (CF0)			54.70	122.49	0.35	
	ΔCS	ΔCS Eur.	$\Delta\Pi$	ΔW	$\Delta Q(\%)$	$\Delta P(\%)$
GMS Removal (CF1)	-1.55	-1.53	-0.64	-2.19	-2.4	-0.4
GMS & 5G Removal (CF2)	-1.55	-1.53	-0.63	-2.18	-2.4	-0.4
Sell Honor (coordinate) (CF3)	-1.10	-1.09	-0.41	-1.51	-1.6	-0.4
Sell Honor (compete) (CF4)	-0.98	-0.97	-0.48	-1.46	-1.5	-0.4
Huawei Removal (CF5)	-3.34	-3.31	-0.87	-4.21	-5.0	-5.0

Notes: Changes in consumer surplus, profits, total welfare, and quantity are measured in billion.The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Figure A.11: Change in Consumer Surplus and Share of Popular Huawei Products by Country (with Constant Returns to Scale)



Note: Huawei's market share is calculated using sales unit data from the year preceding the shock.

Table A.17: Impact of Huawei's Lost Access to GMS on Main Brands (with Constant Returns to Scale)

		CF0: No Sanction		CF1: GMS Removal				CF2: GMS & 5G Removal				CF3: Sell Honor (coordinate)				CF4: Sell Honor (compete)				CF5: Huawei Removal			
Oringin	Brand	R	Π	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$	$\Delta\Pi$	$\Delta\Pi(\%)$	$\Delta Q(\%)$	$\Delta P(\%)$
China	**Huawei**	9.09	3.04	-1.04	-34.3	-30.8	-8.8	-1.04	-34.2	-30.7	-9.2	-1.07	-35.0	-32.1	-8.5	-1.07	-35.3	-30.6	-9.3	-	-	-	-
China	**Honor**	2.03	1.06	-0.42	-40.2	-36.5	-8.3	-0.43	-40.3	-36.6	-8.3	0.03	3.1	5.1	-1.0	0.03	2.9	10.2	-3.3	0.10	9.5	16.7	-2.9
China	Xiaomi	4.14	1.73	0.10	5.6	4.8	0.3	0.10	5.7	4.8	0.4	0.07	4.1	3.3	0.3	0.06	3.6	3.0	0.2	0.22	12.8	10.2	0.9
China	OPPO	0.81	0.23	0.01	4.8	4.7	0.0	0.01	4.8	4.7	0.0	0.01	3.3	3.2	0.0	0.01	3.0	2.9	0.0	0.02	10.0	9.6	0.1
China	Others	5.79	2.07	0.04	2.0	2.0	0.0	0.04	2.0	2.0	0.0	0.03	1.5	1.5	0.0	0.03	1.3	1.3	0.0	0.11	5.2	5.1	0.1
Korea	Samsung	43.02	11.49	0.38	3.3	2.2	0.3	0.38	3.4	2.2	0.3	0.29	2.5	1.6	0.3	0.26	2.3	1.4	0.2	0.96	8.4	4.7	0.9
U.S.	Apple	95.31	32.51	0.24	0.7	0.6	0.1	0.24	0.7	0.6	0.1	0.18	0.6	0.4	0.1	0.16	0.5	0.4	0.1	0.60	1.8	1.3	0.2
	Others	8.15	2.57	0.06	2.3	2.2	0.0	0.06	2.3	2.2	0.0	0.05	1.8	1.8	0.0	0.04	1.6	1.6	0.0	0.16	6.3	6.2	0.1
	Total	168.35	54.70	-0.64	-1.2	-2.4	-0.4	-0.63	-1.2	-2.4	-0.4	-0.41	-0.7	-1.6	-0.4	-0.48	-0.9	-1.5	-0.4	-0.87	-1.6	-5.0	-5.0

Notes: Revenues and profits are measured in billion USD for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

Table A.18: Impact of Huawei's Lost Access to GMS on Consumers by Geographic Region (with Constant Returns to Scale)

	CF0: No Sanction	CF1: GMS Removal			CF2: GMS & 5G Removal			CF3: Sell Honor (coordinate)			CF4: Sell Honor (compete)			CF5: Huawei Removal		
Region	R	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$	ΔCS	$\Delta Q(\%)$	$\Delta P(\%)$
West	43.25	-0.52	-2.9	-0.6	-0.52	-2.9	-0.7	-0.44	-2.5	-0.6	-0.40	-2.3	-0.7	-1.41	-8.3	-8.3
East	9.80	-0.42	-7.3	-1.1	-0.42	-7.3	-1.2	-0.10	-2.0	-0.4	-0.07	-1.4	-0.8	-0.25	-4.6	-6.2
South	13.96	-0.32	-4.2	-1.3	-0.32	-4.2	-1.4	-0.29	-3.9	-1.3	-0.26	-3.6	-1.4	-0.87	-12.1	-16.3
Central-East	9.32	-0.23	-4.8	-1.3	-0.23	-4.8	-1.3	-0.21	-4.4	-1.2	-0.20	-4.1	-1.4	-0.62	-13.1	-16.3
North	6.40	-0.06	-2.1	-0.4	-0.06	-2.1	-0.4	-0.05	-1.7	-0.3	-0.04	-1.5	-0.4	-0.16	-6.2	-5.7
USA	85.62	-0.02	0.0	0.0	-0.02	0.0	0.0	-0.01	0.0	0.0	-0.01	0.0	0.0	-0.03	0.0	0.0
Total	168.35	-1.55	-2.4	-0.4	-1.55	-2.4	-0.4	-1.10	-1.6	-0.4	-0.98	-1.5	-0.4	-3.34	-5.0	-5.0

[1] Revenue and change in consumer welfare are measured in billion US dollars for the period Q2 2019 to Q2 2020. The percentage price changes are sales-weighted averages, where weights are fixed at data-predicted sales shares. CF0 denotes the baseline predicted equilibrium without sanctions, in which all Huawei products can pre-install GMS.

[2] The regional classification of countries used in the analysis is as follows: Southern Europe includes Greece, Italy, Portugal, and Spain; Northern Europe comprises Denmark, Finland, Norway, and Sweden; Western Europe consists of Austria, Belgium, France, Germany, Ireland, the Netherlands, and the United Kingdom; Central and Eastern Europe includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Serbia, and Switzerland; and Eastern Europe comprises Kazakhstan, Russia, and Ukraine.

A.6 Computational Details

Demand Estimation We use analytical gradients to minimize the nonlinear GMM-IV objective function, set the inner convergence criterion for the contraction mapping to $1e^{-14}$, and use a large number of Modified Latin Hypercube Sampling simulation draws (1000 draws) to improve the accuracy of numeric integration. We use 10 starting values and only keep parameter estimates that produce the lowest GMM objective function value and satisfy the local minimum criterion (the norm of the gradient is close to zero and the objective function's Hessian is positive definite).

Counterfactual Simulations Following Duch-Brown et al. (2023), to reduce the iterations in getting a convergent equilibrium, we also apply a globally convergent Anderson Type-I fixed point acceleration scheme in counterfactual simulations (Zhang et al., 2020). In practice, we find that the acceleration scheme is highly effective and reduces the required number of iterations to convergence.

In the constant returns to scale supply specification, marginal costs do not depend on quantities, so the counterfactual equilibrium can be computed separately for each country-quarter market. By contrast, under the non-constant returns to scale specification, the marginal cost of product j depends on its total sales across all countries in quarter t. This creates cross-country interdependence in the supply side, and the counterfactual equilibrium must therefore be computed at the quarter level, pooling all countries within the same period.

Formally, for a given quarter t (suppressed for notational simplicity), we stack all variables across countries into a single vector. We then consider a counterfactual change in product characteristics from x_j to x'_j and from w_j to w'_j. The counterfactual equilibrium is obtained by solving the firms' Bertrand-Nash first-order conditions using the following iterative procedure.

1. **Initialization** Start from an initial price vector p^0_{jc} and compute the corresponding predicted market shares s^1_{jc}.

   $$s^1_{jc} = \int \frac{exp(x_j{}'\beta_i - \alpha_i p^0_{jc} + \lambda_b + \kappa_c + \gamma_t + \xi_{jc})}{1 + \sum_{k=1}^{J} exp(x_k{}'\beta_i - \alpha_i p^0_{kc} + \lambda_b + \kappa_c + \gamma_t + \xi_{kc})} dF(\alpha, \beta)$$

   Then obtain quantities $q^1_{jc} = s^1_{jc} MktSize_c$ and aggregate sales $Q^1_j = \sum_{c=1}^{C} q^1_{jc}$.

2. **Marginal cost update** Update marginal costs using the estimated supply equation:

   $$c^1_{jc} = exp(w_j^{'}\phi + \bar{\xi}_{jt}\tau + \lambda_b + \kappa_c + \gamma_t + \omega_{jc}) * (Q^1_j)^{\eta}$$

3. **Derivative matrix.** Compute the analytical matrix of price derivatives $\Delta^1(p^0_{jc})$ using the individual-level demand predictions.

4. **Price update** Update the price vector by pooling all countries and applying the firms' first-order conditions to obtain:

$$\mathbf{p}^1 = \mathbf{c}^1(\mathbf{p}^0) - (\boldsymbol{\Theta} \odot \boldsymbol{\Delta}^1(\mathbf{p}^0))^{-1}\mathbf{q}^1(\mathbf{p}^0)$$

The procedure is iterated until the sup-norm of the difference between $\mathbf{p}^t$, normalized by the sup-norm of $\mathbf{p}^{t-1}$, falls below $1e^{-11}$.

A.7 Additional References

Table A.19: Industry and Media Sources

Source	Year	Month	URL	Article Title
[The Economist, 2019]	2019	May	https://www.economist.com/business/2019/05/20/holding-out-on-huawei	"Holding out on Huawei"
[Reuters, 2024]	2024	June	https://www.reuters.com/technology/huaweis-harmony-aims-end-chinas-reliance-windows-android-2024-06-27	"Huawei's Harmony aims to end China's reliance on Windows and Android"
[Counterpoint Research, 2025]	2025	Dec.	https://counterpointresearch.com/en/insights/global-smartphone-apsoc-market-share-quarterly	
[Bloomberg, 2019]	2019	Dec.	https://www.bloomberg.com/news/articles/2019-12-30/huawei-to-shake-up-exec-ranks-in-2020-as-trump-curbs-bite-deeper	"Huawei to shake up exec ranks in 2020 as Trump curbs bite deeper"
[Reuters, 2019a]	2019	Sept.	https://www.reuters.com/article/technology/huawei-plans-high-end-phone-launch-under-cloud-of-google-ban-idUSKCN1VI24B	"Huawei plans high-end phone launch under cloud of Google ban"
[Reuters, 2019b]	2019	June	https://www.reuters.com/article/idUSL4N23C3D2/	"Huawei denies report that orders to key suppliers cut after U.S. blacklisting"
[Reuters, 2020	2020	August	https://www.reuters.com/article/technology/us-tightening-restrictions-on-huawei-access-to-technology-chips-idUSKCN25E0BN	"U.S. tightening restrictions on Huawei access to technology chips"
[Huawei, 2026]	2023		https://consumer.huawei.com/be/phones/	
[Financial Times, 2023]	2023	Nov.	https://www.ft.com/content/327414d2-fe13-438e-9767-333cdb94c7e1	"How Huawei surprised the US with a cutting-edge chip made in China"

Continued on next page

Table A.19: Industry and Media Sources (continued)

Source	Year	Month	URL	Article Title
[Huawei, 2020]	2020	Nov.	https://www.huawei.com/en/news/2020/11/huawei-honor-statement	
[Honor, 2024]	2024		https://www.honor.com/my/topic/honor-gms/	
[Statista, 2025]	2025		https://www.statista.com/statistics/632599/smartphone-market-share-by-vendor-in-europe/	
[The Guardian, 2020]	2020	July	https://www.theguardian.com/technology/2020/jul/18/pressure-from-trump-led-to-5g-ban-britain-tells-huawei	"Pressure from Trump led to 5G ban, Britain tells Huawei"
[Federal Reserve Bank of St Louis, 2025]	2025		https://fred.stlouisfed.org/series/USACPIALLMINMEI	
[Google Play, 2025]	2025		https://storage.googleapis.com/play_public/supported_devices.html	
[GSM Arena, 2025]			https://www.gsmarena.com	
[BBC News, 2022]	2022	Nov.	https://www.bbc.com/news/world-us-canada-63764450	"U.S. bans sale of Huawei, ZTE tech amid security fears"
[Reuters, 2023]	2023	July	https://www.reuters.com/technology/chinas-huawei-poised-overcome-us-ban-with-return-5g-phones-research-firms-2023-07-12/	"China's Huawei poised to overcome U.S. ban with return of 5G phones, research firms say"
[European Commission, 2025]	2025		https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts	
[European Commission, 2024]	2024		https://digital-strategy.ec.europa.eu/en/policies/5g-observatory-2025	