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Strategic confusopoly: evidence from the UK mobile market

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Abstract
Do firms strategically confuse their customers? Using a detailed dataset covering virtually all mobile phone tariffs and their handsets in the UK between January 2010 and September 2012, we examine the co-evolution of prices with the differentiation and overlap of operators' product portfolios. Incorporating the fact that mobile tariffs are multidimensional and hard to compare but easy to imitate and cheap to launch, we argue that firms introduced a large number of dominated tariffs as an obfuscation strategy. We show that the increase in dominated tariffs correlates with the increase in average prices despite converging product portfolios. This exploratory study is one of the first to offer suggestive evidence of the existence and role of obfuscation as a firm strategy.

Key words: competitive strategy, obfuscation, mobile telecommunications industry
JEL: L1; L2; L96

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1 Introduction

Products within an industry typically evolve over time to become more similar or more different to each other (Hotelling, 1929). If there is an identifiable mass market, a combination of process innovations and product adjustments in response to demand information can lead to an emerging dominant design used by most firms in the industry (Suarez and Utterback, 1995; Koski and Kretschmer, 2007). Conversely, if firms discover new viable market niches, products will gravitate to different niches, leading to more differentiated products (Swaminathan, 1998; Stahl, 1982; Dudey, 1990). The implications for price-cost margins and ultimately firm profits differ: increasing similarity leads to lower margins and profits, while increasing differentiation leads to higher margins and profits. These predictions rely on the assumptions of firm and consumer rationality: consumers will make optimal choices given their preferences and the available options, and firms will minimize the number of product varieties (the "length" of their product portfolio) to satisfy consumer demand due to fixed cost of launching new product variants.

However, the predictions are less clear if any of these assumptions do not hold. If firms can introduce new products at very low cost, the number of product varieties may increase rapidly and competitive imitation may be fast and complete (MacMillan et al., 1985; Piazzai and Winjberg, 2019). If product features are new or hard to interpret, consumers make boundedly rational decisions and may ultimately choose products that are not optimal given their true preferences. Indeed, if both assumptions do not hold, firms may introduce many varieties of a product to provoke consumer mistakes because many options that are hard (or costly) for them to evaluate are available. This deliberate strategy of "overpopulating" the product space to confuse consumers is what we term obfuscation strategies (Ellison and Ellison, 2009).

Our key question is: *Can obfuscation strategies emerge in an oligopoly market and if so, what are their implications in terms of product prices and consequently margins?* To address this question, we track prices and product differentiation in the UK mobile telecommunications industry over a two-year period and present a puzzling stylized fact: in the early part of our sample period, product differentiation declines, but prices go up. We show that this counterintuitive finding is consistent with the use of obfuscation strategies: the number of tariffs increased

sharply in this period, and many of the tariffs were "dominated", i.e. tariffs for which there is a better alternative offered by the firm for a given set of characteristics. All firms in the industry participated in this "confusopoly", where they jointly increased the number of dominated tariffs to create a "shroud" over the most efficient tariff to raise average prices paid by consumers. In the later part of the sample, firms reduced the number of dominated tariffs, triggered by competition from the smallest operator and a push by the regulator to increase price and product transparency in the market. This period of "competition on transparency", where firms cleared their portfolio of dominated tariffs is associated with a steady decline in prices.

We take a first exploratory look at an important, but understudied dimension of multiproduct strategy: the degree of transparency of product offerings if product introductions are easy and (almost) costless. While we cannot claim to identify the causal structure between three choice variables (price, degree of product differentiation, and degree of transparency), we find strong suggestive evidence that firms do strategically choose the degree of transparency (or lack thereof) in their product portfolio. This tendency is especially pronounced when some important product dimensions are new to consumers (cellular data in our empirical setting). Second, we contribute to the literature on competitive dynamics by documenting that firms do tend to copy each other's moves regarding the most "efficient" tariff while creating a shroud of other tariffs that reduce the impact of increasing similarity with their competitors. Moreover, we contribute to work on demand-side strategy by suggesting that firms occupy several consumer segments simultaneously and compete by considering the degree of consumer sophistication. Relatedly, we connect to behavioral strategy by suggesting that consumers are boundedly rational in their use and valuation of new product characteristics and as such may fall victim to a "confusopoly" of firms offering a shroud of tariffs that makes understanding and comparison particularly difficult.

2 Firm Choices in Multiproduct Settings

2.1 Strategic decision making in a competitive setting

Among others, firms strategically choose the price and non-price dimensions for the products in their portfolio. We discuss the most important choices below.

Products and Product Portfolios. When managing a portfolio, firms have to decide on how many products to have in their portfolio (product line length). Firms also decide on the attributes of their products, and how to position them compared to the competitors' and their own other products (product differentiation or variety). Portfolios are also periodically renewed through the introduction and withdrawal of individual products. All these decisions are influenced by factors such as costs, the allocation of fungible resources, the ease (and cost) of introducing new products, but also the competitive environment such as the number and size of rival firms. Naturally, firms also account for the demand side, i.e. consumers' budget constraints and heterogeneity of tastes. For example, when firms introduce a new product or a new product attribute, they may initially be ignorant about potential demand and therefore experiment – at least in the short run – before they settle on a dominant design (Suarez and Utterback, 1995). The literature on intra-industry diversification has highlighted firms' portfolio decisions from a different perspective. Intra-industry diversification has a strong impact on firm performance (Zahavi and Lavie, 2013; Stern and Henderson, 2004), mainly due to economies of scope arising from the reuse of valuable resources (Barroso and Giarratana, 2013) or presence in related markets with network effects or demand spillovers (Tanriverdi and Lee, 2008). Most of the literature on intra-industry diversification focuses on firm resources and their reuse in different industry segments (Danneels, 2007; Barroso and Giarratana, 2013; Chatterjee and Wernerfelt, 1991). Sorenson (2000) considers product portfolio choices as means to learn about consumer preferences and finds that there is competitive crowding out as well as value in releasing product variants under high uncertainty as the value of learning is highest in these cases.

Product line length. One fundamental choice of multiproduct firms is how many products (or product lines) to offer. The size of the product portfolio – or product line length – matters crucially for competition and firms' performance. Prior work has shown that firms can expand their product line to increase consumer loyalty and charge higher prices (Draganska and Jain, 2005), deter imitation by competitors (Piazzai and Wijnberg, 2019) or simply respond to rival moves (Bayus and Putsis, 1999, Putsis and Bayus, 2001). In competitive markets, firms' portfolio changes in response to competitors often differ between groups of firms, especially between

established firms defending their position and new or lagging firms that strive to improve theirs (Shankar, 2006; Zucchini et al., 2019). A complementary line of research looks at resource allocation decisions across different product categories. The literature on resource allocation and product line decisions emphasizes that in the presence of fungible resources, product line decisions tend to be grouped together by the extent to which resources can be reused across product categories (Barroso and Giarratana, 2013). Giachetti and Dagnino (2014) have shown that competitive position has a nonlinear relationship with product line length: using data on handset models introduced between 1968 and 2010, they show that low and moderate levels of competition are positively associated with product line length, while intense competition leads to more concentrated product lines. Relatedly, in the market for telecom services, where products (the tariffs) are basically combinations of attributes that are homogeneous across operators, product lines are strategic complements, i.e. one firm's product line expansion leads to competitors expanding theirs too (Miravete, 2009).

Product differentiation. Firms can differentiate their products by introducing a new attribute, a new technology, or a new pricing scheme. One rationale suggests that firms have incentives to locate as far as possible from each other to soften price competition (D'Aspremont et al., 1979). Product characteristics may also diverge in the later stages of an industry as demand becomes less uncertain and more heterogeneous (Corrocher and Zirulia, 2010; Koski and Kretschmer, 2007). Finally, introducing a specific (popular) product attribute may aid firm survival, as argued in the literature on dominant design (Suarez and Utterback, 1995). Berry and Waldfogel (2001) highlight that an increase in the market concentration led to an increase in the variety offered in the radio broadcasting industry, while Götz and Gugler (2006) document the opposite effect in the retail gasoline market. Finally, Sweeting (2010) documents a twofold effect on the radio broadcasting industry at the firm- and industry level: firms differentiate their products more after a merger to reduce potential audience cannibalization, but the aggregate variety does not increase because the merged firm tends to look more like its competitors.

Prices. Price is, naturally, another important dimension of the product that will determine its success. Theory predicts that firms located close to each other compete fiercely in prices (minimal differentiation), while they can increase their prices if they locate far enough from each other, i.e. if they differentiate their products, thanks to their attributes or advertising (maximal differentiation). Hotelling's (1929) standard result is that firms choose minimum differentiation for stable prices. This has been supported by work suggesting that firms may locate their product close to rivals' if demand is concentrated spatially (Stahl, 1982), if there are demand spillovers (Gavazza, 2011), or if consumers face search costs (Dudey, 1990). These papers all explore the tension between the market area effect and the substitution effect. The market area effect arises from the positive impact a cluster of firms may generate on demand. As consumers face search costs (similar to transportation costs), they prefer to visit a cluster of firms where they can compare prices. Price comparison drives the substitution effect. Richards et al. (2013) test the trade-off between the two effects in the US yogurt industry and study firm decisions regarding attribute composition and prices. They find that consumers tend to prefer products with similar attributes due to the existence of switching costs, so that the market area effect outweighs the competitive effect and firms can raise prices by launching products in congested attribute spaces. Argentesi et al. (2016) show that a major merger in the Dutch retail market did not affect prices but reduced the range of products offered by supermarkets.

2.2 The Role of Consumer (Ir-)Rationality

Increasing the product line length or adding a new attribute to a product clearly affects consumer decisions. Indeed, their choices become more difficult if they have to evaluate a large number of alternatives, receive only a confusing description, or face a sophisticated pricing scheme. Such settings have been described in markets such as retail (Ellison and Ellison, 2009; Richards et al., 2019), healthcare (Ketcham et al., 2012), or retail banking (Gu and Wenzel, 2012).

Consumers have search costs. When consumers make choices, they often face search costs. Diamond (1971) shows how firms can end up setting monopoly prices in a competitive setting if consumers have search costs. If the number of different products becomes prohibitively high

to assess every one of them (given even a small search cost), this may create choice overload and ultimately confuse consumers. The existence of search costs for consumers gives a rationale for firms to use obfuscation strategies in an oligopoly setting (Ellison and Wolitzky, 2012). Obfuscation strategies can be implemented by "increasing the complexity of price structure or presentation" (Gu and Wenzel, 2012), for example by adding a high-priced add-on (Ellison, 2005). In an online setting, Ellison and Ellison (2009) describe how the complicated description of products or the existence of multiple versions of a product can increase consumer search costs.

Consumers are imperfectly rational. DellaVigna (2009) lists three sources of non-standard consumer behavior: non-standard preferences (dynamically inconsistent choices, loss aversion, endowment effect), beliefs (overconfidence, projection bias), and decision making (limited attention, ambiguity aversion, default bias). These various biases may result in the consumers being "boundedly rational" (Spiegler, 2011) and making choices that may not appear optimal for them given their preferences.

Spiegler (2006) argues that it is optimal for firms facing increased competition to increase obfuscation rather than decreasing their prices. In subsequent work, Spiegler (2016) argues that obfuscation strategies are used particularly for products with multiple attributes – where consumers end up "overpaying" for some product attributes because they only observe the aggregate price for the product and cannot evaluate each attribute on its own. This may lead to inefficient products surviving on the market. In the context of telecommunications tariffs, Miravete (2013) studies "foggy pricing" in menus of cellular phone tariffs and defines fogginess as the existence of tariff options dominated by another one by the same firm. In his context and time period, the transition from a monopoly to a duopoly did not trigger the use of deceptive strategies. Relatedly, Gabaix and Laibson (2006) document how firms use shrouded attributes or prices to exploit consumers' naiveté, again suggesting the use of deliberate obfuscation strategies to raise profits in a competitive setting.

Firm strategies to exploit consumer limitations. Search costs as in Ellison and Ellison (2009), limited attention or attention as in Spiegler (2006), myopia as in Gabaix and Laibson

(2006), overconfidence as in DellaVigna and Malmendier (2014), uncertainty of usages as in Lambrecht et al. (2007) or various choice biases such as flat-rate biases as described in Lambrecht and Skiera (2006) can be exploited by firms to increase their prices and profit. Spiegler (2011) offers a comprehensive overview of how the pricing strategies of firms are influenced by their knowledge of the bounded rationality of consumers. Limited attention or dynamically inconsistent preferences may enable firms to set what he describes as exploitative contracts. He discusses the use of pricing itself as a strategic tool. Similarly, Gabaix and Laibson (2006) show how firm can introduce a high-priced add-on to extract profits from myopic consumers. DellaVigna and Malmendier (2014) show how firms can exploit overconfident consumers to raise profits. Finally, Miravete (2013) shows how mobile operators use 'foggy pricing' and introduce dominated options in a competitive market. Beyond complex contracts and pricing schemes, other techniques have been described as source of firms' exploitation, in particular the complexity of the description of the products and the introduction of multiple versions of a same product as in Ellison and Ellison (2009).

3 Competition in Mobile Telecommunications Markets

3.1 Multiproduct firms and heterogeneous consumers

In most industrialized economies, the retail level of the mobile telecommunications industry is mature and technologically largely homogeneous (innovation takes place mainly at the hardware manufacturer level). Regulatory restrictions and technological availability ensure that mobile networks in a given country operate on the same standard and with similar geographical coverage. Competition, therefore, takes place through setting tariffs and marketing them accordingly. Products ("tariffs") are typically bundles of attributes and prices combined in one contract. Because of the very low cost of designing a product – basically recombining the contract attributes – tariffs can be introduced and withdrawn very quickly by firms.[1] They can also serve a heterogeneous mass of consumers with different tastes and budget constraints. This is interesting

[1]There can be of course marketing expenses. However, retail firms at that stage of the industry were not advertising specific tariffs, but rather spending with the aim to build their brand image overall.

because it calls into question one of the fundamental propositions of multiproduct firms in differentiated markets: offer the minimum number of product variants needed to cover the market, i.e. to serve all (potentially profitable) consumers. If the cost of releasing products approaches zero, we would expect an ever-increasing number of minimally differentiated products to populate the market. Importantly, however, all the tariffs would optimally serve different (micro-)segments of the market. In a pioneering study, Miravete (2013) shows that in the early days of the US mobile industry, operators offered a relatively small number of tariffs,[2] implying that there was a non-negligible cost of marketing a tariff at this stage.

3.2 Enlightened firms facing imperfectly rational consumers

In digital markets, firms can also easily observe and monitor what is offered by competitors. Hence, imitation is easy in this industry: there are no patents or complex technology, just combinations of attributes (voice, text, data) that are common across firms. In addition, firms observe and analyze the actual consumption of their users, which provides them with insights about consumers' usage patterns and trends. The availability of information on supply and demand makes it easy for firms to position their products in the attribute space. Put simply, firms in this setting can test and explore consumers' lack of complete rationality and the various costs that enter their utility functions when making a choice. A number of recent studies have documented this behavior (Lambrecht and Skiera, 2006; Lambrecht et al., 2007; Cullen and Shcherbakov, 2010; Grzybowski and Liang, 2015).

Moreover, some characteristics are more or less salient for consumers. For example, consumers can very easily observe the upfront cost of the handset, monthly charge for the tariffs, the allowances of sms, voice and data. On the contrary, observing the implicit price of the phone, the level of subsidy or more marginal characteristics (e.g. access to a premium customer service line) can be more complicated for consumers, in particular if the operators do not provide perfectly transparent information. This setting is close to what is described by Spiegler (2006) where firms exploit the limited attention or understanding of consumers to make profits

[2]Miravete shows that, in the US, between 1984 and 1988, operators were offering between 1 and 6 tariffs, with an average of 2.5 tariffs in monopolistic markets and 3.5 in duopolistic markets.

and avoid the downward pressure on price in a competitive setting. This resembles a shrouding strategy as defined by Gabaix and Laibson (2006). Even in the case of perfect information, consumers may not pay attention to some of the characteristics, which allows firms to introduce tariffs that are fundamentally similar but come at different prices – meaning that they keep "dominated" products in their portfolio. The pricing structure itself can be used as a competitive device as described in Miravete (2013).

3.3 Obfuscation as a strategy

In most industries, firms would not have an incentive to introduce dominated or redundant products. However, since introducing tariffs is so easy, mobile telecommunication markets differ in this regard. Indeed, operators may use the fact that they can introduce new product quickly at almost no cost to create confusion and increase the search costs of consumers who cannot easily compare the different options. This setting is particularly interesting because cellular data has added another dimension to mobile tariffs, and the number of tariffs and product dimensions will reduce transparency for consumers (Ellison and Ellison, 2009)). The use of data came along with a whole new range of handsets (in particular smartphones) that saw the choice set for consumers expand from 2,309 varieties in January 2010 to 12,897 varieties in January 2011.[3]

Our setting combines various features that makes it particularly prone to observing obfuscation strategies: an oligopoly (Ellison and Wolitzky, 2012) of multiproduct firms (Spiegler, 2016) introducing a new product attribute (Spiegler, 2006) - facing boundedly rational consumers with search costs. This intuition is shared by policymakers (European Commission, 2007 and 2017; Ofcom, 2018), which have repeatedly raised concerns about possible consumers detriment in these markets, arising in particular from the lack of transparency of offers.

[3]Figure A.3 shows how the growth rate of combinations and tariffs evolved over the whole period.

4 Data

4.1 The UK mobile telecommunication market

At the end of the year 2012, the UK counted 83 million mobile subscribers, with 53% of them with a post-paid contract.[4] There are four Mobile Network Operators (MNOs) in the United Kingdom: Everything Everywhere (owned by British Telecoms, representing 34% of market share by the end of 2012), O2 (owned by Téléfonica, representing about 29% of market share), Vodafone (25% market share) and Three (12% market share).

Figure 1 shows the market shares of the operators since 2006. In 2010, the structure of the UK market changed through the merger of Orange and T-Mobile, two global players. The merger was announced in September 2009 and cleared by the European Commission in March 2010, resulting in the creation of Everything Everywhere in May 2010. Although run by the same company, Orange and T-Mobile continued operating under their own brands and kept their own shops and service centers as well as independent marketing campaigns. In August 2012, EE obtained the right to refarm[5] its 2G frequencies to offer LTE services, which gave the operator a head start over its competitors. In September 2012, Everything Everywhere launched a new subsidiary brand, EE, offering its own services. One month later, the first 4G tariffs were commercialized and the LTE network was 'switched on' in eleven large cities in the UK. Spectrum bands 800 Mhz and 2.6 Ghz were awarded in March 2013 and other operators were able to launch their 4G services then. In 2015, EE finally shut down Orange and T-Mobile in the UK, offering its services exclusively under the name of EE.[6] The introduction of 4G licenses also

[4] The average revenue per user was between 24 and 26 GBP over the period 2010-2012 for the post-paid segment and about 6.5 GBP for the pre-paid (Ofcom, 2012)

[5] "Refarming is the term used for the process governing the repurposing of frequency bands that have historically been allocated for 2G mobile services (using GSM technology) for new generation of mobile technologies, including both third generation (using UMTS technology) and fourth generation (using LTE technology)." GSMA (2016).

[6] Allen et al. (2017) show that the prices for mobile services declined of 2 to 18% as a result of the merger, depending on the consumption profile.

meant that cellular data became gradually available in tariffs in late 2009.[7] However, to make full use of this option consumers needed new mobile devices (smartphones). Some operators initially offered unlimited data in various tariffs, but most of them quickly switched to limited data allowances — a pattern common to most countries at that time.

4.2 Data set construction

We have a complete list of post-paid mobile tariffs offered by MNOs in the UK between January 2010 and September 2012.[8] This data originates from a price comparison website, BillMonitor, the first to be accredited by the UK's telecommunication regulator Ofcom as providing impartial consumer information.[9] For each tariff, we have information on the monthly price in GBP and the allowances of voice, text, data, mixed allowance (when voice, and sms are combined), and on-net volume of calls.[10]

Our data include two distinct types of contracts: the traditional ones, where mobile services are bundled with a handset subsidized by the operator, and tariffs which only include mobile services, also known as *sim-only* tariffs. For the latter, consumers either use a handset they already own, or purchase a new or used device of their choice. These two types of tariffs serve two differentiated segments of consumers.[11]

For tariffs bundled with handsets, we have information on the model and the upfront cost paid by the consumer. We observe 342 different handsets associated with the tariffs. The original data set consists of 3,812,523 observations at the daily level. Once aggregated to monthly, we have 191,653 observations of 53,421 unique tariffs. A tariff is defined as a combination of a network (O2, Orange, Three, T-Mobile, or Vodafone), a contract length (between 1 and 36 months),

[7] This coincides with the release of Apple's iPhone 3G, basically the first smartphone able to connect to the cellular network.

[8] For data availability reasons, December 2011 and January, June, and July 2012 are missing, giving us 29 months in total.

[9] This website provides impartial information to consumers and helps them to choose the contract that best fits their usages. To provide this service to consumers, the website collects information on all tariffs available on the market on a regular basis. See Genakos et al., (2019) for a comprehensive description of the website.

[10] Unlimited allowances are originally coded with an arbitrary value that is set at 10 000. The normalization of the sms, voice, and data allowances described in Section 4.4 is made in a way that this value is not relevant in the analysis, with the unlimited option corresponding to the value 1, while no allowance corresponds to the value 0.

[11] In 2010, Ofcom reported that sim-only contracts accounted "for more than one in five new pay-monthly connections". Nowadays, sim-only subscribers represent 39% of the market in the UK (Ofcom, 2021).

allowances of sms, voice and data, on-net calls, mixed allowance (from zero to unlimited) and a handset (defined by its manufacturer and model - or no handset alternatively). We can infer the list price of handsets as some tariffs include no subsidy, which lets us observe the "true" price – i.e. the list price of the handset and consequently the exact amount of subsidy offered with every combination of tariff and handset. It is worth noting is that the tariff price we use in our analyses is the list price for a given mobile plan. This price does not necessarily correspond to the final bill paid by consumers. Indeed, on top of the extra cost related to the use of special numbers and international roaming, consumers can be charged for usages beyond their allowances, when their mobile plan is not unlimited. The price of additional sms, minutes, or data (often called *out-of-bundle rates*) varies across operators, and can be either linear or non-linear. We do not observe these prices in our dataset, so the price we consider in our analyses is not the final invoice for any given consumer, but rather the fixed price for a product, i.e. a bundle of attributes.

We complement this data with a data set scraped from GSMArena[12] giving handset characteristics (dimensions, weight, camera quality, date of release, CPU, GPU, etc). We merge about 80% of observations including a handset, i.e. 155,258 observations and 42,642 unique tariffs. We use this dataset for our hedonic price regressions.

Excluding different handset models and defining our tariffs as a combination of network, contract length, allowances, and a sim-only dummy, we have 10,485 observations with 1,311 unique tariffs. We use this dataset to compute the distance between tariffs — we do not account for handsets in this case. This eventually gives 1,981,060 pairs of tariffs.

Finally, we collected information on the state of competition in the market – market shares, concentration level, number of MVNOs as well as information on regulated prices — mobile termination rates, wholesale roaming price caps — and information on the evolution of demand – – share of post-paid subscribers and mobile broadband usage from the regulator Ofcom's website.

4.3 General descriptive statistics

Table 1 gives some descriptive statistics of the prices and characteristics of tariffs (combined with various handsets). On average, a tariff costs 33 GBP (monthly charge), and the handset

[12]The data were collected in 2014.

39 GBP (one-off charge). We observe two types of tariffs serving two segments of consumers: the tariffs associated with a handset (about 99.8% of the combinations) and sim-only tariffs.

Table A.1 shows how characteristics and prices of tariffs vary across operators. Note that Three offers the cheapest tariffs on average (about 23 GBP), while Vodafone charges 39.5 GBP on average. Table A.2 shows that the typical contract length for sim-only tariffs is 1 month (57%), followed by 12 months (37%). With handsets, the typical contract lasts 24 months (53%) or 18 months (45%). Table A.3 provides similar statistics for unique tariffs, i.e. without the handset duplicates. Here, we can see that the sim-only tariffs represent about 31% of tariffs offered on the market.[13] The other statistics are comparable.

4.4 Variables of interest

Tariff Prices. We define mobile tariffs' prices (in GBP) as a combination of monthly allowances of sms, voice and data, and a handset —- when the tariff is not a sim-only contract. All contracts are post-paid, meaning that consumers pay the tariff price at the end of the month, plus possible extra costs related to usage, for example if the actual usage exceeds the allowance.

Product Differentiation. We measure the level of differentiation of tariffs in the market by computing the Euclidean distance between each tariff pair available on the market in a given month. Because the allowances have different measures (sms are counted in units, voice in minutes, and data in GB) and some tariffs include one or more flat-rates (i.e. unlimited units of sms, voice and/or data), we normalize the allowances using the following formula:

$$z_i = \frac{x_i - min(x)}{max(x) - min(x)}$$

[13]This is significantly higher than the 2% of sim-only combinations described before. Indeed, by design, the tariffs with handsets are "overrepresented" in the list of combinations as a tariff can be combined with any handset.

The normalized allowances take a value between 0 and 1, 0 corresponding to no allowance and 1 to unlimited allowance. Descriptive statistics on the normalized allowances are presented in Table A.4. Then, for each pair of tariffs i and j observed in month t and for an attribute $k \in \{data, voice, sms\}$, we compute the following:

$$distance_{kijt} = (k_{it} - k_{jt})^2$$

Finally, we obtain our product differentiation measure by computing the following:

$$distance_{ijt} = \sum_{k=1}^{K} (k_{it} - k_{jt})^2$$

This measure captures how tariffs are positioned relative to each other in the attribute space including the allowances of sms, voice, and data.

Table A.5 shows descriptive statistics on the pairwise distance ranging between 0 and 3.[14] For example, a tariff with no allowance at all will have a pairwise distance of 3 with a tariff with unlimited voice, text and data – while the distance will be 2 for a tariff with unlimited voice and text and no data at all. Figure A.1 shows that the average distance between products declined over time, driven by a reduction of the distance within and between operators' portfolios.

Dominated tariffs. We compute the number and share of dominated tariffs for each month. It broadly corresponds to Miravete's (2013) fogginess measure which identifies for each level of consumption the cheapest option available on the market at a given time. All tariffs allowing the same level of consumption for a higher monthly charge are considered dominated. Miravete (2013) covers two-part tariffs where the allowance (priced $P_{\bar{q}}$) allows for a given volume of minutes $\bar{q}$, and the usage price corresponds to a unit price p for all minutes consumed beyond the allowance. A tariff then takes the form $Bill = P_{\bar{q}} + p(min0, q - \bar{q})$. In our setting, the tariffs include a larger number of attributes, including handset cost and subsidy and contract length, which affect utility, but are not consumed in a linear fashion. Hence, for simplicity, we do not consider the unit price beyond the allowances in our computation.

[14] The maximum distance between two tariffs in each of the dimensions (sms, voice, data) is 1, the maximum overall distance is 3.

We compute the cheapest option for each combination of allowances for sms, voice, and data, as well as upfront handset cost (the price effectively paid by consumers at the beginning of the contract), handset subsidy (in amount ranges), and contract length. All tariffs offering similar attributes at a higher cost are considered dominated. We consider alternative measures with fewer or more elements entering the computation to mimic lower or higher levels of attention of consumers. Our favored measure assumes an intermediate level of attention of individuals. Figure A.2 gives the share of dominated tariffs based on various definitions of dominated tariffs.[15]

We also compute the total number of tariffs available each month to capture the stock of products available to consumers and, by extension, the level of product proliferation. We also compute the corresponding growth rates (Figure A.3).

4.5 Descriptive evidence

Figures A.4, A.5 and A.6 document the evolution of our variables of interest over our study period. The average price of tariffs over time is shown in Figure A.4. We observe a decline of about 4 GBP before the merger, which is quickly recovered in January 2011. Prices then decline from 34 GBP to 30 GBP until August 2012. Figure A.5 gives the evolution of the average pairwise distance between tariffs at the industry level. It first consistently decreases and stabilizes after January 2012. The share of dominated tariffs available in the market in each month is shown in Figure A.6. It gravitates around 10%, with a sustained increase over the last months of 2010, reaching its peak in January 2011. We now subject these unconditional statistics to more rigorous econometric tests.

5 Econometric Analysis

Our measures of prices, product differentiation, and dominated tariffs are affected by a host of factors, including product, firm, and market characteristics. We first regress our indices individually on a set of controls to retrieve the residual variation over time for our three choice variables. We then explore their interdependencies by regressing price on product differentiation

[15] We show in the appendix that all measures evolve in a similar fashion over time, which is what matters for our obfuscation index. Therefore, our eventually chosen definition of dominated tariffs does not affect the results.

and obfuscation and the set of controls.

5.1 Price regression

We first estimate the role of tariff characteristics and monthly dummy variables in tariff price through the following hedonic price regression (Griliches, 1961):

$$price_{it} = \alpha + X_{it}\beta + \delta_t d_t 1(k = t) + \varepsilon_{it} \tag{1}$$

In this equation, $price_{it}$ denotes the list price in GBP of tariff i available in month t. The coefficients (α, β, δ) are estimated by ordinary least squares (OLS). The vector of tariff characteristics X_{it} includes: (i) contract length (ii) unlimited voice dummy (iii) voice allowance (iv) unlimited sms dummy (v) sms allowance (vi) unlimited data dummy (vii) data allowance (viii) mixed allowance (voice and sms) (ix) handset subsidy dummy (x) amount of subsidy and (xi) operator dummy. The normally distributed error term is denoted by ε_{it}. The estimated coefficients δ_t of the monthly dummies $d_t 1(k = t)$ then represent the quality-adjusted price index. The price of a tariff is our main variable of interest and a measure of product performance.

5.2 Product differentiation regression

$$distance_{ijt} = a + X_{it}b + \gamma_t d_t 1(k = t) + \varepsilon_{it} \tag{2}$$

In this dyad-level equation, $distance_{ijt}$ denotes the distance between tariff i and tariff j in month t. The coefficients (a,b,γ_t) are estimated using ordinary least squares (OLS). The vector of pairwise characteristics X_{ijt} includes a dummy for each combination of operators and a linear time trend. The normally distributed error term is denoted by ε_{it}. The estimated coefficients γ_t of the monthly dummy variables $d_t 1(k = t)$ capture the product differentiation index.

5.3 Dominated tariff regression

We identify the dominated tariffs offered by each operator in each month. To do so, we note the minimal price observed for a combination of sms, voice, and data, with similar contract length,

handset cost and level of handset subsidy, offered by a given operator.[16]

$$dominated_{it} = \mu + \sigma_1 Net_i + \sigma_2 NT_t + \sigma_3 Dist_{iIt} + \theta_t d_t 1(k = t) + \varepsilon_{it} \quad (3)$$

In this equation, $dominated_{it}$ is a dummy variable with value 1 if a tariff is dominated and 0 otherwise, Net_i captures operator fixed effects, NT_t denotes the number of available tariffs available on the market in month t, $Dist_{iIt}$ is a vector of distances between allowances of the tariff i and the average of the industry I at time t. d_t are month dummies. The coefficients (μ, θ_t) are estimated using an OLS and, alternatively a logistic regression. The coefficients for month dummies capture the obfuscation index.

5.4 Linking Price, Product Differentiation and Obfuscation

With the three models above, we characterize the evolution of the firms' strategies, i.e. price, product positioning, and obfuscation, conditional on observable factors. Visual inspection of Figure 2 suggests that the three do not move independently of each other, which is not surprising given they are three choice variables by the firms. Therefore, a unified framework lets us take their interdependencies into account. However, note that of the three, the price firms charge for their tariffs is ultimately most closely related to performance. We consider all the combinations i of tariffs and handsets observed in month t to estimate the following model:

$$price_{it} = \alpha + X_{it}\beta + \beta_1 ShareDom_{st} + \beta_2 Dom_i + \beta_3 Distance_{st} + \beta_4 Distance_{it} + \delta_t Trend_t + \varepsilon_{it} \quad (4)$$

where $ShareDom_{st}$ denotes the share of dominated tariffs within segment s (either sim-only or tariffs with handset subsidy) at time t, Dom_i is a dummy coded 1 if the tariff i was dominated at the time of introduction. While the former captures the industry-level obfuscation intensity, the latter is tariff-specific. $Distance_{st}$ is the average distance between tariffs in segment s at time t and $Distance_{it}$ is the average distance between tariff i and the other available tariffs available at time t. While the former captures the industry-level differentiation of products, the

[16] We considered alternative definitions, as shown in Figure A.2.

latter captures the positioning of a given tariff compared to competitors in attribute space.

6 Estimation results

6.1 Price, differentiation and obfuscation indices

Prices Estimation results for the price regression are shown in Table A.6. Using O2 tariffs as a base, we can see that tariffs offered by Three, for example, are 9.4 GBP cheaper ceteris paribus. We also see that the contract length significantly influences the price of the tariff. Compared to a "standard" 24-month contract, shorter commitment periods are associated with higher prices. This corresponds to the discounts offered by the operators when consumers agree to be locked-in. On average, unlimited voice costs 34.8 GBP per month, unlimited sms 0.5 GBP and unlimited data 3.13 GBP.[17] Tariffs associated with handsets are, on average, 14.5 GBP more expensive. In addition, each pound of handset subsidy implicitly costs 0.01 GBP per month. For example, if a consumer selects a tariff associated with a phone that costs 300 GBP and for which the upfront cost is 100 GBP, the amount of subsidy is 200 GBP. In this case, the total implicit price of the handset subsidy is 16.5 GBP[18] per month. We also see that different brands of phones are associated with different implicit prices. For example, a tariff bundled with an iPhone will be 6.4 GBP more expensive compared to the same tariff bundled with a ZTE phone. Figure 2a shows the quality-adjusted price index, i.e. the monthly dummy coefficients, obtained from this regression. We comment on differences across segments and operators in Section 6.3.

Product differentiation. Estimation results from the product differentiation regression are shown in Table A.7. This regression includes dyad fixed-effects that capture the distance within and between products offered by operators, with the base category being the distance between

[17] These values are evolving over time – but their average prices are pooled in the estimates for month dummies. These correspond to January 2010 values.

[18] This value results from the following computation: 14.5 + (200 x 0.01) = 16.5 GBP . This is for a ZTE phone, our base category for brands.

O2's products.[19] We obtain positive and significant coefficients for all operators except Vodafone, meaning that compared to O2, Vodafone's products are more similar to each other. T-mobile appears to have the most differentiated tariffs with a coefficient of 0.25.

Further, operators are positioned in a specific way vis-à-vis each other, and this is stable over time, as suggested by the significant estimates for the "between-operator fixed effect" coefficients. Some operators position their products particularly distant from each other. For example, the average distance between products of O2 and T-mobile (0.51) or products from O2 and Three (0.30) is clearly higher than the average distance within products in operators' portfolios (between -0.06 and 0.25, with 0 being the distance within O2's portfolio).

Hence, operators do not occupy exactly the same space —- and that is true over the period we observe. Figure 2b plots the product differentiation index over time, i.e. the month dummies obtained from our estimation. Product differentiation is clearly declining over time, with a significant drop at the beginning of the period, corresponding to the merger months. We observe two other drops at the beginning of 2011 and 2012, which reflects the fact that operators usually remodel their range of tariffs at the start of the year. Figure A.1 also shows that the decline in differentiation occurs both within and between operators' portfolios. We comment on differences across segments and operators in Section 6.3.

Obfuscation. We present results from the dominated tariff regressions in Table A.8 and discuss the results from column 2, our preferred model (logit). Compared to O2, tariffs by Orange are less likely to be dominated, while tariffs introduced by Three, T-Mobile and Vodafone are more likely to be dominated. Further, sim-only tariffs are less likely to be dominated, not surprisingly given the limited number of attributes they usually include. In particular, these tariffs do not include the subsidy dimension that often renders a tariff dominated by others. Hence, we expect tariffs with handsets to be dominated more often. Distance between a tariff and the average of the industry in terms of sms or data increases its chance of being dominated. Distances with the portfolio of the operator also have differential effects across attributes: a tariff

[19]This implies that all dyads involving O2's tariffs have a zero dyad fixed effect. Therefore, the estimates for the within- and between- operators dyad fixed effects have to be interpreted in comparison to this base group, i.e. "within O2".

far away from the other products of an operator in terms of sms is less likely to be dominated while distance in terms of voice or data does not have any significant effect. Figure 2c plots the obfuscation index, i.e. the coefficients for the month dummies obtained in Column 2. We comment on differences across segments and operators in Section 6.3.

Co-evolution of indices. Next, we examine the co-evolution of the three indices. Figure 2 gives an overview of this evolution, and Table A.9 provides some statistics on the values taken by each index and their correlation. We observe a reduction in product differentiation over time: firms tend to introduce their products closer to each other in attribute space. Standard theory would therefore suggest a reduction in quality-adjusted prices. However, prices increased in the first year of our analysis (April 2010 to January 2011). Overall, there seem to be two phases: initially, price and differentiation of products are negatively correlated, while later, the correlation turns positive. What could drive this pattern?

The first explanation could be that the merger between Orange and T-Mobile led to an increased concentration of the market, which resulted in higher prices despite declining product differentiation. While appealing at first glance, this argument is incomplete: first, it seems counter-intuitive that firms grow more similar in a market occupied by fewer players, and second, it is not clear what triggered the second phase.

We propose a related, but richer explanation. As discussed, the quality-adjusted price index is highly correlated with the obfuscation index (Pearson's correlation coefficient is 0.69, significant at 1%), reflecting the increase and later decrease of dominated tariffs on the market. Put differently, prices and obfuscation may be part of the same process, with product differentiation less closely connected. The initial increase in dominated tariffs by all mobile operators could simply be the competitive equilibrium outcome at that time. As Gabaix and Laibson (2006) show, introducing "shrouded" attributes, or more generally making it difficult for consumers to pick their optimal product among a multitude of options can be optimal for competing oligopolists. However, the subsequent decrease in dominated tariffs from 2011 onward suggests that something triggered a breakdown of this equilibrium.

Interestingly, anecdotal market evidence corroborates this narrative. The last operator to

enter the market and consequently the smallest (Three) attempted to de-bias consumers by advertising how clear and simple its tariffs were. Specifically, the introduction of the unlimited "The One Plan" by Three in December 2010 may have marked the end of the "confusopoly" period in our study period. As Figure 1 shows, the market share of Three steadily increased over time, apparently at the expense of Orange and T-Mobile — which, incidentally, were the operators using dominated tariffs most extensively. The last entrant (Three) hence behaves differently from the rest of the incumbent players, both in terms of pricing and in terms of tariff clarity, and may have triggered a breakdown of the confusopoly. In a similar vein, Bourreau et al. (2021) show that the entry of a new operator, Free, in the French market led to a breakdown of tacit collusion via the introduction of fighting brands. In our setting, the maverick firm seems to be responsible for the breakdown of strategic obfuscation strategies.

We now discuss the results obtained in our combined model in Equation (4).

6.2 A unified framework

Table 2 shows the estimation results for the price regressions including various measures of obfuscation (column 1) and product differentiation (column 2) both at the industry and at the product level first separately and then all together (column 3). We present coefficients from the most complete specification in column 3 with their confidence intervals in Figure 3.

From column 3 we can see that the overall obfuscation level of the industry and the characteristics of individual tariffs are associated with a price premium, and therefore increased margins for the firms. Firms charge on average and ceteris paribus 1.21 GBP or 3.7% more for a dominated tariff.[20] Similarly, a 1 percentage point increase of the share of dominated tariffs at the industry level is associated with an additional 0.2 GBP. Given that the average share of dominated tariffs ranges between 0 and 58% over our sample, with an average of 17.24 (between 0 and 8% (average of 1%) for sim-only tariffs and between 3 and 58% (average of 17%) for

[20]The average price of a tariff is 33 GBP.

handset tariffs), this point estimate translates into a price premium ranging from 0-11.5 GBP, with an average of 3.45 GBP over the period. The differentiation of the products at the industry level does not have any significant impact. Finally, we observe that the distance of the tariff with the other available options is associated with a higher price — as theory would predict.

As the descriptive statistics and the indices we computed indicate, the price trend reverses in January 2011. Therefore, we interact our coefficients of interest with a "Post-01/11 dummy" to see if our coefficients of interest differ before and after this date. We present results in Table 3 and Figure 4 below. The share of dominated tariffs at the industry level is positively associated with the average tariff price, but by 0.10 GBP before January 2011 and only about 0.01 GBP after January 2011, a tenfold decrease in magnitude. The price premium charged for a dominated tariff also changes from about 2.5 GBP during the confusopoly period and about 0.82 GBP after. Regarding the impact of the differentiation of products, letting the coefficient vary by time gives some interesting insights. The coefficient on the degree of differentiation of tariffs at the industry level is negative and significant before January 2011, which means that the overall differentiation of products has a negative association with prices. This is counter-intuitive as we would expect the degree of differentiation to co-move with price. We also see that the coefficient on the average distance of the focal tariff to the other available ones changes. In the early (confusopoly) period, distance is not significantly associated with price, while after January 2011, the price is again positively correlated with the degree of differentiation. Hence, operators can increase their prices if they differentiate their products from competitors.

6.3 Additional insights

We now explore some additional aspects of the mobile operators' strategies.

From product proliferation to obfuscation. We present a set of additional price regressions in Table A.10 to disentangle the effects of product proliferation and obfuscation. First, we

estimate a price regression with tariffs and handset characteristics, together with a time trend, in which we add the overall number of tariffs available at time t (column 1) or the number of tariffs by segment s (column 2). This captures the joint association of both product proliferation and obfuscation with the price of products. Using the growth rate of the number of tariffs gives qualitatively identical results (column 3). Second, to isolate the impact of obfuscation, we include the number of dominated tariffs at time t as regressor (column 4). Last, in Column 5, we use the share of dominated tariffs in a given segment at time t to disentangle the effect of product proliferation from the obfuscation strategy of operators. Confirming our main results from Table 2, we find that it is dominated tariffs that drive the positive association with prices.

Introduction and withdrawal of dominated tariffs. We conducted a hazard rate analysis (reported in Table A.11) to see if dominated tariffs differ from "efficient" ones in their time on the market. On the one hand, dominated tariffs may be the most profitable, so that firms keep them on the market the longest. On the other hand, dominated tariffs may be "hit and run" products introduced as part of the obfuscation strategy and then taken off the market more quickly than non-dominated tariffs. Our results suggest that dominated tariffs are more likely to "disappear" from the market, i.e. to be withdrawn by the operators. First, this confirms that dominated tariffs are indeed different, and second it indicates that they are not introduced as "core" products of operators' portfolios, but rather as tools for obfuscation purposes.

Comparing sim-only–tariffs with handsets. Figure A.7 highlights the difference observed for price indices computed for the two segments of the market, i.e. sim-only tariffs and tariffs with handsets. The aggregate index closely corresponds to the tariffs with handsets segment. Indeed, almost all the estimates for month dummies are not significant for the sim-only index, meaning that the quality-adjusted prices did not change. Figure A.8 shows how the differentiation index differs across the segments. The product differentiation index is roughly similar, with a decline of a similar magnitude, although sim-only tariffs converge less quickly than tariffs with handsets. Most interestingly, we see in Figure A.9 that the overall shape of the obfuscation index is completely driven by tariffs with handsets. Due to the low number of dominated sim-only

tariffs, the index is incomplete and estimation very imprecise. It is not surprising to see so few dominated tariffs among sim-only contracts: they usually include a limited number of attributes, most notably no subsidy (subsidies often result in a tariff being dominated). To summarize, the obfuscation we observe is almost completely driven by traditional tariffs, which are selected by most subscribers in the early 2010s (around 83% in the UK, Ofcom, 2011; OECD, 2013), suggesting that the phenomenon we document affects the "main" market of mobile consumers.

Heterogeneity across operators. Comparing the indices obtained for each operator provides interesting additional insights. Indeed, the trends observed at the aggregate level hold almost always for all players in the industry. Figure A.10 shows how the quality-adjusted price index of each operator follows the inverted U-shape highlighted at the industry level - save for Three, which decreased prices between the summers of 2010 and 2011. Regarding product differentiation (Figure A.11), almost all operators stabilized the distance between their products after the merger, albeit at different levels. Vodafone differs slightly, with an initial increase in the distance between its products post-merger followed by a continuous decline from January 2011. Finally, the obfuscation index computed for each firm (Figure A.12) highlights how the use of dominated tariffs has been evolving for each operator. Overall, all indices again have an inverted U-shape, even though their levels differ.

Obfuscation for tariffs bundled with iPhones. We further differentiated the level of obfuscation by looking at tariffs bundled with phones by Apple compared to the others (see Figure A.13). Apple's products were less often part of dominated tariffs before January 2011, but became more frequently associated with them after this period. The difference to the other brands is particularly salient after July 2011 (shortly before the release of the iPhone 4S). This is consistent with a price discrimination strategy targeted at Apple users as they are probably less sensitive to price or more captive to the brand and consequently less prone to comparing prices. Further, operators may have lower bargaining power vis-à-vis Apple than other manufacturers, leading them to "package" Apple products into dominated (higher-margin) tariffs.

While our main analyses uncovered the existence of obfuscation strategies, this section high-

lighted *how* firms actually implement them. We find that the bundling of tariffs with handsets introduces the complexity that makes comparison particularly challenging for consumers. Therefore, we observe obfuscation mostly with traditional tariffs, i.e. those combined with handsets. This is particularly salient for contracts that include high-value handsets such as iPhones.

7 Discussion and conclusion

We documented the evolution of prices, product differentiation, and dominated tariffs in the UK mobile phone market between January 2010 and September 2012. We document how prices and product differentiation do not always move in the same direction, as standard theory would predict. To reconcile these movements, we include the level of obfuscation by operators, i.e. the share of dominated tariffs, and find close co-movement between prices and the share of dominated tariffs on the market. Thus, one plausible explanation of this unexpected relation between product differentiation and prices is that firms introduce a shroud of products to make it harder for consumers to pick their best alternative and to relax competition that way.

Clearly, some caveats are in order. First, we do not observe consumer choices, just firm offerings. However, the existence and pattern of obfuscated tariffs suggest they did attract some consumers. Second, our obfuscation measure may be imprecise. However, we see the same pattern for more and less stringent definitions. Third, and most importantly, we document the evolution of three variables over a limited time. Many confounding factors or industry events could blur the link we posit or even account for the co-movement through an alternative channel. Most notably, the merger of two large players may have driven prices up initially. However, applying Occam's Razor, our candidate explanation uses just one additional assumption (firms introduce tariffs to obfuscate and the smallest firm had the least to gain from the obfuscation regime) to explain the evolution of prices. Statements by policymakers and industry participants support the view that obfuscation is indeed a deliberate strategy chosen by firms in this industry. Our data does not let us make a causal statement of the kind "obfuscation leads to higher prices": prices, product differentiation and the share of dominated tariffs are all choice variables by the firm, and the ease of launching and terminating tariffs makes it impossible to establish

a temporary chain of events to establish causality. However, based on our descriptive and econometric evidence we can state that "obfuscation and higher prices go hand in hand" and that this can dominate the otherwise stable relationship of product differentiation and prices.

Our study offers suggestive evidence of strategic behavior that has largely gone unnoticed by scholars: product choices in multiproduct firms have been studied from the perspective of firm resources (Barroso and Giarratana, 2013; Chatterjee and Wernerfelt, 1991) and from a market-based perspective (Sorenson, 2000), but the motivation of firms to create a shroud, or thicket, of products to reduce price pressures and to keep prices high is rarely discussed. Studying how firms identify their ability to obfuscate and how they implement it in practice, in a causal setting, would be very promising. For example, the introduction of labeling or transparency requirements would allow for studying the causal effect of obfuscation and transparency on performance. The dearth of research on obfuscation strategies offers many avenues for future work.

To underscore the continued relevance of obfuscation strategies, we refer to recent regulatory statements on this matter. In September 2018, the UK national telecommunications regulator Ofcom published a proposal to promote "clear and fair handset charges for mobile users" suggesting that the lack of transparency for mobile consumers is still a concern. In their press release, they name requiring the operators to "break down of the cost of the different parts of the mobile package" as one way to increase transparency.[21] With the current deployment of 5G networks and the incoming commercial launch of new services — which will require consumers to equip themselves with new, compatible devices, operators may use similar strategies again.

Obfuscation strategies are not limited to the mobile telecommunications industry. Indeed, any industry in which contracts (or products) are complex and firms can release new products at low cost lends itself to obfuscation strategies. Interestingly, the expectation that the internet and digital sales will lead to an increase in transparency through the reduction in search costs (Goldfarb and Tucker, 2019) may be offset by the ease of firms introducing variants of their products, creating confusion or fatigue among consumers. More generally, we document how

[21] Ofcom's statement reads: "We are also concerned that, when a mobile customer signs up for a bundled contract, providers are not transparent about the respective costs of the handset and the airtime. This means customers cannot tell how much they are paying for the different parts of their deal. We think this is unacceptable. Consumers should be able to clearly identify the goods and services they are paying for, so they can make an informed decision about what to buy."

firms in competitive markets with homogeneous and mature technology may still use innovative strategies to keep the market from becoming perfectly competitive. We also add to the literature that analyzes firm strategies to exploit search costs and bounded rationality of consumers, even in highly populated product markets. To conclude, while we cannot claim to have answered all questions about obfuscation strategies and their impact, our exploratory study is one of the first to identify, operationalize and analyze them in oligopolistic markets. We hope that documenting this phenomenon will lead to follow-up research on this frequently "hidden" part of firm strategy.

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Tables and Figures

Table 1: Descriptive statistics on combinations of tariff and handset

Variable	Mean	Std. Dev.	Min.	Max.
Tariff cost	32.88	13.73	0	125
Handset cost	38.79	75.31	0	649.99
Contract length	20.83	3.85	1	36
Sim-only tariff (0/1)	0.02	0.13	0	1
Voice allowance	649.75	621.9	0	3000
Sms allowance	291.77	824.71	0	5000
Data allowance	253.76	379.15	0	3072
On-net voice allowance	52.82	504.47	0	5000
Mixed allowance	8.44	100.14	0	3875
Unlimited voice (0/1)	0.04	0.2	0	1
Unlimited data (0/1)	0.56	0.5	0	1
Unlimited data (0/1)	0.18	0.38	0	1
Unlimited on-net voice (0/1)	0.12	0.33	0	1
N		191,653		

70% of tariffs are associated with a zero handset cost, meaning that they are fully subsidized by the operator. Sim-only tariffs are, by design, associated with a 0 handset cost.

Table 2: Main price regression

Dep. Var.	(1) Tariff price		(2) Tariff price		(3) Tariff price	
Share of dominated tariffs, own segment	0.02***	(0.00)			0.02***	(0.00)
Tariff was a dominated tariff at introduction	1.22***	(0.06)			1.21***	(0.06)
Average distance industry, own segment			-1.24***	(0.33)	0.56	(0.34)
Distance with other tariffs, own segment			0.61***	(0.16)	0.54***	(0.16)
Time trend	0.01	(0.00)	-0.01	(0.01)	0.02***	(0.01)
Tariff characteristics	Yes		Yes		Yes	
Handset characteristics	Yes		Yes		Yes	
Constant	-3.88	(2.51)	7.11*	(3.39)	-14.05***	(3.53)
Observations	155,258		154,683		154,683	
R2	0.87		0.87		0.87	

Standard errors in parentheses, clustered at the tariff-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

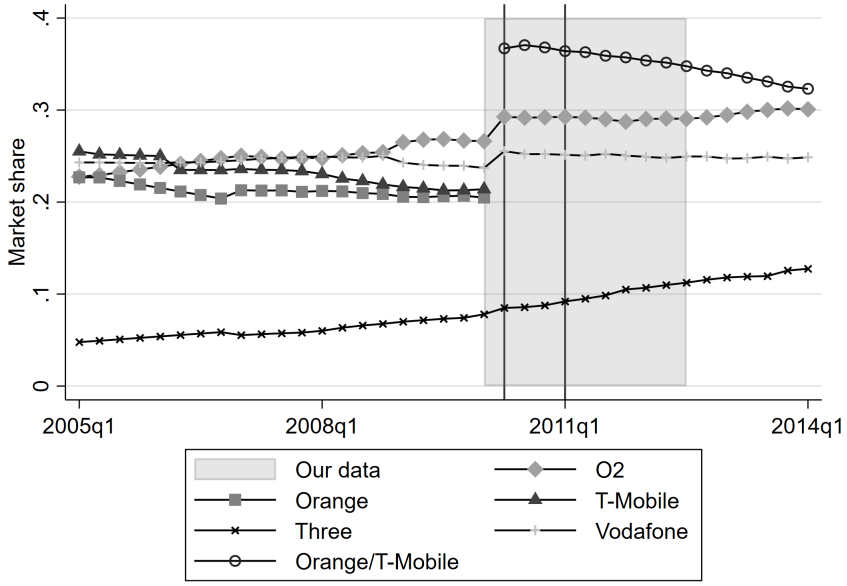
Note: Some observations are lost when we introduce the dummy variable for dominated at release. Indeed, we can only compute this variable if we observe the release of a tariff - which is not the case for those observed in January 2010, our first time period.

Table 3: Main price regression (with post dummy)

Dep. Var.	(1) Tariff price	
Share of dominated tariffs, own segment		
Post=0	0.10***	(0.01)
Post=1	0.01***	(0.00)
Tariff was a dominated tariff at introduction		
Post=0	2.54***	(0.11)
Post=1	0.82***	(0.07)
Average distance industry, own segment		
Post=0	-1.70***	(0.40)
Post=1	-0.00	(0.36)
Distance with other tariffs, own segment		
Post=0	-0.20	(0.18)
Post=1	0.81***	(0.18)
Time trend	-0.03***	(0.01)
Tariff characteristics	Yes	
Handset characteristics	Yes	
Constant	18.75***	(4.12)
Observations	154,683	
R2	0.87	

Standard errors in parentheses, clustered at the tariff-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

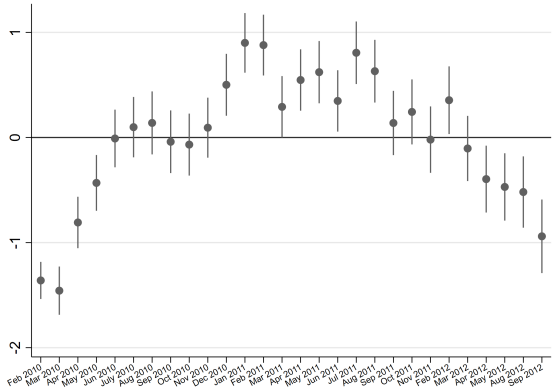
Figure 1: Market share of subscribers in UK



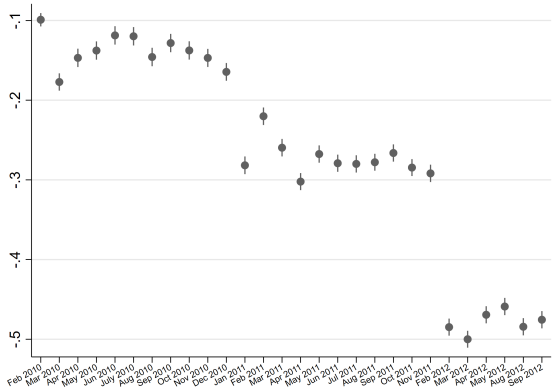
The first vertical shows where the merger between Orange and T-Mobile took place. The second vertical line corresponds to the beginning of the year 2011.

Figure 2: Evolution of indices

2a. Price index



2b. Differentiation index



2c. Obfuscation index

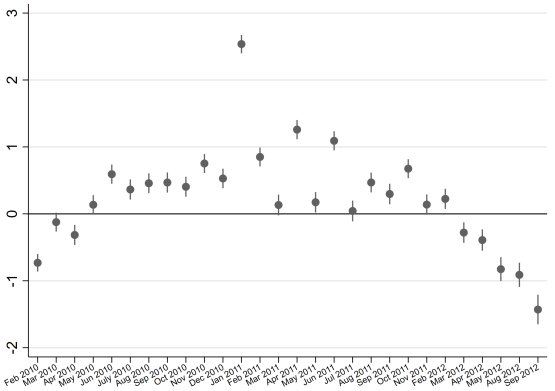


Figure 3: Estimation results from the main price regression

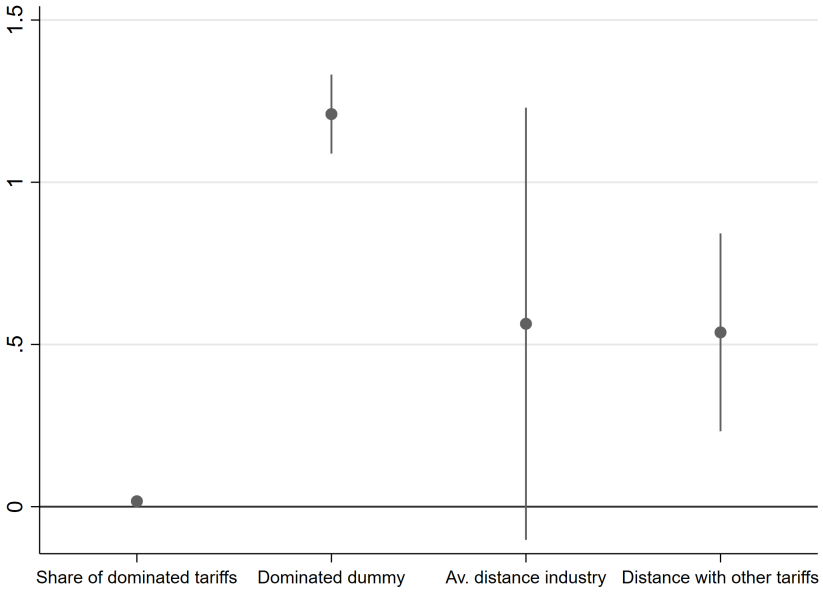
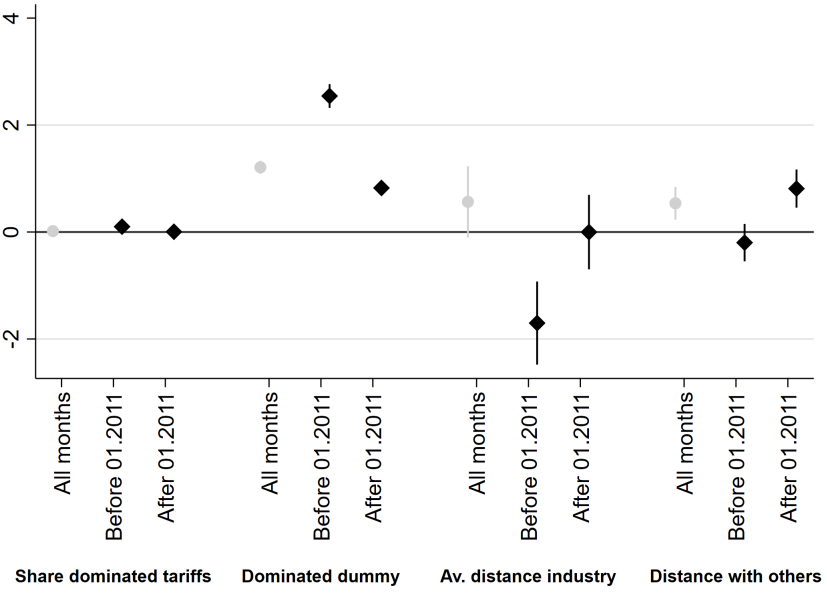


Figure 4: Estimation results from the main price regression with "Post January 2011" dummy



Appendix

Table A.1: Descriptive statistics on combinations of tariff and handset (per operator)

	Tariff cost	Handset cost	Contract length	Sim-only	Voice	Sms	Data	On-net allowance	Mixed allowance	Unlimited voice	Unlimited sms	Unlimited data	Unlimited on-net
O2	37.9	24.3	20.6	0.02	509	64	333	1.5	0.0	0.14	0.85	0.07	0.11
Orange	32.5	32.4	21.1	0.01	662	79	307	0.0	0.0	0	0.74	0.09	0
Three	23.1	16.1	22.5	0.03	529	2871	342	1131.7	141.0	0	0.17	0.37	0.16
T-Mobile	27.9	64.0	20.8	0.01	554	290	122	0.0	5.7	0.02	0.28	0.28	0.27
Vodafone	39.5	22.0	20.5	0.02	1104	180	318	0.0	0.0	0	0.57	0.16	0
Total	32.9	38.8	20.8	0.02	650	292	254	52.8	8.5	0.04	0.56	0.18	0.12

Table A.2: Contract length (in percent of combinations) per tariff type

	Sim-only tariff	Tariffs with handsets
1	57.2	0
3	1.9	0
12	36.7	1.83
18	3.05	45.15
24	0.65	52.9
30	0.5	0
36	0	0.13
N	191,653	

Table A.3: Descriptive statistics on tariffs

Variable	Mean	Std. Dev.	Min.	Max.
Tariff cost	30.44	14.27	0	125
Handset cost	17.2	50.41	0	459.99
Contract length	16.46	8.35	1	36
Sim-only tariff (0/1)	0.31	0.46	0	1
Voice allowance	648.87	607.53	0	3000
Sms allowance	372.46	978.91	0	5000
Data allowance	270.53	390.64	0	3072
On-net voice allowance	41.06	398.19	0	5000
Mixed allowance	7.16	85.84	0	3875
Unlimited voice (0/1)	0.05	0.21	0	1
Unlimited data (0/1)	0.58	0.49	0	1
Unlimited data (0/1)	0.13	0.34	0	1
Unlimited on-net voice (0/1)	0.1	0.31	0	1
N		10,485		

Table A.4: Statistics on normalized allowances

Variable	Mean	Std. Dev.	Min.	Max.
Normalized allowance of sms	0.62	0.46	0	1
Normalized allowance of voice	0.12	0.21	0	1
Normalized allowance of data	0.16	0.33	0	1
N		10,485		

Note: Average allowance of sms is very stable over time (0.6). Average allowance of voice declines from 0.28 to 0.1 and stays stable afterwards, until the end of the period. The average allowance of data starts around 0.25 in January 2010, stays stable until November 2010. It declines to 0.1, where is stabilizes until the end of the period.

Table A.5: Descriptive statistics on pairwise distances

Variable	Mean	Std. Dev.	Min.	Max.
Distance (sms, voice, data)	0.70	0.64	0	3
Distance sms	0.41	0.44	0	1
Distance voice	0.09	0.25	0	1
Distance data	0.2	0.38	0	1
N		1,981,060		

Table A.6: Estimation results from the hedonic price regression

	(1)	
Dep. Var.	Tariff price	
O2	0.00	(.)
Orange	-2.48***	(0.08)
Three	-9.42***	(0.26)
T-Mobile	-5.95***	(0.08)
Vodafone	-3.22***	(0.09)
Contract length=1	13.81***	(0.44)
Contract length=3	11.74***	(0.69)
Contract length=12	9.66***	(0.17)
Contract length=18	5.68***	(0.05)
Contract length=24	0.00	(.)
Contract length=30	14.51***	(0.75)
Contract length=36	-4.99***	(0.51)
Unlimited voice=0	0.00	(.)
Unlimited voice=1	34.83***	(0.19)
Voice allowance	0.02***	(0.00)
Unlimited SMS=0	0.00	(.)
Unlimited SMS=1	0.49***	(0.07)
SMS allowance	-0.00***	(0.00)
Unlimited data=1	3.13***	(0.09)
Data allowance	0.01***	(0.00)
Mixed allowance	0.01***	(0.00)
Handset subsidy=1	14.49***	(1.55)
Handset subsidy=1 × Amount of subsidy	0.01***	(0.00)
Smartphone=1	0.51***	(0.06)
Sim Only	0.00	(.)
Acer	6.40***	(1.55)
Apple	6.36***	(1.51)
Blackberry	4.34**	(1.50)
Dell	5.61***	(1.52)
Emporia	-0.09	(1.72)
Htc	3.30*	(1.50)
Huawei	2.71	(1.69)
Inq	3.03	(1.60)
Lg	3.51*	(1.50)
Motorola	3.22*	(1.51)
Nokia	3.11*	(1.50)
Orange	4.23**	(1.51)
Palm	8.40***	(1.51)
Samsung	3.21*	(1.50)
Sony	5.96***	(1.53)
Sony Ericsson	3.10*	(1.50)
T-Mobile	3.85*	(1.52)
Toshiba	2.37	(1.55)
Vodafone	7.22***	(1.64)
Zte	0.00	(.)
Month dummies	Yes	(.)
Constant	0.19	(0.42)
Observations	155,258	
R2	0.87	

Standard errors in parentheses, clustered at the tariff-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.7: Product differentiation regressions

Dep. Var.	(1) Pairwise distance	
Within operator FEs		
O2 to O2	0.00	(.)
Orange to Orange	0.01	(0.01)
Three to Three	0.02	(0.02)
T-mobile to T-mobile	0.25***	(0.01)
Vodafone to Vodafone	-0.06***	(0.01)
Between operators FEs		
O2 to Orange	0.06***	(0.01)
O2 to Three	0.30***	(0.01)
O2 to T-mobile	0.51***	(0.01)
O2 to Vodafone	0.08***	(0.01)
Orange to Three	0.14***	(0.01)
Orange to T-mobile	0.32***	(0.01)
Orange to Vodafone	0.02***	(0.01)
Three to T-mobile	0.25***	(0.01)
Three to Vodafone	0.09***	(0.01)
T-mobile to Vodafone	0.31***	(0.01)
Tariff types FE		
Tariff with handset to Tariff with handset	0.17***	(0.00)
Sim-only to Tariff with handset/Tariff with handset to Sim-only	0.12***	(0.00)
Sim-only to Sim-only	0.00	(.)
Month dummies	Yes	(.)
Constant	0.67***	(0.01)
Observations	1,981,060	
R2	0.11	

Standard errors in parentheses, clustered at the pair-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.8: Dominated tariffs regressions

	(1)		(2)	
Dep. Var.	Dummy dominated		Dummy dominated	
Model	OLS		Logit	
O2	0.00	(.)	0.00	(.)
Orange	-0.06***	(0.00)	-0.55***	(0.03)
Three	0.29***	(0.01)	1.97***	(0.07)
T-Mobile	0.01***	(0.00)	0.13***	(0.04)
Vodafone	0.06***	(0.00)	0.40***	(0.03)
Sim-only=1	-0.14***	(0.01)	-3.12***	(0.21)
Months FE	0.00	(.)	0.00	(.)
Distance with the industry average (sms)	-0.04*	(0.02)	-0.33***	(0.09)
Distance with the industry average (voice)	-0.00	(0.02)	-0.02	(0.15)
Distance with the industry average (data)	-0.02	(0.01)	-0.30**	(0.10)
Distance with the operator average (sms)	-0.09***	(0.02)	-1.08***	(0.14)
Distance with the operator average (voice)	0.04	(0.02)	0.30	(0.17)
Distance with the operator average (data)	0.00	(0.01)	0.12	(0.10)
Constant	0.11***	(0.01)	-2.21***	(0.07)
Observations	191,653		191,653	
R2	0.14			
Log Likelihood			-76205.74	

Standard errors in parentheses, clustered at the tariff-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.9: Statistics on indices and correlations matrix

	Statistics				Correlations		
Variable	Mean	Std. Dev.	Min.	Max.	Price	Diff	Obf
Price index	-0.017	0.605	-1.457	0.9	1.000		
Differentiation index	-0.255	0.137	-0.5	0	-0.028	1.000	
Obfuscation index	0.225	0.749	-1.43	2.536	0.688***	0.313	1.000
N	29						

*** denotes a 1% significance level

Table A.10: Price regression with only proliferation and obfuscation measures

Dep. Var.	(1) Tariff price	(2) Tariff price	(3) Tariff price	(4) Tariff price	(5) Tariff price
Number of tariffs	0.0002***				
	(0.0000)				
Number of tariffs with handsets		0.0002***			
		(0.0000)			
Number of sim-only tariffs		0.0095***			
		(0.0009)			
Growth of number of combinations			0.0039***		
			(0.0002)		
Number of dominated tariffs				0.0002***	
				(0.0000)	
Share of dominated tariffs, own segment					0.0260***
					(0.0013)
Time trend	-0.0071	-0.0271***	-0.0071	0.0063	0.0123**
	(0.0040)	(0.0045)	(0.0040)	(0.0041)	(0.0041)
Tariff characteristics	Yes	Yes	Yes	Yes	Yes
Handset characteristics	Yes	Yes	Yes	Yes	Yes
Constant	3.5318	14.7702***	3.9267	-3.7767	-7.3225**
	(2.5198)	(2.7599)	(2.5198)	(2.5379)	(2.5489)
Observations	155,258	155,258	155,258	155,258	155258
R2	0.87	0.87	0.87	0.87	0.87

Standard errors in parentheses, clustered at the tariff-level
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.11: Cox proportional hazards models

Dep. Var.	(1) Exit rate		(2) Exit rate		(3) Exit rate	
Dominated tariff (0/1)	1.34***	(0.02)	1.33***	(0.02)	1.34***	(0.02)
Simonly tariff (0/1)	0.30***	(0.02)	0.30***	(0.02)	0.29***	(0.02)
Number of tariffs	1.00***	(0.00)	1.00***	(0.00)	1.00***	(0.00)
O2	1.00	(.)	1.00	(.)	1.00	(.)
Orange	1.17***	(0.02)	1.16***	(0.02)	1.18***	(0.02)
Three	1.57***	(0.04)	2.24***	(0.08)	2.45***	(0.11)
T-Mobile	0.92***	(0.01)	0.89***	(0.01)	1.02	(0.02)
Vodafone	1.37***	(0.02)	1.35***	(0.02)	1.43***	(0.02)
Time trend	1.00***	(0.00)	1.01***	(0.00)	1.01***	(0.00)
Distance with industry (sms)			0.63***	(0.03)	0.65***	(0.03)
Distance with industry (voice)			1.19***	(0.04)	2.77***	(0.19)
Distance with industry (data)			0.50***	(0.02)	0.27***	(0.01)
Distance from other tariffs of the operator (sms)					0.83**	(0.06)
Distance from other tariffs of the operator (voice)					0.34***	(0.03)
Distance from other tariffs of the operator (data)					2.35***	(0.11)
Observations	184,858		184,858		184,858	

Exponentiated coefficients; Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure A.1: Evolution of average pairwise distance over time

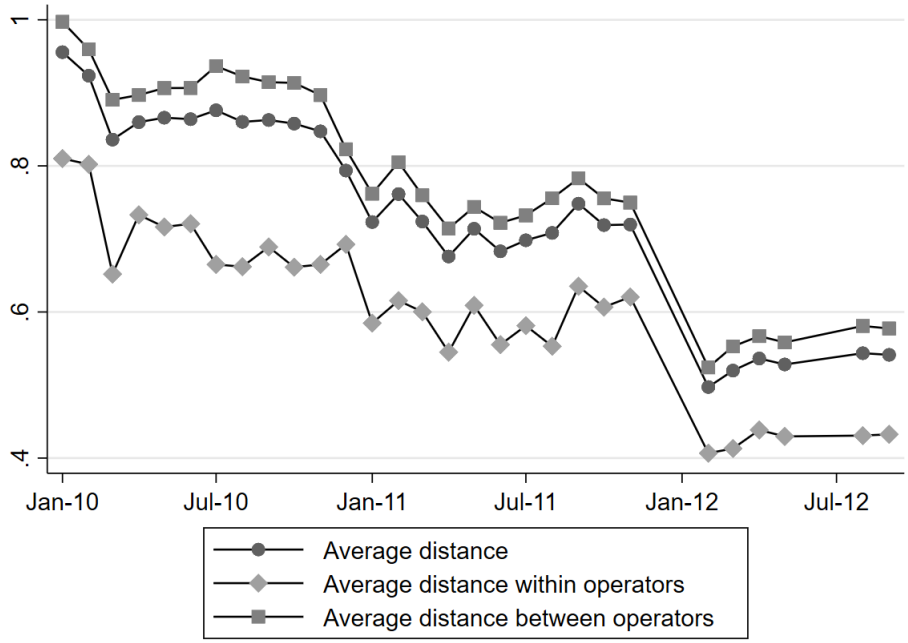
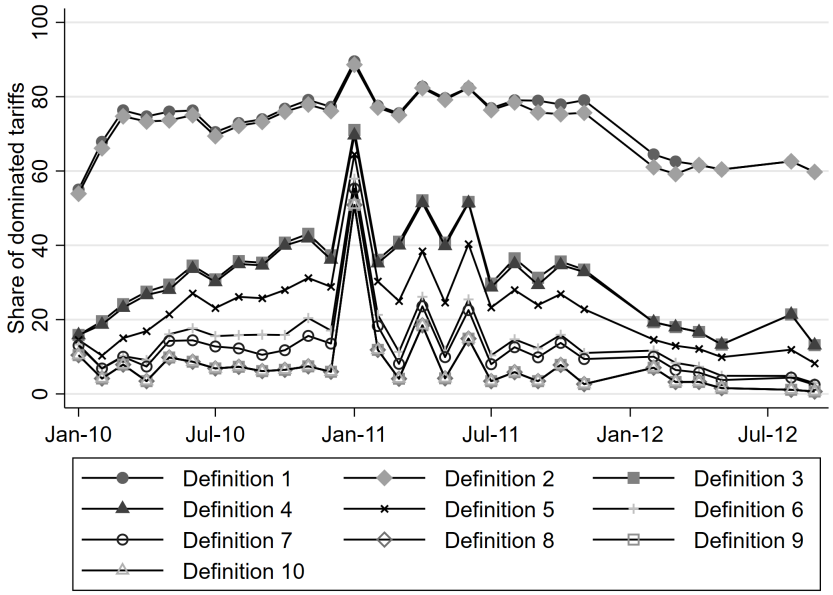


Figure A.2: Share of dominated tariffs according to various definitions



To create the obfuscation index, we define which tariffs are dominated. Because we are facing particularly complex combinations of attributes, we have considered several definitions for a dominated tariff, described below:

- Definition 1: Allowances of sms, voice, and data are the same.
- Definition 2: Allowances of sms, voice, data, and on net calls are the same.
- Definition 3: Allowances of sms, voice, data, and contract length are the same.
- Definition 4: Allowances of sms, voice, data, on net calls, and contract length are the same.
- Definition 5: Allowances of sms, voice, data, contract length, and handset cost are the same.
- Definition 6: Allowances of sms, voice, data, contract length, handset cost, and level of handset subsidy are the same.
- Definition 7: Allowances of sms, voice, data, contract length, handset cost, and amount of handset subsidy are the same.
- Definition 8: Allowances of sms, voice, data, contract length, handset cost, and handset model are the same.
- Definition 9: Allowances of sms, voice, data, onnet calls, contract length, handset cost, handset model, and level of handset subsidy are the same.
- Definition 10: Allowances of sms, voice, data, onnet calls, contract length, handset cost, handset model, and amount of handset subsidy are the same.

Figure A.3: Growth rate of the number of tariffs

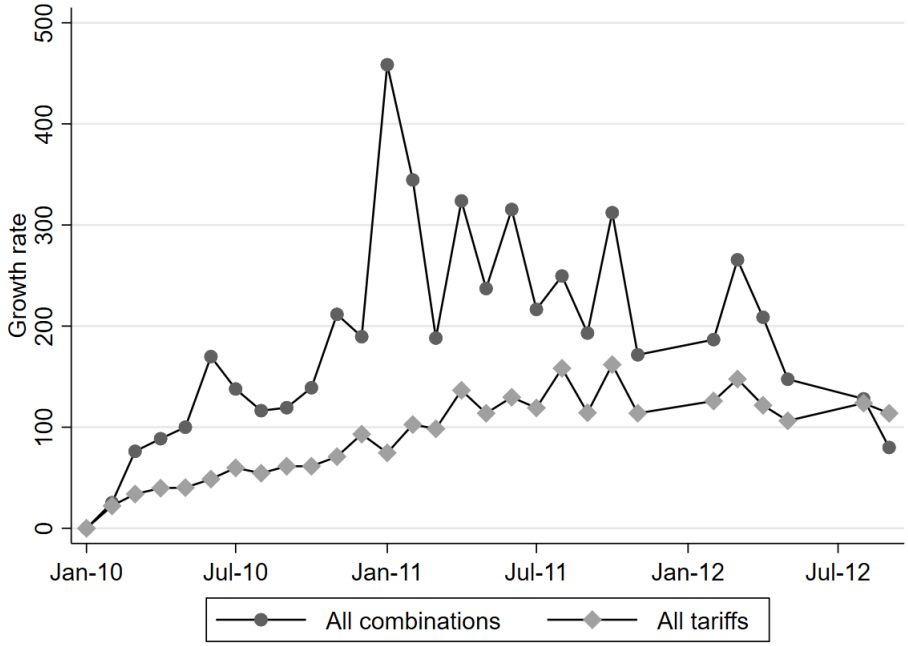
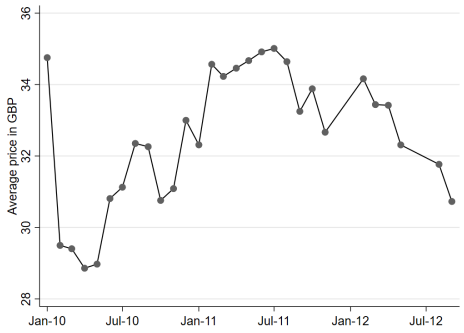
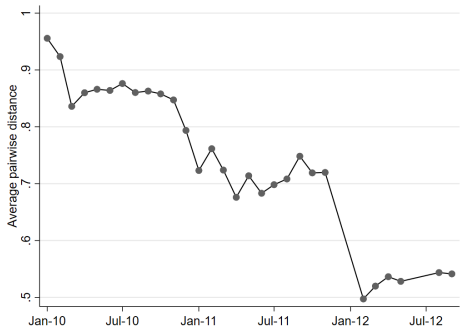


Figure A.4: Average price



Unweighted averages computed on the 191,653 combinations

Figure A.5: Average pairwise distance



Average pairwise distance computed on the 1,981,060 pairs

Figure A.6: Share of dominated tariffs

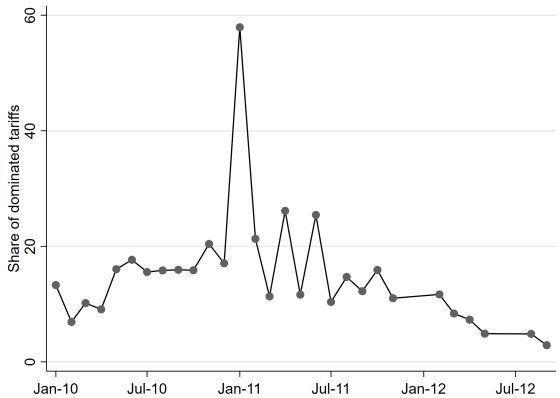


Figure A.7: Price indices sim-only/tariffs with handsets

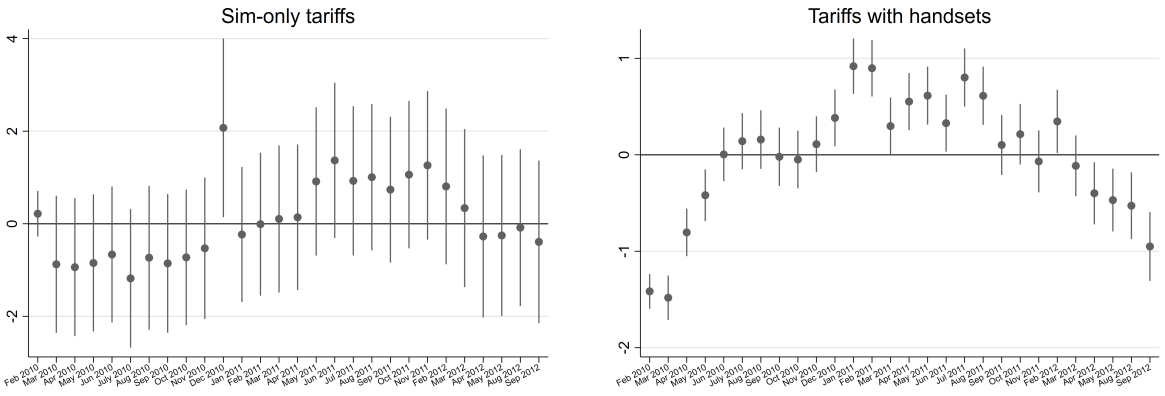


Figure A.8: Differentiation indices sim-only/tariffs with handsets

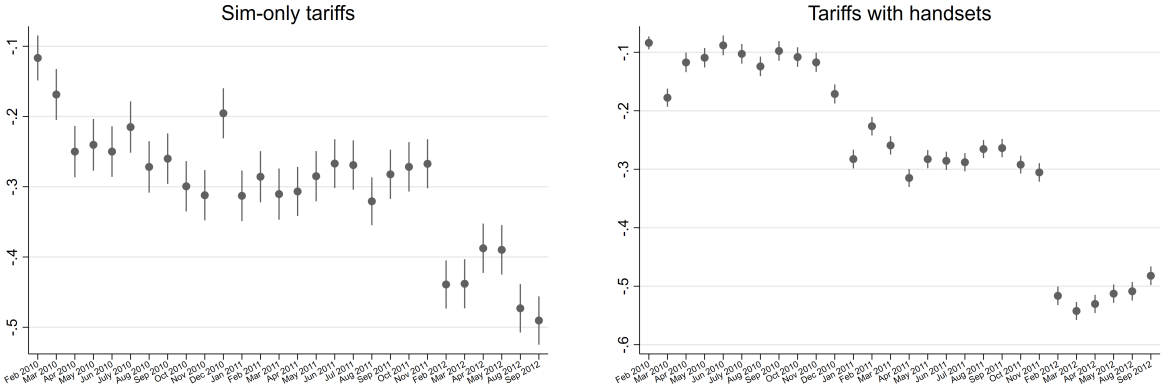


Figure A.9: Obfuscation indices sim-only/tariffs with handsets

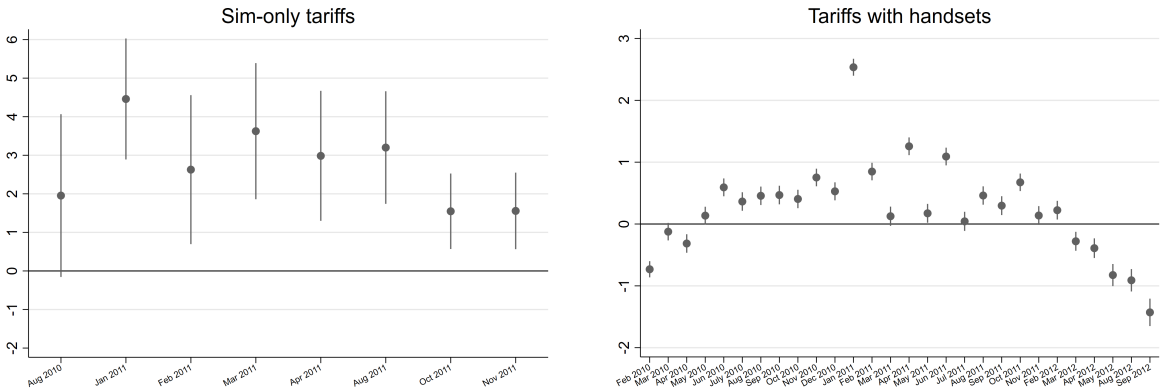


Figure A.10: Price indices per operators

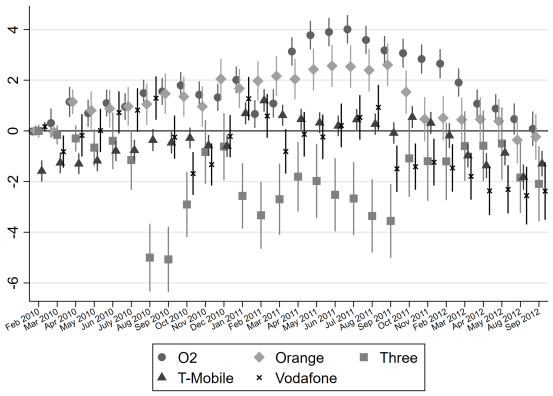


Figure A.11: Differentiation indices per operators

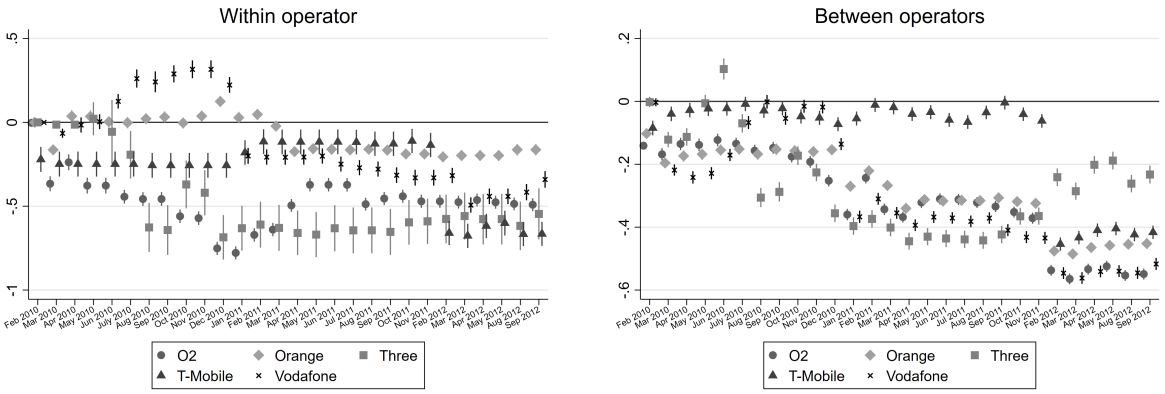


Figure A.12: Obfuscation indices per operators

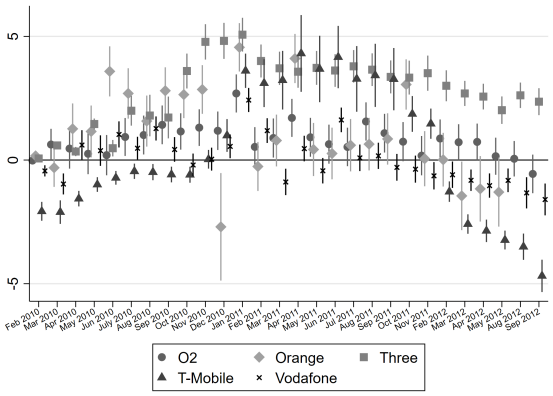
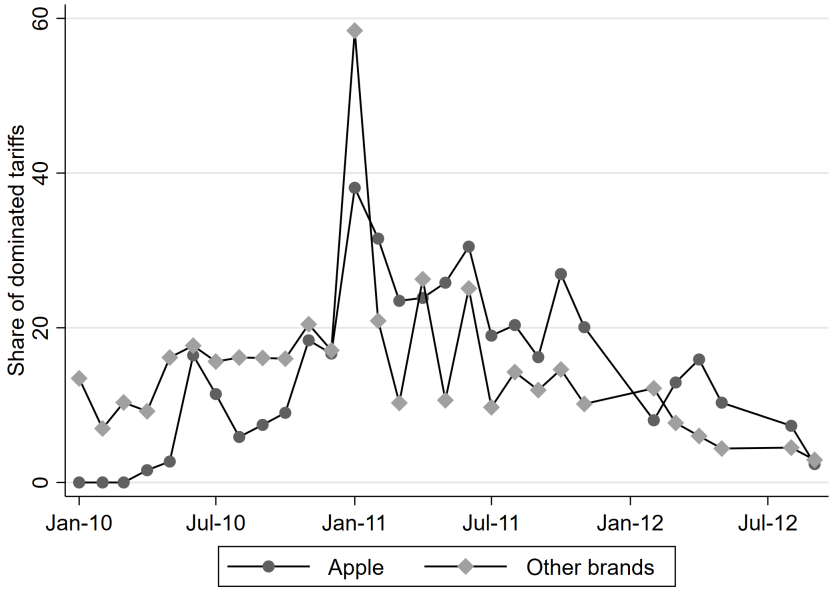


Figure A.13: Share of dominated tariffs: Apple vs other brands



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