Essays in empirical industrial organization : demand and supply in the mobile telecommunications market

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ESSAYS IN EMPIRICAL INDUSTRIAL ORGANIZATION: DEMAND AND SUPPLY IN THE MOBILE TELECOMMUNICATIONS MARKETS

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Introduction

Industrial economics is concerned with the structure of industries in the economy and the behavior of firms and individuals in these industries. It emphasizes imperfection of markets, which may be related to inherent characteristics of the industry -high fixed costs, scarcity of main resource- or firm's strategy to gain market power, i.e. collusion, mergers or vertical constraints. Because market structure may affect their efficiency and welfare, some of them are particularly regulated since their liberalization, for example, the telecommunications industries. This thesis offers a focus on a particularly dynamic branch of telecommunications, the mobile telecommunications. Mobile telecommunications share characteristics with other traditional network industries: a constrained production with a non-storable output, an infrastructure which is not easily replicable and significant positive network externalities. The scarcity of the main resource represents a significant barrier to entry, which combined with existence of economies of scale and network effects, are rationale for regulation. Indeed, the market cannot be perfectly competitive, and monopoly and oligopoly are commonly observed. This industry is also pointed out as being long restrained by the lock-in effect related to handset sim-locking or absence of number portability for example. Constantly evolving regulatory framework reduced in a large extent technical restrictions consumer used to face when switching service provider; although switching costs related to search costs, learning costs and uncertainty about the quality of other alternatives may still exists. Close complement to mobile services, handsets are also at the heart of an industry which is suspected to be imperfectly competitive, in particular because of the size of the players involved, their presence throughout the value chain or their agreements with verticals. Indeed, along with

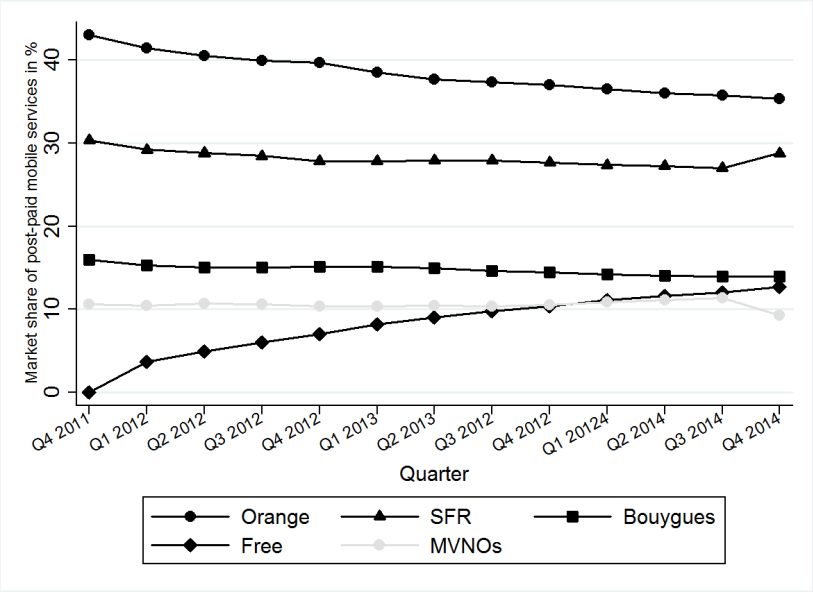
smartphones emerged a full ecosystem where not only manufacturers and operators are interacting but also application stores, developers, advertisers, search engines. Handset initial purchase and switching are relatively complex decisions influenced by individual's tastes and budget constraint, price and characteristics of available and forthcoming products, but also potentially driven by mobile operators through subsidy and loyalty programs. This thesis aims to contribute to the understanding of mobile telecommunication markets, in exploring how structure, technological investments of players and regulation have affected prices of services; but also, in measuring the magnitude of consumer inertia and myopia in a rapidly evolving environment.

Evolution of Mobile Services Prices in France

The French mobile market has recently gone through a period of significant changes, initiated by the entry of a fourth MNO in January 2012, followed by the commercial launch of 4G services, and punctuated by reduction of regulated wholesale prices for termination rate and roaming. In December 2009, the French regulatory authority (ARCEP) awarded a fourth 3G license to Free Mobile. In its application for the license, Free announced its will to offer consumers the possibility to unbundle handset and mobile services in offering free-of-commitment sim-only tariffs, what turned out to be at the core of its strategy to penetrate the market. In March 2011, Free Mobile signed a national roaming agreement with Orange for the provision of 2G and 3G services to increase its network coverage before launching mobile services. Six months later, ARCEP awarded licenses to operate 4G LTE networks to Orange, SFR, Bouygues, and Free Mobile. In October 2011, all three established MNOs launched their low-costs brands: Sosh (Orange), Red (SFR) and B&You (Bouygues Telecom) offering free-of-commitment sim-only tariffs, exclusively available online.[1] Free Mobile launched its services in January 2012 with two tariffs, one including unlimited texts, 2 hours of calls for 2€ per month and the other including unlimited texts, unlimited calls and 20 GB of data for

[1] These brands are described as fighting brands in Bourreau, Sun and Verboven (2018), that is, the strategical response of established firms to the entry of a new firm.

Figure 1 – Market shares of post-paid services in France



Own computation based on data from ARCEP and Yankee Group

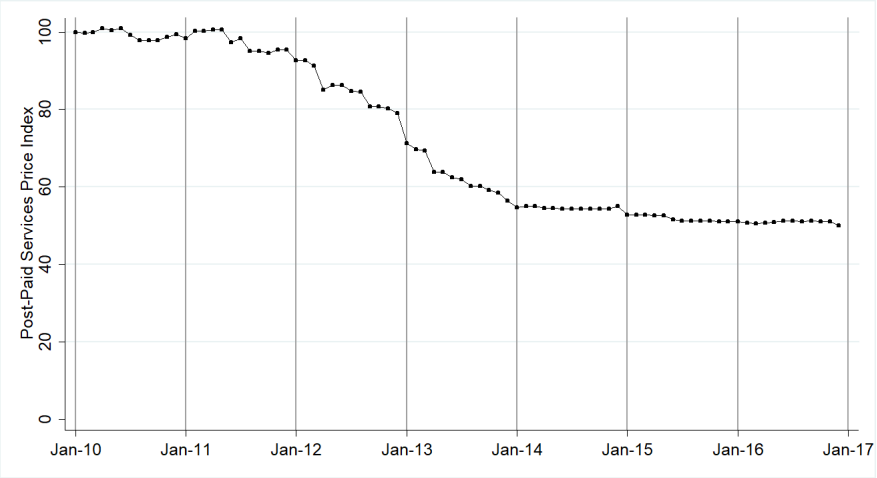
15.99€. Free rapidly gained market shares, at the expense of the three existing operators as shown in Fig.1.

In November 2012, SFR pioneered the launch of 4G tariffs, followed by Orange in April 2013, Bouygues Telecom in June 2013 and Free, in December 2013. Introduction of 4G services allowed for increased quality of speed for mobile broadband and offered a new potential source of revenue for operators, although requiring consequent network investments. Given the competitive pressure on the market, operators were not able to impose a premium for 4G access, unlike in other countries.[2]

Besides obligations of MVNOs hosting and coverage stated in their license agreements, French operators are subject to regulation through mobile termination rates and wholesale roaming price caps. On the one hand, mobile termination rates represent the price paid by one operator to another for terminating calls (or sms) on its network. These rates are determined by ARCEP in a relevant market analysis. On the other hand, wholesale roaming price caps are defined by the European Commission and represent the maximum price paid by a foreign

[2] According to a report by Analysys Mason, this premium was about 5 dollars in Italy, 15 dollars in UK, 35 dollars in Germany and 65 dollars in US, in 2013.

Figure 2 – National price index for post-paid services



Source: ARCEP

operator to terminate a call (or a sms) on the national network. Mobile termination rates as well as wholesale price caps have been steadily lowered over time.

The national price index of post-paid mobile services published by the national regulator ARCEP indicates a large price decline between 2011 and 2014 (See Fig. 2). This decline is commonly attributed to the effect of the entry of Free Mobile in the market. Nevertheless, this may not be the unique determinant of the price decrease. Consequently, we investigate in the first chapter of the thesis how changes in market structure, introduction of a new technology and regulation have respectively impacted prices of mobile services in France. We estimate hedonic price regressions using data on post-paid tariffs offered by the main mobile telecommunications operator between May 2011 and December 2014. Then, we relate the quality-adjusted prices to a set of variables which captures evolution of competitive pressure, technological investments and regulated price such as MTRs and roaming charges. We find that the obtained quality-adjusted price index decreased by about 42.8% as compared to a decline in weighted average prices without quality-adjustment of 8.7%. We also show that the launch of 4G networks by mobile operators was the main driver of price reductions for classic tariffs with commitment. Low-cost tariffs without commitment which were introduced to pre-empt the entry of low-cost competitor declined at the time of entry. Moreover, we find that regulation, which is approximated by the level of mobile termination charges and

international roaming price caps for voice and data, has a joint significant impact on quality-adjusted prices. In percentage terms, competition is responsible for about 23.4% of total price decline and investments in 4G for 56.1%. We conclude that the reduction in quality-adjusted prices in the last years was largely caused by competition between operators for a new 4G technology and by entry of a fourth low-cost operator. Our results are also robust in comparison to other constructed price indices. When we compare the results from our hedonic price regressions with the alternative OECD and ARCEP basket approach, we can draw similar conclusions. However, we consider that hedonic price regressions represent a more accurate methodology to assess price changes of telecommunications markets and should be preferred by the regulators.

Consumer Myopia in Handset and Tariff Choices

Handsets and mobile tariffs have traditionally been sold as a bundle by mobile operators. These bundles, which traditionally involve a handset subsidy by the operator, enable consumers to purchase a device at a discounted price, in exchange for a fixed period of commitment during which they keep the same contract. Handset subsidies is a major driver for consumer acquisition and retention in many countries and are still widely used to stimulate device upgrade and technology adoption (OECD, 2013). The commitment period associated with these tariffs (24 or 36 months) is pointed out as potentially responsible for consumers lock-in in increasing their switching costs. Consequently, regulators kept a close look on operators' practices and implemented policies aimed at reducing consumers lock-in.

For example, the practice of sim-locking, which implies that the handset can only be used on the network of the service provider, have been increasingly regulated in various countries to allow consumers unlocking it after a certain period, while the practice has been completely banned in some others.[3] Another potential regulation is to directly impact the commitment period associated with the contracts, what was the case in European Union, which imposed in 2011 that contracts cannot exceed 24 months. Three years prior to this decision, the Loi

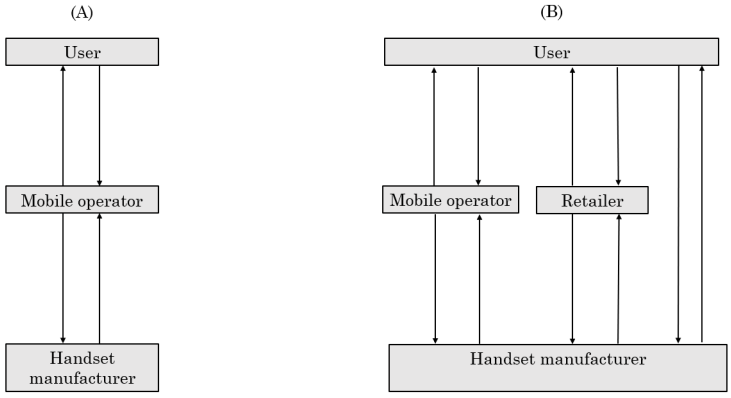
[3]Sim-locking is illegal in Singapore since 1997, in China and Chile since 2012 and in Canada since 2017.

Châtel in France imposed mobile operators to offer 12-months equivalent tariff of all their 24-months tariffs. Early-termination fee, which may also represent a significant barrier to service provider switching, have also been considered for regulation in some countries. The Loi Châtel in France imposes, since 2008, a strict rule for early-termination-fee computation so to reduce those charges for consumers willing to switch and increase competition between operators. To finish, regulators also considered or put into force measures aiming at improving transparency of pricing for consumers, for example in advertising not only the discounted price of handset but also the list price or in requiring operators to show charges from mobile services and repayment of the handset separately.

Several countries made a more radical move in imposing a ban of handset subsidies. Among them, Belgium, from 1991 to 2010, Korea from 2000 to 2006 and Finland from 1996 to 2006. These bans are documented to have negatively impacted adoption and usage of mobile broadband (OECD 2013). Recent experience in several countries shows that markets may also 'naturally' eliminate or, at least, reduce significantly handset subsidies. In 2012, Telefonica and Vodafone in Spain were among the first operators in Europe to announce their will to cut off handset subsidies to decrease operational costs, as the increasing demand for smartphones and high-end smartphones were involving constantly higher subsidies which affected their short-term profitability. In US, the same year, ATT and Verizon both reduced their handset subsidies and introduced a new financing scheme, based on an upgrade fee. Reduction of handset subsidies may also be the result of increased competition on the mobile market, related to the entry of a new player such as Three in UK and Free Mobile in France.

The rise of sim-only tariffs came hand in hand with the decline of handset subsidies. These tariffs, associated with no device and in many cases no commitment period, have been introduced as the result of operators' financial constraints and increased competitive pressure we described before; but also to meet an evolving and heterogeneous demand. Indeed, sim-only tariffs serve several consumer segments which were not or poorly served with traditional tariffs: highly price elastic or commitment-averse individuals, consumers not finding a handset matching their preferences in the operator's catalog or consumers not expecting to switch their

Figure 3 – Distribution chain before (A) and after (B) introduction of sim-only tariff



handset as often as the subsidization system would enable them to do, as well as consumers with a faster handset replacement cycle. Introduction and adoption of sim-only tariffs impacted the distribution chain of handsets which was traditionally controlled by the operators, leading to the emergence of new players such as large supermarkets, specialized shops and online retailers as represented in Fig.3. The decline of subsidy system also shifted a part of the demand towards cheaper handsets. Consumers accustomed to face low handset upfront prices due to the subsidization scheme increasingly considered cheaper models, what contributed to the emergence of new or marginal brands, as well as refurbished and second-hand handsets.

The introduction of sim-only tariffs impacted both mobile services and handset markets and expanded significantly consumers set of possible choices. In the second chapter of the thesis, we explore how this evolution affected consumer's decision, in particular how individuals tradeoff current and future expenses in a situation where both sim-only tariffs and traditional tariffs with handset subsidies coexist. To do so, we estimate a discrete choice model for combinations of mobile tariffs and handsets using a cross-section of 16 743 subscribers of a European telecommunications carrier, observed between April 2011 and December 2014. We then use our estimates to compute an average value for consumer myopia, which capture how individuals value future when making their choice, for each quarter. We show that, under assumptions underlying the econometric model, consumer myopia decreases significantly over time and stabilizes around a value reasonably close to myopia estimated in other markets. We

then explore the relationship between myopia evolution and a set of variables which capture the most significant changes on the market and conclude that we cannot confidently disentangle the respective impact of a new MNO, introduction of low-costs brands, launch of 4G services and increasing availability of sim-only tariffs. Nevertheless, we provide robust evidence of the decline of myopia not being mechanically driven by the increased market share of sim-only tariffs as the result hold in estimating our model only on consumers who chose tariffs with handset subsidy. This study offers a measure of one of the potential sources of detriment listed by the European Commission (2007) based on observed data. It suggests a significant and positive role of competition in reducing one of the source of consumer's welfare loss, i.e. myopia.

Consumer Inertia in Smartphone Choice

Like the mobile services market, the handset market has witnessed significant changes during the last decade, in particular related to the emergence of smartphones. Since the release of the first iPhone in 2007, smartphones have gradually been adopted to reach about 57% of global population in 2018 -with a particularly high penetration in US (80% in 2017, predicted 91% in 2025) and Europe (70% in 2017, predicted 81% in 2025)[4]. The handset market is polarized between the smartphones and the feature phones, the former tending to be more differentiated -at least on the hardware level- while the latter tends to homogenize. Size of the screen, weight, thickness, color, camera quality: hardware characteristics have a significant weight in consumer decision,[5] although price is still the major determinant for purchase according to a recent report by Kantar.[6] Hardware aside, smartphones require an operating system which may be proprietary (iOS for Apple, BlackBerryOs for Blackberry) or open-source (like AndroidOs). A very limited number of them are widely used, among which two

[4]The Mobile Economy, 2018 - GSMA

[5]According to a report by Kantar (2017), the top 3 purchase drivers among those who purchase a smartphone in 2016 in US, UK and China are (1) Screen size, (2) Camera quality and (3) Phone reliability for US and UK, Screen resolution in China.

[6]In the same report listing the top 3 purchase influencers, price of the phone is at first place for US, UK and China.

are clearly dominating the market, Android OS and iOS, representing respectively 75.3% and 19.6% of the global market in April 2018. These two operating systems function with a specific application store, come with a search engine pre-installed by default and feature some proprietary applications like Gmail, GoogleDrive and Youtube for Android OS and FaceTime and iMessage for iOS. Contractual agreements between operating systems, manufacturers and search engines may be involved. For example, Google pays Apple to be the default search engine on iOS and has also agreements with manufacturers willing to use its operating system Android and feature applications from Google Suite (Gmail, Google Drive, Youtube, etc.). The latter were at the core of a case by the European Commission which points out these agreements[7] as potentially anti-competitive. This case resulted in a fine of 4.34 billion€ to Google, announced on the 18th of July 2018.

These operating systems are part of mobile ecosystems which consumers may access through several devices: smartphones, tablets, watches and computers (in the case of Apple). Existence of such ecosystems, although potentially beneficial for users, may be source of switching costs. The market research firm Kantar documented in 2017 that loyalty rate, i.e. the percent of users staying with the same operating system when upgrading their phone, for individuals owning only an iPhone was about 92%, and 96% for users using both iPhone and a iPad. A similar phenomenon exists among Samsung smartphone owners – loyalty to the phone alone was 67%, increasing to 74% if the consumer owned both a Samsung phone and tablet.[8]. Switching costs are traditionally described as detrimental for competition, in term of prices, in enabling higher price for locked-in consumer, but also in deterring the entry of alternative -potentially superior- products.

Due to the role which smartphones started to play in our daily lives and their increasing role as a platform for distribution of products and services, there is an immense interest in what drives the evolution and success in this industry. Moreover, the extremely high concentration in operating systems market and the winner-takes-all feature of this market has drawn attention of the policy makers. In this paper, we shed light on competition between

[7] Android's Anti-Fragmentation Agreement, Mobile Application Distribution Agreements and Revenue Sharing Agreement

[8] Kantar WorldPanel: An incredible decade for the smartphone 2017

smartphone manufacturers and operating systems by revealing some facts with respect to consumer behavior in this market. In particular, we attempt to estimate consumers inertia in smartphone choice. We estimate consumer choices of smartphone models using a database of subscribers to a single mobile operator in a European country on monthly basis between March 2012 and December 2014. In our estimation we consider subscribers to sim-only tariffs without commitment and we only focus on consumers and observations in which handset switching takes place. We use our model to simulate market shares of brands and operating systems in the absence of switching costs. Our estimation results indicate that there is significant state-dependency in the choices of operating systems and smartphone brands. In general, we observe that it is harder for consumers to switch from iOS to other operating systems, except Blackberry. These higher switching costs may be also linked to the cost of changing the whole ecosystem build by Apple around iPhone. Switching from Android to iOS and Windows is also costly but the switching costs in this direction are lower than average. It is also easier than average to switch from Blackberry to iOS. There is no difference from average in switching from Windows to different operating systems. Smartphones made by Blackberry and Apple have proprietary operating systems and the state dependency between operating systems and brands cannot be separated. Moreover, we find that there is significant time-persistent heterogeneity in preferences for different smartphone brands and operating systems, which also leads to state-dependent choices. In our counterfactual, we find that in the absence of switching costs iOS and Apple lose market share, while Android's market share increases We can conclude that the market position of Android would be even stronger towards monopoly in the absence of switching costs between operating systems and brands.

Chapter 1

Evolution of Mobile Services Prices in France

This chapter is a joint work with Lukasz Grzybowski and Christine Zulehner and is published in *Economic Inquiry* as "Impact of competition, investment, and regulation on prices of mobile services: Evidence from France". [1]

Abstract In this paper, we assess the impact of competition, investment and regulation on prices of mobile services in France. We estimate hedonic price regressions using data on tariff plans offered by the main mobile telecommunications operator in France between May 2011 and December 2014. In this time period, the obtained quality-adjusted price index decreased by about 42.8% as compared to a decline in weighted average prices without quality-adjustment of 8.7%. In a second step, we relate the quality-adjusted prices to a set of competition, investment and regulation variables and find that the launch of 4G networks by mobile operators was the main driver of price reductions for classic tariffs with commitment. Low-cost tariffs without commitment which were introduced to pre-empt the entry of low-cost competitor declined at the time of entry. Moreover, we find that regulation, which is approximated by the level of mobile termination charges and international roaming price caps

[1] The paper was presented at the Liège Competition and Innovation Institute Seminar (Liège, Belgium) in 2016 and during the 66th Annual Meeting of the French Economic Association (Nice, France) and the ITS Conference (Passau, Germany) in 2017.

for voice and data, has a joint significant impact on quality-adjusted prices. In percentage terms, competition is responsible for about 23.4% of total price decline and investments in 4G for 56.1%. We conclude that the reduction in quality-adjusted prices in the last years was largely caused by competition between operators for a new 4G technology and by entry of fourth low-cost operator.

1.1 Introduction

The competitiveness of mobile telecommunications industry is commonly assessed by the industry regulators on the basis of price comparisons over time and across countries.[2] But such comparisons are not easy for industries which exhibit dynamic changes in both price and quality of products. Pricing of mobile telecommunications services has remained complex since the launch of mobile technology in 1990s. Initially, mobile operators charged different prices for calls to mobile and fixed-line numbers as well as calls made peak and off-peak, on- and off-net with different billing intervals per second, per 10 seconds, per minute, which also could differ for the first and subsequent minutes of the call. Apart from that, the price of calls differed depending on tariff and monthly subscription fee, length of contract and handset subsidy. Over time, much simpler pre-paid tariffs were introduced without commitment and tariffs with included minutes allowances. But operators also started to complicate tariffs by introducing special prices for selected numbers, family offers, etc. In addition, new services were introduced which were either substitutes or complements to voice calls, including SMS, MMS, voice mail, roaming, etc. The next pricing revolution came with the development of 4G networks and increasing demand for mobile Internet access. Mobile operators now typically offer unlimited voice calls and data allowances which makes them more transparent to consumers than before. Still, a wide range of tariffs are offered on monthly basis which are replaced by new ones in the next months.

The pricing strategies of mobile operators, and continuous changes in the range of offered services, make it very difficult to follow the evolution of prices in the recent years. At the same

[2] See for example the reports published by the OECD, European Commission and national regulators.

time, it is very important to understand price changes in mobile telecommunications because they represent a significant share in monthly expenditure of every household and are typically included in the 'basket' of products and services used to calculate inflation.[3] Moreover, prices of mobile services are closely watched by industry regulators because they can be influenced by regulation of termination charges and roaming. Also, an ongoing convergence of fixed-line and mobile technologies and increased popularity of bundled offers affect prices and draw attention of the policy makers.[4]

Mobile prices were at the core of antitrust investigations including collusion and merger cases. For instance, collusion in mobile telephony was detected and prosecuted in France in 2005. In the last years, several mergers took place between mobile operators, including mergers which were cleared by the competition authorities such as the acquisition of tele.ring by T-Mobile in Austria in 2006, a merger between T-Mobile and Orange in the Netherlands in 2007, a merger between T-Mobile and Orange in the UK in 2010 and a merger between O2 and E-Plus in Germany in 2014[5]. Other mergers were blocked by the competition authorities, for instance the recently proposed transaction between Three and O2 in the UK. The post-merger prices of mobile services were the main concern in deciding on these transactions. Apart from mergers, also when deciding about the number of new spectrum licences the regulators take into account their impact on retail prices. Even though the numbers of mobile competitors was largely decided in the 1990s during spectrum auctions for 2G and 3G technologies, the more recent 4G auctions brought changes to the market structure. It is therefore interesting to know whether entry and launch of new technology increase competition and results in lower prices.

In this paper, we estimate hedonic price regressions using a complete database of tar-

[3] In France, the consumer price index (CPI) for the first time took into account a price index for mobile services in January 2004. The index was calculated using the customer profile method, which was recognized as the best approach by statisticians dealing with price indices. However, both data requirements and resources needed to establish and maintain this approach are substantial. Aghion et al. (2017) demonstrate how challenges to measure inflation when quality and variety of products change may understate estimates of economic growth.

[4] According to a report by Analysys Mason, about 42% of fixed broadband households in France bundled mobile voice contracts with their fixed broadband service at the end of 2012, which based on their forecasts should increase to 75% by the end of 2017.

[5] See for example, Aguzzoni et al. (2015) for an ex-post analysis of two mobile telecom mergers in Austria and the Netherlands

iff plans offered by the leading mobile telecommunications operator in France, Orange, on monthly basis between May 2011 and December 2014.[6] We divide the tariff plans into two groups: classic contract tariffs with commitment, and low-cost contract tariffs without commitment and without handset subsidy. In the latter case, consumers do not have to commit to stay with the operator for 12 or 24 months and can quit the contract at any time. Low-cost tariffs were introduced by Orange in October 2011 before the entry of fourth mobile operator, Free Mobile. We regress the cost of tariffs on a set of characteristics including monthly dummy variables, and derive a quality-adjusted price index. In this time period, the quality-adjusted price index decreased by about 42.8% as compared to a decline in average prices without quality-adjustment of 8.7%. Next, we regress the quality-adjusted prices on a set of competition, investment and regulation variables and find that the launch of 4G networks by mobile operators was the main driver of price reductions for classic tariffs with commitment. At the same time, low-cost tariffs without commitment were introduced to pre-empt entry of low-cost competitor Free Mobile and declined at the time of their entry. Moreover, we find that regulation, which is approximated by the level of mobile termination charges and international roaming price caps for voice and data, has a joint significant impact on quality-adjusted prices. In percentage terms, competition is responsible for about 23.4% of total price decline, launch of 4G technology for 56.1%, with the remaining effect being regulation and other factors. Thus, we conclude that the reduction in quality-adjusted prices in the last years was largely caused by competition between operators for a new 4G technology and by entry of fourth low-cost operator. We also compare the results from our hedonic price regressions with alternative approaches which track price changes over time based on consumer usage profiles, such as the OECD usage basket method. This approach is commonly used to analyze the evolution of prices of telecommunications services. It also indicates that entry, launch of low-cost brands and investments in 4G networks led to significant price reductions. However, we consider that hedonic price regressions represent a more accurate methodology to assess price

[6] Orange, formerly France Telecom, is the incumbent fixed-line operator in France. Orange is also market leader in mobile market and its pricing strategies are representative for the whole market. It was followed by the competitors in the decisions to launch low-cost tariffs and 4G services. According to data from Analysys Mason Telecom Market Matrix, the market share of Orange in mobile market was 39% as of Q3 2016.

changes of telecommunications markets and should be preferred by the regulators.

Our study contributes to the literature on hedonic price regressions with an application to the telecommunications industry. This is the first paper which relies on detailed tariff information for a period of few years to quantify the impact of both entry and investments in new 4G technology on quality-adjusted prices for mobile telecommunications services. The hedonic price model is based on the idea that any product can be viewed as a bundle of attributes. Firms and consumers trade with each other to determine the price attached to each attribute (see Griliches (1961) and Rosen (1974) for a formal presentation of this model in perfectly competitive framework). There are only a few empirical studies of prices indices for mobile telecommunications services. For instance, Karamti and Grzybowski (2010) estimate hedonic price regression using monthly tariff data from mobile operators in France in the period between June 1996 and December 2002. They find that quality-adjusted prices decreased in the earlier part of this period and stabilized over time. There were also significant differences in quality-adjusted prices between operators which diminished over time. Greenstein and McDevitt (2011) analyze changes in quality-adjusted prices using data on 1,500 tariffs for DSL and Cable services in the U.S. in years 2004-2009 based on a mixture of matched-model methods and consumer price indices. Whilst they found only a modest decline in prices, they were nonetheless falling faster than indicated by the price index for Internet access constructed by the Bureau of Labor Statistics. In another paper, Wallsten and Riso (2014) estimate a linear hedonic model using data on over 25,000 broadband prices from OECD countries in years 2007-2009, while Calzada and Martinez-Santos (2014) estimate price regressions using broadband tariffs data from 15 EU countries in years 2008-2011. Finally, Coynes and Lyons (2015) estimate hedonic price regressions using daily observations of plans offered in Ireland from 2007 to 2013. They find that average nominal prices remain stable throughout the sample period but quality of service increased dramatically over time, particularly with respect to download speed.[7]

Among studies on the impact of regulation on prices of telecommunications services,

[7]There is also a number of recent papers estimating hedonic price regressions in application to other industries including wine. See for example Costanigro, Mittelhammer and McCluskey (2009), and Dimson, Rousseau and Spaenjers (2015).

Genakos and Valletti (2011) analyze how the regulatory intervention to cut fixed-to-mobile (F2M) termination rates impacts mobile retail prices. Using panel data of prices and profit margins for mobile operators in more than 20 countries in a period of over six years, they find that a reduction in F2M termination rates leads to an increase in retail prices,[8] which they call the "waterbed" effect.[9] In a more recent paper by the same authors, Genakos and Valletti (2015) estimate the impact of regulation of F2M termination rates on mobile phone bills using a large panel covering 27 countries. They find that the "waterbed" phenomenon becomes insignificant on average over the 10-year period, 2002-2011. They argue that this is due to the changing nature of the industry, whereby mobile-to-mobile traffic surpassed fixed-to-mobile traffic.[10] Moreover, among studies on the impact of competition on prices in telecommunications markets, Genakos et al. (2015) analyze how entries and exits influence prices of mobile services and investments in networks using cross-section panel data for 33 OECD countries in years 2002-2014. They also approximate mobile prices using Teligen's baskets and use the estimates to comment on the effects of mergers on prices and investments. They find that mobile markets become more concentrated in the analyzed period and prices increased, while the effect of concentration on investment is not significant at the industry level. The reminder of this paper is organized as follows. Section 1.2 discusses the main changes in mobile telecommunications industry in France. Section 3.2 presents the data used in the estimation. Section 3.3 introduces the econometric framework. Section 3.4 presents the estimation results. Finally, Section 3.5 concludes.

[8] They obtained information on retail prices from a consultancy firm Teligen, which collects telecommunications pricing data. The prices are expressed in terms of three representative usage baskets (heavy, medium and low) based on a number of characteristics (number of calls and messages, average call length, time and type of call, etc.) which are then held fixed across countries and over time.

[9] The "waterbed" effect suggests that pressing down prices in one part of firms' operations causes another set of prices to rise.

[10] A decade ago there was a burgeoning theoretical literature on the impact of mobile termination rates on prices, which started with the seminal works of Armstrong (1998) and Laffont et al. (1998). For surveys, see Armstrong (2002) and Laffont and Tirole (2000).

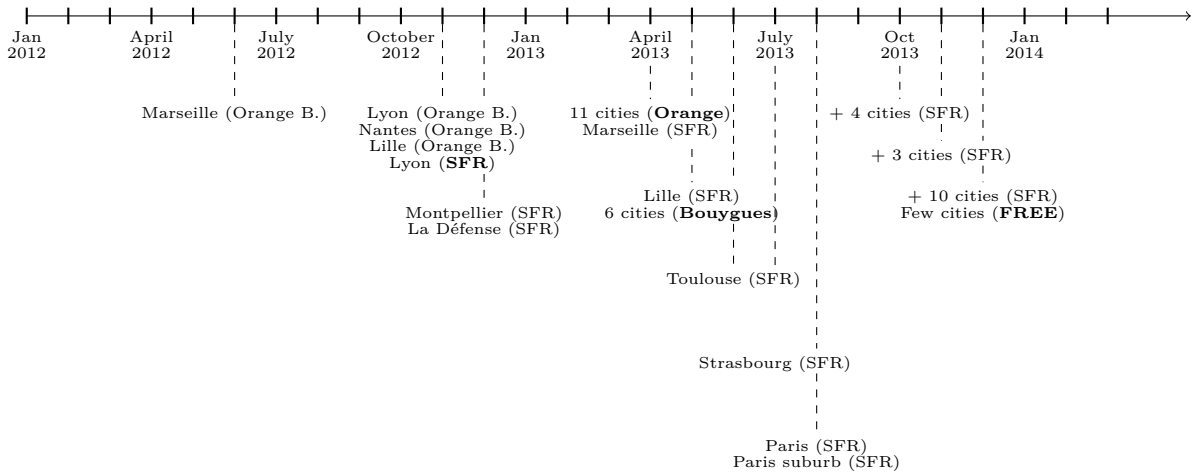
1.2 The Mobile industry in France

This section describes the main events that took place in the mobile telecommunications industry in France. The start of mobile telecommunications in France dates back to March 1992 when two licences for digital mobile services GSM 900 were granted to the fixed-line incumbent operator France Telecom Mobiles and Societe Francaise de Radiotelephonie (SFR). In June 1996, a third network operator, Bouygues Telecom, entered the market after being granted a licence to operate digital technology GSM 1800. In June 2001, the French government awarded two out of four 3G (UMTS) licences to France Telecom and SFR using a "beauty contest", while Bouygues and other players pulled out of the bidding due to the high licence price. In 2002, the authorities altered the licence conditions and published a new call for two 3G licences, which were not granted in the first round. The only bidder was Bouygues, which received the licence in October 2002. Between October 2002 and December 2009, there was no new entry into the market, except for a number of entries and exits of MVNOs.[11] In December 2009, the French regulatory authority (ARCEP) awarded a fourth 3G license to Free Mobile. Several months later, in March 2011, Free Mobile signed a national roaming agreement with Orange for the provision of 2G and 3G services to increase its network coverage before launching mobile services. In September 2011, ARCEP awarded licences to operate 4G LTE networks to Orange, SFR, Bouygues and Free Mobile.

In October 2011, three existing mobile operators, Orange, Bouygues Telecom and SFR, launched offers under new brands called respectively Sosh, B&You and RED aiming to preempt market entry of Free Mobile. These brands offered tariffs with no handset subsidy and no commitment. After entry in January 2012, Free Mobile also launched two tariffs with no handset subsidy and no commitment. About a year later, in November 2012, SFR pioneered launch of 4G services which were initially available only in one city (Lyon). Orange on the other hand, pioneered 4G business offers, which started in June 2012 in Marseille and expanded to three other cities in November 2012. Residential 4G offers were launched by

[11] A Mobile Virtual Network Operator (MVNO) provides mobile services without having allocated own spectrum and thus relying on network and spectrum of mobile network operators. MVNOs can apply own pricing strategies and provide customer services.

Figure A.1 – Timeline of deployment of 4G services in France



'Orange B.' denotes Orange Business offers. The bold text denotes the date of official launch of commercial 4G services by each operator.

Orange in April 2013 in 11 cities. Bouygues Telecom had the best 4G coverage thanks to spectrum refarming authorization on its 1800 Mhz band, which enabled the operator to have a coverage of 40% of the French Metropolitan population when starting its 4G services.[12] It commercialized its 4G services since May 2013, but the official launch took place in October 2013. At this time Bouygues Telecom offered a 4G mobile plan for 15 Euros per month, which was considered to be the best available 4G tariff on the market. Finally, Free Mobile launched its 4G services in December 2013. Figure B.1 shows the timeline of the launch of 4G networks by mobile operators in France.

As discussed above, during the time period of our analysis, there were two major market disruptions: entry of a fourth operator, Free Mobile, and commercial launch of 4G networks by all four operators. We analyze how these events influenced prices of mobile services in France. Moreover, we consider whether regulation of termination rates by ARCEP, and of roaming charges by the European Commission, impacted quality-adjusted prices.[13] The papers by Genakos and Valletti (2011) and Genakos and Valletti (2015) mentioned above used fixed-to-mobile (F2M) termination rates to explain changes in mobile retail prices. However, since

[12]Spectrum refarming is reallocation of bands in the radio spectrum to gain more efficiency.

[13]The termination rate is the fee that Operator A pays Operator B when one of A's customers calls one of B's customers. Operator B is paid for the cost of carrying the call on its network.

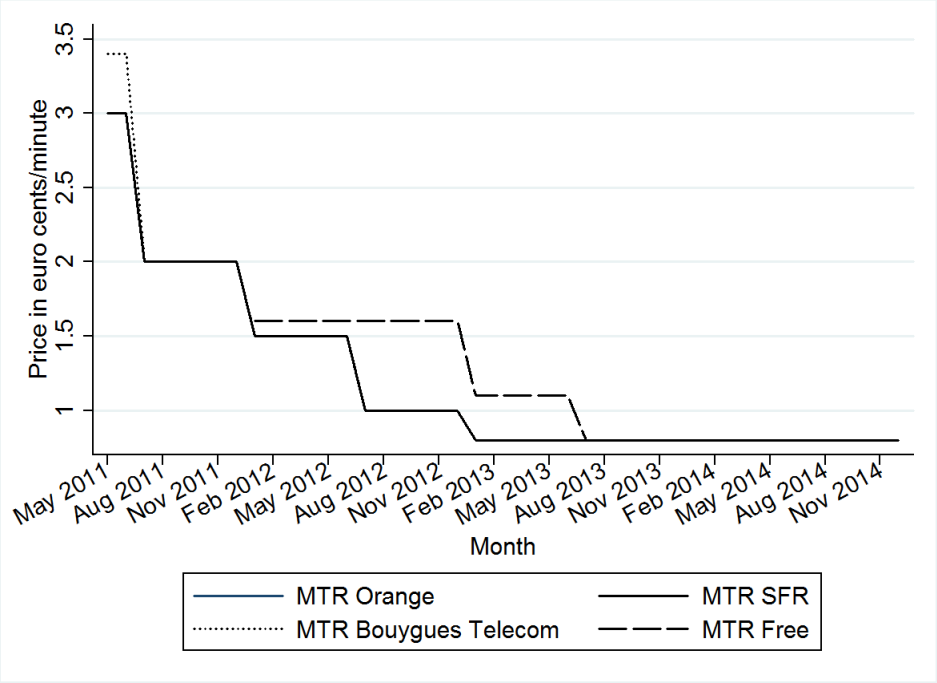
at the time of our analysis calls from fixed to mobile networks had declined in importance, we instead use mobile-to-mobile (M2M) termination rates in our regressions. Nevertheless, in France F2M and M2M are the same due to non-discrimination obligations. Two points are worth noting: firstly, due to the increasing importance of mobile data, the share of M2M termination rates in operators' revenues is decreasing and the regulation of these charges is becoming less important. Secondly, the theoretical literature does not provide clear conclusions on the impact of M2M termination rates on retail prices (see Armstrong (1998) and Laffont, Rey and Tirole (1998)).

In France, the M2M and F2M termination rates are determined by ARCEP in a relevant market analysis. The price caps are set on the basis of long-run incremental costs (LRIC) following bottom-up approach, which takes into account network design (technologies and coverage), traffic (volume, busy-hour characteristics) and cost (capex, opex, asset lifetime).[14] As shown in Figure A.2, the M2M termination rates declined over time.

In addition, operators often state that regulating roaming charges will result in higher retail prices. For this reason, we consider the impact of roaming regulation on retail prices. Roaming charges within the European Union are regulated by the European Commission, which sets both the charges a mobile network operator can impose on its subscribers for using telephone and data services outside of the network's country, and the wholesale rates networks can charge each other to allow their subscribers access to each other's networks. Since 2007, the roaming regulations have steadily lowered the maximum roaming charges allowable. Figure A.3 shows euro-tariffs, which are the retail price-cap that cannot be exceeded by the operators when charging fees to their customers for calling and using Internet in another EU country.

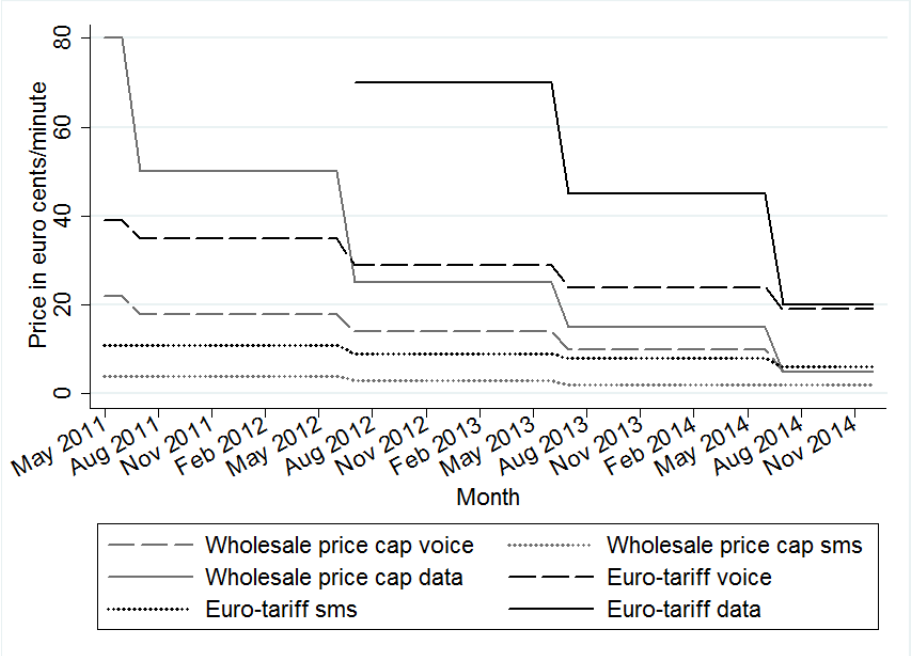
[14] Based on the European Commission's Recommendation from 2009, MTRs should be set on a 'pure LRIC' basis, i.e., reflecting the long run incremental cost exclusive of any fixed and common costs. See "Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU - Implications for Industry, Competition and Consumers (07/05/2009)".

Figure A.2 – Mobile-to-mobile termination rates in France



Source: ARCEP

Figure A.3 – Euro-tariffs and wholesale roaming price caps in the EU



Source: European Commission

1.3 The Data

For the purpose of our analysis, we combine the following data sets. First, we use a complete list of mobile tariffs offered between May 2011 and December 2014 offered by Orange, the main mobile operator in France.[15] Even though we use price information for a single firm, we can demonstrate that our price index is representative for the whole industry.[16]

The number of unique tariffs in this period was 1,112 and the number of available tariffs on a monthly basis with repetitions was 7,346. Each tariff is characterized by: (i) voice and data allowances; (ii) unit prices of voice and data over the voice and data allowances; (iii) indicator of quadruple play tariff (QP), which includes a fixed access to Internet via DSL or FttH technology; (iv) indicator for handset subsidy; (v) commitment period of 12 or 24 months; (vi) indicator for low-cost tariffs without commitment; (vii) premium access to music streaming called Deezer. Each tariff has a unique identifier which is associated with the set of characteristics. Whenever any of these characteristics changes, the tariff is considered to be different with a new identifier. Table A.1 shows the number of unique tariffs with the starting date in a given year with summary statistics for their characteristics. When there is a promotion and a tariff is offered at a lower price, it is considered to be a new tariff with a different identifier. Thus, we are directly able to take promotions into consideration in our analysis. Moreover, some tariffs may include allowances for the use of data and voice abroad. We account for unlimited international calls and voice roaming included in tariff, but we do not have information about data roaming charges to include them in the analysis. In hedonic price regressions we cluster the error terms using the tariff identifier, thus allowing for correlation between observations of the same tariff.

Second, we use an unbalanced panel of roughly 116,100 customers observed between May 2011 and December 2014 provided by Orange to compute the number of subscribers to each

[15] In general, detailed historical pricing information for mobile telecommunications services is not easily available because of a large number of tariffs which change on monthly basis. We obtained detailed information on monthly basis using tariff catalogs from Orange. Unfortunately, it is impossible for us to get tariff information in such level of detail for the other market players.

[16] We used data from a consultancy firm Teligen to compare prices of Orange and SFR for different market segments. For all market segments the prices of Orange and SFR are comparable and change in a similar manner over time.

Table A.1 – Summary statistics for tariffs

Year	Av.Price	Av.Data allowance	Av.Voice allowance	Share of unlimited calls plan (%)	Share of low-cost (%)	Share of QP tariffs (%)
2011	45.1	0.60	118.3	6.2	1.4	10.4
2012	43.2	0.75	105.3	20.1	2.0	13.5
2013	40.2	1.04	95.1	37.7	3.8	22.7
2014	40.5	1.69	76.1	40.8	5.9	29.7
All	42.1	1.03	100.3	31.9	3.2	19.5

Prices are in euros, data allowance in GB and voice allowance in minutes.

tariff in each month. These figures are used as weights in the hedonic price regressions. The list of available tariffs in each month and the number of subscribers per tariff are merged together. Third, information about the level of M2M termination rates are collected from the website of ARCEP and information on roaming price caps from the website of the European Commission. The information on market shares of mobile operators in France comes from a consultancy firm Yankee Group.

1.4 Econometric Model

We estimate the impact of tariff characteristics and monthly dummy variables on the cost of tariffs based on the following hedonic price regression:

$$y_{it} = \alpha + X_{it}\beta + \delta_k d_t \mathbf{1}(k = t) + u_{it} \tag{1.1}$$

where y_{it} denotes the list price in Euros of tariff i which was available in month t.[17] The vector of tariff characteristics X_{it} includes: (i) dummy variables for unlimited national and unlimited national/international voice calls; (ii) voice allowance for tariffs with limited voice minutes; (iii) dummy variables for data allowance of 0.5 GB, 1 GB, 2 GB, 3 GB, 5 GB, 6 GB, 10 GB and 14 GB; (iv) dummy variables for quadruple play tariff with DSL and FttH connections; (v) a dummy variable for handset subsidy; (vi) dummy variables for commitment period of 12 and 24 months; (vii) dummy variables for low-cost mobile plans and fixed-price

[17] As a robustness check, we also estimate the model using log of dependent variable, for which the resulting quality-adjusted price index remains unchanged.

contract;[18] (viii) a dummy variable for a discount of 5 Euros for 3G tariffs at the time of launching 4G tariffs.[19]

At the time of introduction of 4G services, new tariffs were introduced offering 4G Internet access, while exactly the same tariffs with 3G Internet access were offered with a discount of 5 Euros. The estimated coefficients δ_t of the monthly dummy variables $d_t \mathbf{1}(k = t)$ represent the quality-adjusted price index. The normally distributed error term is denoted by u_{it}, and the vector of coefficients $\gamma = (\alpha, \beta, \delta)$ is estimated using ordinary least squares (OLS) and weighted least squares (WLS) with weights being the shares of subscribers to a particular tariffs in a given month.[20]

In a next step, we regress the quality-adjusted price index δ_t on a set of competition, investment and regulation variables:

$$\delta_t = \gamma + Z_t \eta + R_t \lambda + \varepsilon_t \tag{1.2}$$

where Z_t denotes a set of dummy variables for competition and investments: (i) the introduction of new tariffs without commitment and handset subsidies; (ii) entry of Free Mobile; (iii) launch of 4G networks by SFR, Orange, Bouygues and Free Mobile; and R_t includes regulatory variables: mobile termination rates on Orange's network and wholesale roaming price caps for voice and data. Finally, ε_t is normally distributed error term.

1.5 Estimation Results

We show our estimation results in two parts. We start with the estimation results of the hedonic price equation (1.1) in Subsection 1.5.1 and then provide the estimation results of the quality-adjusted price equation (1.2) in Subsection 1.5.2. Finally in Subsection 1.5.4, we compare our results to other price indices which are constructed using the consumer usage

[18] A fixed-price contract is a tariff which ensures that consumer's bill does not surpass the price of tariff. For these tariffs, consumption beyond allowances is not possible. These contracts are mostly targeted at teenagers.

[19] Another tariff characteristics which may influence price is sponsored data which is currently under regulatory debate. There was no sponsored data in the period of our analysis.

[20] It is common to use weights when computing changes in prices over time. This is also the case of consumer price index (CPI) which is used as a measure of inflation.

basket methodology. These indices are commonly used by the OECD, European Commission and national regulators including ARCEP in France.

1.5.1 Hedonic Price Regressions

Table A.2 shows the estimation results for the hedonic price equation (1.1) based on all tariffs using OLS in column (1) and WLS in column (2).[21] Both regressions have relatively high R-squared values equal to 0.74 for OLS and 0.85 for WLS. We discuss the results of WLS estimation because it accounts for differences in the popularity of tariffs.

All tariff characteristics in the regressions are highly significant with the expected signs. Data and voice allowances have a positive impact on the cost of tariffs. For instance, compared to tariffs without data allowance, tariffs with 2 GB data allowance are about 15.3 Euros more expensive, with 5 GB allowance are about 33.5 Euros more expensive and with 14 GB allowance are about 138.6 Euros more expensive. If a tariff is bundled with fixed broadband services, an additional 25.4 Euros are added to the contract for DSL connection and 28.2 Euros for FttH connection. Tariffs with unlimited national voice calls are 24.3 Euros more expensive and tariffs with unlimited national and international calls are 27.9 Euros more expensive. For tariffs with limited minutes, one minute costs about 11 cents. Tariffs with subsidized handsets are on average 12 Euros more expensive. Tariffs with 24 months commitment are on average 7.2 Euros cheaper than tariffs without commitment and also tariffs with 12 months commitment. Furthermore, web only tariffs are 18.7 Euros cheaper, while fixed price contracts are 6 Euros cheaper. Finally, tariffs with 3G Internet are about 5.1 Euros cheaper than tariffs with 4G Internet. As mentioned earlier, this is because at the time of introduction of 4G services, new tariffs were introduced offering 4G Internet access, while exactly the same tariffs with 3G Internet access were offered with a discount of 5 Euros.[22] We also include in the estimations premium access to music streaming called Deezer. This option was available for about 20% of the tariffs with commitment. The impact of this variable is not significant in the WLS regressions. Deezer was the only over-the-top content (OTT) which was included in

[21] The estimates of 44 monthly dummy variables for these two regressions are shown in Table A.6 in the Appendix 1.7.1 due to space constraints.

[22] The advertised speed for mobile tariffs is 4G and only in very few cases H+.

selected tariffs.

Table A.2 – Hedonic price regressions for all tariffs

	(1) OLS		(2) WLS	
Data allowance				
Data=0.5GB	7.27***	(0.45)	4.22***	(0.65)
Data=1GB	13.34***	(0.97)	9.81***	(0.82)
Data=2GB	25.06***	(0.78)	15.30***	(0.82)
Data=3GB	35.80***	(1.41)	21.39***	(1.71)
Data=5GB	43.51***	(1.76)	33.50***	(1.76)
Data=6GB	64.45***	(5.23)	41.19***	(1.80)
Data=10GB	99.66***	(17.60)	82.92***	(15.82)
Data=14GB	150.12***	(1.59)	138.60***	(1.19)
Bundle with fixed line				
Quadruple Play with broadband internet	23.07***	(0.54)	25.43***	(0.46)
Quadruple Play with fiber internet	24.62***	(0.80)	28.23***	(0.60)
Voice				
Voice allowance in minute if not unlimited	0.09***	(0.01)	0.11***	(0.00)
Dummy for unlimited national calls	25.60***	(1.76)	24.33***	(0.83)
Dummy for unlimited international calls	38.75***	(5.93)	27.87***	(2.17)
Other attributes				
Handset subsidy dummy	14.57***	(0.52)	12.01***	(0.52)
Commitment period of the mobile plan=12	-3.98***	(0.59)	-2.24	(1.38)
Commitment period of the mobile plan=24	-7.97***	(0.61)	-7.18***	(1.32)
Discount 3G=1	-17.77***	(2.60)	-5.12**	(1.54)
Web-only mobile plan	-23.30***	(1.45)	-18.66***	(1.95)
Dummy for fixed price contract	-7.60***	(0.44)	-6.04***	(0.64)
Dummy for music streaming	-3.87***	(0.70)	-0.11	(0.71)
Month dummies	Yes		Yes	
Constant	17.98***	(0.86)	17.36***	(1.73)
Observations	7306		7306	
R^2	0.74		0.85	

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Data allowance reference group is zero allowance. Data allowances below 0.5 are grouped in data=0.5. Data allowance of 4GB are grouped with data allowance of 5GB. Data allowance of 7GB are grouped with allowance of 6GB. Data allowance of 0.5GB are grouped with allowance of 1GB for low-cost data allowance. Discount for 3G tariffs was introduced when 4G tariffs were launched.

We plot the estimated coefficients of the monthly dummy variables for both OLS and WLS regressions in Figure A.4. These coefficients reflect the quality-adjusted price index. The estimates of time dummy variables are highly significant and become more negative over time relative to the starting month which is May 2011. This means that quality-adjusted prices decrease over time. We observe that the decline in quality-adjusted prices is slow at the early period of our data but then accelerates with a particularly large decrease in April-May 2013. In an attempt to associate particular market events with observed price changes

we plot three vertical lines. The first line reflects the reaction of incumbents to the announced entry of Free Mobile by launching new tariffs without commitment, to which we refer as low-cost or 'fighting' brands.[23] The second one is the actual entry of Free Mobile and the third one is the launch of 4G networks and in consequence the introduction of 4G tariffs.

We notice that prices seem to react without a lag to the introduction of low-cost brands. The acceleration of the price decrease starts soon after the incumbents introduced low-cost brands but before the entry of Free Mobile. After Free Mobile had entered the market, Orange tariffs experienced further reductions in quality-adjusted prices. The largest price drop in our observation period seems to have been induced by the introduction of 4G tariffs. Afterwards, quality-adjusted prices still decline but at a much slower rate. For a comparison, we also show the estimates of monthly dummy coefficients based on the OLS estimation without any tariff characteristics, which reflect price changes without adjusting for quality. These prices decreased only by approximately 11% during the period of this analysis, as opposed to the 42.8% decrease in quality-adjusted prices. In summary, the rapid improvement in the service offered meant that the price per characteristic was falling far faster than the price of the service in general.

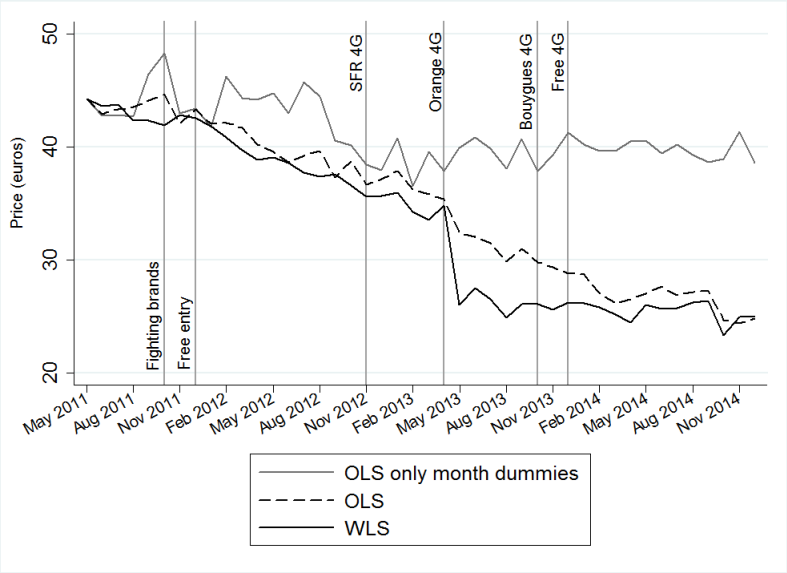
As the entry of Free Mobile might affect low-cost tariffs rather the classic tariffs, we additionally distinguish between these two categories of tariffs and run separate hedonic price regressions. Table A.3 shows the estimation results based on WLS.[24] The results are broadly comparable to the estimation for all tariffs, except for the magnitude of some variables. For instance, compared to tariffs without data allowance, tariffs with 2 GB data allowance are about 20.6 Euros more expensive for classic tariffs and 8 Euros for low-cost tariffs. The cost of a minute in tariffs with allowance is about 11 cents for classic tariffs and 2 cents for low-cost tariffs.

Again, we plot the estimated coefficients of the monthly dummies. Figure A.5 shows

[23] In marketing, a 'fighting brand' is a lower-priced offering launched by a company to combat a competitor that is threatening to take market shares away from a company's main brand. See Johnson and Myatt (2003) for a theoretical exposition and Bourreau, Sun and Verboven (2016) for a structural analysis of the mobile industry in France at the time of entry of Free Mobile.

[24] Again, due to space constraints we show the estimated coefficients of monthly dummy variables for these regressions in Table A.7 in the Appendix 1.7.1.

Figure A.4 – Monthly coefficients (+ weighted average price in May 2011) for all tariffs



Note: The weighted average price of all tariffs in May 2011 was 44.2€.

them separately for classic tariffs and low-cost tariffs and in comparison to previous estimates for all tariffs based on WLS. The estimates of monthly dummy variables differ significantly across tariff categories, which suggests that quality-adjusted prices for classic and low-cost tariffs follow a different pattern over time. The low-cost tariffs were introduced shortly before entry of Free Mobile and their quality-adjusted price decreased when Free Mobile entered the market in January 2012, and again around the time when 4G networks were launched, but remained roughly constant afterwards. The quality-adjusted prices for classic tariffs declined across the entire period, but experienced a particularly sharp drop when the 4G networks were launched.

1.5.2 Determinants of Quality-Adjusted Price Index

For the second part of our analysis, we use the estimated coefficients of the 44 monthly dummy variables which form the quality-adjusted price index and serve as the dependent variable in our second set of regressions. It should be acknowledged that the number of observations in this regression is very small and the results should be interpreted with caution.

First, we use the estimates for all tariffs from Table A.6 and then the estimates which

Table A.3 – Hedonic price regressions for classic and low-cost tariffs (WLS)

	(1) Classic tariffs		(2) Low-cost tariffs	
Data allowance				
Data=0.5GB	7.98***	(0.36)		
Data=1GB	12.74***	(0.77)	5.96***	(0.87)
Data=2GB	20.62***	(0.52)	8.02***	(0.98)
Data=3GB	27.98***	(1.77)	10.39***	(0.20)
Data=5GB	38.12***	(1.38)	12.40***	(1.04)
Data=6GB	46.26***	(1.88)		
Data=10GB	87.88***	(15.67)		
Data=14GB	144.10***	(1.18)		
Bundle with fixed line				
Quadruple Play with broadband internet	24.69***	(0.42)	26.33***	(0.71)
Quadruple Play with fiber internet	27.47***	(0.58)		
Voice				
Voice allowance in minute if not unlimited	0.11***	(0.00)	0.02*	(0.01)
Dummy for unlimited national calls	25.71***	(0.88)	7.57***	(1.06)
Dummy for unlimited international calls	28.78***	(2.12)		
Other attributes				
Handset subsidy dummy	10.87***	(0.57)		
Commitment period of the mobile plan=12	-3.22*	(1.42)		
Commitment period of the mobile plan=24	-8.00***	(1.35)		
Discount 3G=1	-6.22***	(1.59)	1.56	(0.93)
Web-only mobile plan	0.00	(.)		
Dummy for fixed price contract	-6.27***	(0.56)	0.37	(0.22)
Dummy for music streaming	-1.26	(0.94)		
Month dummies	Yes		Yes	
Constant	17.12***	(1.73)	16.46***	(1.28)
Observations	7094		212	
R^2	0.85		0.98	

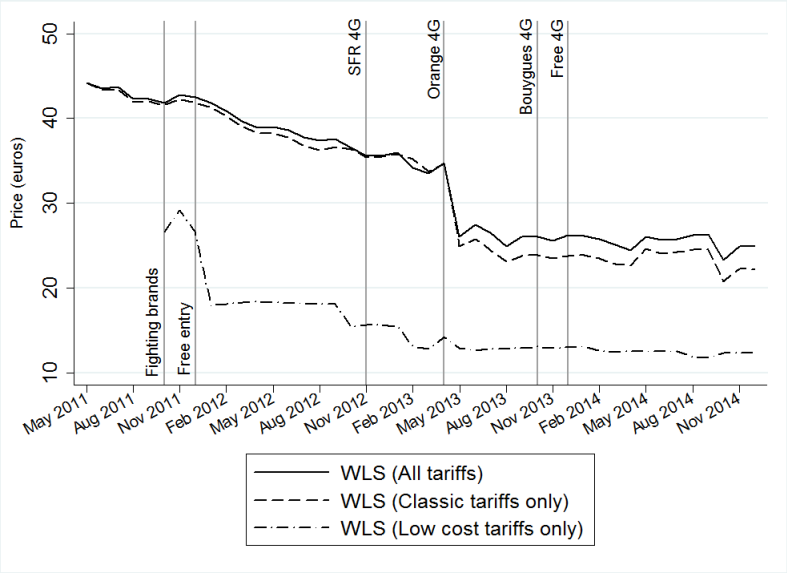
Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Data allowance reference group is zero allowance. Data allowances below 0.5 are grouped in data=0.5. Data allowance of 4GB are grouped with data allowance of 5GB. Data allowance of 7GB are grouped with allowance of 6GB. Data allowance of 0.5GB are grouped with allowance of 1GB for low-cost data allowance. Discount for 3G tariffs was introduced when 4G tariffs were launched.

we obtain from the separate regressions for classic and low-cost tariffs from Table A.7 in the Appendix 1.7.1. We regress the quality-adjusted prices on variables that describe competition, investments and regulation. Competition is driven by the introduction of low-cost brands and entry of Free Mobile. We also approximate competition by Herfindahl-Hirschmann index (HHI) as is commonly done in empirical studies. The value of HHI index declined from 3154 in April 2011 to 2429 in December 2014, which suggests that the industry became more competitive. Investments are related to the launch of 4G networks by SFR, Orange, Bouygues and Free Mobile. Regulation is approximated by mobile termination rates on Orange network

Figure A.5 – Monthly coefficients (+ weighted average price in the first period) for classic and low-cost tariffs



Note: The weighted average price of tariffs in May 2011 was 44.2€. The weighted average price of low-cost tariffs was 26.6€ in October 2011

and wholesale roaming price caps for voice and data. As shown in Figures (A.2) and (A.3), mobile termination rates and wholesale roaming price caps decrease stepwise over time.

The quality-adjusted prices are not only affected by competition between network operators, but also by competition from other messaging applications such as 'Whatsapp'. However, the penetration rate of messaging applications in France was very low, as stated in the communications between the European Commission and ARCEP with respect to market definition for termination of SMSs on mobile networks.[25] This may be due to the fact that prices of SMSs were low in France as a result of regulation. Also, all tariffs in our database include unlimited messaging. Accordingly, we do not consider that messaging applications played an important role in the time period of our analysis.

The estimation results are shown in Table A.4. We estimate two model specifications with either HHI index or dummy variable for entry of Free Mobile because both variables approximate competition and are highly correlated. Free Mobile managed to gain substantial market share very fast which led to lower value of HHI index. The HHI index is also highly

[25]Source: European Commission C(2014) 9270 final.

correlated with the regulatory variables, values of which declined over time and with dummy variables for the launch of 4G networks.

The results indicate that, in itself, the introduction of low-cost brands by itself had no impact on the quality-adjusted prices of classic tariffs. Decreases in the prices of classic tariffs coincided with two events. First, there was a drop by 5.05 Euros on average after entry of Free Mobile. Second, the main reduction by 8.55 Euros on average came with the launch of 4G network by Orange. Prices also declined with the launch of 4G network by SFR which took place a few months before Orange (with significance level of 10%). When included in the estimation, the HHI index is positive and significant in the regression for all tariffs, but it is insignificant in the other two regressions for classic and low-cost tariffs, though it does have a positive sign. In the regression for low-cost tariffs the 4G launch variables become insignificant due to collinearity with HHI. The regulatory variables used in the regression do not have a significant impact on the quality-adjusted prices of all and classic tariffs in separation, though they significantly impact low-cost tariffs. However, since wholesale roaming price caps for voice and data and mobile termination rates are highly correlated, it is difficult to comment on the impact of particular regulatory variables. An F-test, testing the joint significance of regulatory variables, does not reject the hypothesis that the regulatory variables have a joint significant impact on the quality-adjusted prices for classic tariffs.

In the regression for low-cost tariffs, the entry of Free Mobile had a negative impact on the level of quality-adjusted prices, which dropped on average by 4.98 Euros. There is also a significant but smaller effect of the launch of 4G networks by SFR, which led to decline of low-cost tariffs by 1.92 Euros on average. Termination rates have a significant and positive impact. Thus, higher termination rates lead to higher quality-adjusted prices. The roaming price caps for voice and data are also significant, but with opposing signs, which may be due to a high correlation of 0.95. The impact of regulatory variables should be therefore interpreted with caution. Again, testing the joint significance of regulatory variables does not reject the hypothesis that the regulatory variables have a joint significant impact on the quality-adjusted prices for low-cost tariffs.

Since classic tariffs have a greater weight in the price index than low-cost tariffs, the estimation results for all tariffs are similar to the estimation results for classic tariffs. The entry of Free Mobile reduced prices on average by 4.31 Euros and the launch of 4G tariffs by Orange by 6.99 Euros, while the launch of 4G tariffs by SFR led to additional reduction by 2.83 Euros. The regulatory variables are significant jointly but not separately. Our results confirm that low-cost tariffs were introduced to compete with new entrant, Free Mobile, while classic tariffs compete with the other established operators in the market.[26]

Overall, the weighted average cost of classic tariffs (weighted by sales) increased marginally from 44.2 Euros in May 2011 to 44.4 Euros in December 2014. In the same time period, the quality-adjusted classic price index declined by 49%, as indicated by time coefficients plotted on Figure A.5. The weighted average cost of low-cost tariffs declined by 34.9% from 26.6 Euros at their launch in October 2011 to 17.3 Euros in December 2014. In the same time period, the quality-adjusted low-cost price index declined by 54%. Finally, the weighted average cost of all tariffs declined by 8.7% from 44.2 Euros in May 2011 to 40.4 Euros in December 2014, while the quality-adjusted price index declined by 42.8%.[27]

We can compute the contribution of competition and investments to these price declines. The contribution of competition is the summation of coefficients on competition variables divided by total price decline in absolute value. The contribution of investments is calculated similarly. In percentage terms, competition is responsible for about 23.4% of total price decline for all tariffs and investments for 56.1%. Classic tariffs declined by 25.1% due to competition and by 52.9% due to investments, while low-cost tariffs declined by 38.4% due to competition and 21.1% due to investments.

[26] We also estimated the same models for all, classic and low-cost tariffs in which we in addition used the number of 4G antennas deployed countrywide by four network operators. The number of 4G antennas is not significant in all three regressions. The other variables remain significant and the same conclusions can be drawn. The estimation results can be provided upon request.

[27] The quality-adjusted price indices result from separate regressions. Hence, the price index for all tariffs is not an average of price indices for classic and low-cost tariffs.

Table A.4 – OLS with time dummies coefficient from hedonic regression

	(1) All tariffs	(2) All tariffs	(3) Classic tariffs	(4) Classic tariffs	(5) Low-cost tariffs	(6) Low-cost tariffs
Low-cost brands	-0.20	0.06	-0.48	-0.28	0.00	0.00
	(1.24)	(1.24)	(1.42)	(1.47)	(.)	(.)
Sfr 4G	-2.83**	-1.80	-1.89	-0.93	-1.92**	-0.77
	(0.98)	(1.04)	(1.12)	(1.23)	(0.65)	(0.57)
Orange 4G	-6.99***	-5.92***	-8.55***	-7.51***	-0.79	0.04
	(1.01)	(1.03)	(1.16)	(1.22)	(0.51)	(0.58)
Bouygues 4G	-1.15	-0.78	-1.60	-1.35	-0.06	0.01
	(1.30)	(1.32)	(1.49)	(1.56)	(0.64)	(0.72)
Free 4G	0.17	0.83	0.39	0.99	-0.25	0.12
	(1.24)	(1.25)	(1.42)	(1.48)	(0.60)	(0.70)
MTR Orange	-3.33	-1.66	-4.63	-0.83	8.50*	14.43***
	(4.26)	(3.40)	(4.88)	(4.01)	(3.30)	(2.56)
Wholesale roaming voice	-0.13	0.09	-0.14	0.24	0.59*	1.01***
	(0.43)	(0.35)	(0.49)	(0.41)	(0.24)	(0.19)
Wholesale roaming data	0.18	0.06	0.22	0.04	-0.23*	-0.44***
	(0.17)	(0.12)	(0.20)	(0.15)	(0.10)	(0.07)
Dummy Free	-4.31		-5.05		-4.98**	
	(2.20)		(2.52)		(1.74)	
HHI		0.01*		0.01		0.01
		(0.01)		(0.01)		(0.00)
Constant	-1.67	-40.20**	-1.19	-37.77*	-15.07*	-42.85***
	(7.54)	(13.19)	(8.63)	(15.57)	(5.55)	(9.68)
Observations	44	44	44	44	39	39
R^2	0.96	0.96	0.96	0.96	0.98	0.97
F-stat(All variables)	100.57	101.91	93.45	88.94	146.31	121.06
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
F-stat (Regulatory)	3.25	1.20	3.49	1.49	3.52	14.16
Prob > F	0.033	0.325	0.026	0.234	0.027	0.000

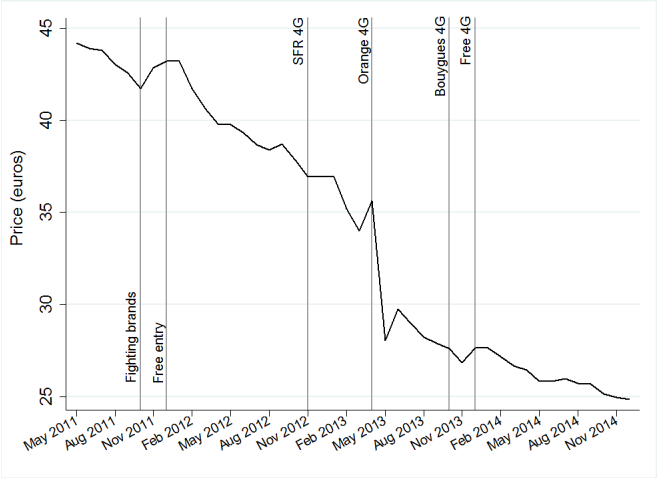
Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

1.5.3 Robustness Checks

As a robustness check, we estimate separate hedonic price regressions year by year for all tariffs. The estimation results are shown in Table A.8 in Appendix 1.7.1. The range of tariffs with particular characteristics changes from year to year and the estimates of coefficients show some differences. In particular, new tariffs with greater data allowances were introduced in years 2013 and 2014. Figure A.6 shows evolution of quality-adjusted prices based on these regressions. The resulting price index is very similar to the price index shown in Figure A.4. The quality-adjusted prices decline over time with two main drops at the time of entry of Free Mobile and at the time of launch of 4G networks, thus leading to the same conclusions.

Figure A.6 – Monthly coefficients for year-by-year regressions (+ average weighted price in the first month for all tariffs



Note : The average weighted price of all tariffs in May 2011 was 44.2€.

1.5.4 Comparison to Other Indices

We also compare the quality-adjusted price index constructed using our hedonic price regression with price indices constructed using the consumer usage basket methodology, which is commonly used by the OECD, European Commission and national regulators including ARCEP in France. Table A.9 in the Appendix 1.7.2 shows definitions of different usage baskets according to ARCEP and the OECD and their evolution in years 2011-2014. While the OECD baskets stay constant over time, the ARCEP baskets take into account potential changes in the consumer behavior in France. To obtain a price index for these baskets, we calculate the bill of a representative consumer with a given usage basket using all tariff plans of Orange, which are available in each month. Next, we select the tariff which yields the lowest bill in a month. We first do this for all tariffs and then for tariffs with handset subsidy only. Price index constructed based on tariffs with handset subsidy corresponds to classic tariffs in our analysis and price index constructed based on all tariffs corresponds to low-cost tariffs.[28]

To compare the baskets approach with our quality-adjusted price indices, we now regress

[28] Figures (A.7) and (A.8) in the Appendix 1.7.2 show price indices constructed using ARCEP basket methodology, respectively based on the price of the cheapest tariff among all tariffs considered and based on the cheapest tariff with handset subsidy. Figures (A.9) and (A.10) also in the Appendix 1.7.2 show analogous price indices for OECD baskets.

Table A.5 – OLS with prices based on ARCEP and OECD baskets

	Prices from ARCEP baskets All tariffs	Prices from ARCEP baskets Only handset sub.	Prices from OECD baskets All tariffs	Prices from OECD baskets Only handset sub.
Low-cost brands	-38.28***	-12.33***	-38.28***	-11.51**
	(2.21)	(3.24)	(2.21)	(3.26)
Sfr 4G	-4.53*	-2.48	-4.52*	-0.92
	(1.75)	(2.56)	(1.75)	(2.58)
Orange 4G	-4.39*	-15.01***	-4.37*	-16.92***
	(1.80)	(2.63)	(1.80)	(2.65)
Bouygues 4G	-0.61	1.06	-0.60	0.75
	(2.32)	(3.40)	(2.32)	(3.43)
Free 4G	0.26	-0.18	0.26	-0.14
	(2.20)	(3.22)	(2.20)	(3.25)
MTR Orange	27.63***	-13.51	27.57***	-4.49
	(7.59)	(11.12)	(7.58)	(11.20)
Wholesale roaming voice	1.62*	-2.65*	1.61*	-1.94
	(0.76)	(1.11)	(0.76)	(1.12)
Wholesale roaming data	-0.77*	1.27**	-0.77*	0.93*
	(0.30)	(0.45)	(0.30)	(0.45)
Dummy Free	-1.25	-21.41***	-1.28	-18.72**
	(3.92)	(5.74)	(3.92)	(5.79)
Constant	32.21*	93.31***	32.30*	81.54***
	(13.42)	(19.66)	(13.40)	(19.80)
Observations	44	44	44	44
R^2	0.989	0.973	0.989	0.975
F-stat(All variables)	327.38	137.08	327.85	144.46
Prob > F	0.000	0.000	0.000	0.000
F-stat (Regulatory)	8.22	15.38	8.22	14.15
Prob > F	0.003	0.000	0.003	0.000

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

selected OECD and ARCEP baskets on competition, investment and regulation variables. The estimation results are shown in Table A.5. These regressions broadly confirm our conclusions. Low-cost brands introduced to pre-empt entry of Free Mobile and launch of 4G networks are the main contributors to price reductions. As before, the effect of low-cost brands is stronger on the price indices based on all tariffs and the effect of 4G launch is stronger for the price indices based on tariffs with handset subsidy. The impact of regulatory variables has a joint significant impact.

The price indices based on the OECD and ARCEP baskets suggest stronger reductions due to entry of Free Mobile and launch of low-cost brands than were seen in the quality-adjusted price index based on hedonic regressions, while the effect of investments in 4G networks appears to be smaller. When comparing these different methodologies, there are strong reasons

to prefer the hedonic price approach. First, the methodology using baskets considers the cost of a bill paid by a representative consumer, and the quality-adjusted price index represents the producer's price after controlling for quality of tariffs, as a result the latter is independent on usage which is an advantage. Second, by using quantities as weights we account for the popularity of tariffs. The basket method, however, cannot consider consumer preferences. It also assumes perfectly rational behavior of the representative consumer choosing the cheapest tariff.

1.6 Conclusions

Using a database that includes tariffs offered by the main mobile telecommunications operator in France, Orange, between May 2011 and December 2014, we assessed the impacts of competition, investment into a new technology (4G) and of regulation, on prices of mobile services. In a first step, we estimated hedonic price regressions that accounted for the effect of product characteristics and obtained a quality-adjusted prices index. In a second step, we used this price index and related it to variables measuring competition, investments and regulation in the industry. We looked at all tariffs, classic contract tariffs with commitment, and low-cost tariffs without commitment, which were introduced by Orange in October 2011 before the entry of fourth mobile operator, Free Mobile.

Over the analyzed time period, the quality-adjusted price index obtained decreased by about 51% whilst the decline in average prices without quality-adjustment was only 8.7%. We find that main driver of price reductions for classic tariffs with commitment was the launch of 4G networks by mobile operators. Low-cost tariffs without commitment, which were introduced to pre-empt the entry of a low-cost competitor, declined mainly at the time of entry of Free Mobile. Moreover, we find that regulation, which is approximated by the level of mobile termination charges and international roaming price caps for voice and data, has a joint significant impact on quality-adjusted prices.

In percentage terms, competition measured by the launch of low-cost brands and entry of Free Mobile, is responsible for about 23.4%, and investment into the 4G technology is respon-

sible for about 56.1% of the total price decline, with the remaining effect being regulation and other factors. Classic tariffs declined by 25.1% due to competition, and by 52.9% due to investments, while low-cost tariffs declined by 38.4% due to competition and by 21.1% due to investments. Thus, our main conclusion is that the reduction in quality-adjusted prices in the last years was largely caused by competition between operators for a new technology (4G). The entry of a fourth low-cost operator also induced a quality-adjusted price decrease, although at a lower scale.

Our results are also robust in comparison to other constructed price indices. When we compare the results from our hedonic price regressions with the alternative OECD and ARCEP basket approach, we can draw similar conclusions. However, we consider that hedonic price regressions represent a more accurate methodology to assess price changes of telecommunications markets and should be preferred by the regulators.

The results of the second stage of our empirical analysis, which is based on only 44 observations, have to be taken cautiously. This emphasizes the importance of further research by, for example, investigating other countries as well, or extending the time period so that we could also include the future development of 5G networks. Keeping the limitations of our analysis in mind, the policy implications of our analysis are threefold. First, competition for new technologies matters. Firms competing for being able to provide consumers the newest technology do so also by offering lower (quality-adjusted) prices. Second, the entry of the low-cost firm Free Mobile was good for competition, but to a smaller extent than the introduction of a new technology. However, we cannot say anything about the investment effect if there were only three firms in the market. And finally, at this stage in the life-cycle of the mobile industry, the contribution of regulation to the quality-adjusted price decrease is smaller than of competition.

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1.7 Appendix

1.7.1 Hedonic Price Regressions

Table A.6 – Hedonic price regressions for all tariffs

	(1) OLS		(2) WLS	
Data allowance				
Data=0.5GB	7.27***	(0.45)	4.22***	(0.65)
Data=1GB	13.34***	(0.97)	9.81***	(0.82)
Data=2GB	25.06***	(0.78)	15.30***	(0.82)
Data=3GB	35.80***	(1.41)	21.39***	(1.71)
Data=5GB	43.51***	(1.76)	33.50***	(1.76)
Data=6GB	64.45***	(5.23)	41.19***	(1.80)
Data=10GB	99.66***	(17.60)	82.92***	(15.82)
Data=14GB	150.12***	(1.59)	138.60***	(1.19)
Bundle with fixed line				
Quadruple Play with broadband internet	23.07***	(0.54)	25.43***	(0.46)
Quadruple Play with fiber internet	24.62***	(0.80)	28.23***	(0.60)
Voice				
Voice allowance in minute if not unlimited	0.09***	(0.01)	0.11***	(0.00)
Dummy for unlimited national calls	25.60***	(1.76)	24.33***	(0.83)
Dummy for unlimited international calls	38.75***	(5.93)	27.87***	(2.17)
Other attributes				
Handset subsidy dummy	14.57***	(0.52)	12.01***	(0.52)
Commitment period of the mobile plan=12	-3.98***	(0.59)	-2.24	(1.38)
Commitment period of the mobile plan=24	-7.97***	(0.61)	-7.18***	(1.32)
Discount 3G=1	-17.77***	(2.60)	-5.12**	(1.54)
Web-only mobile plan	-23.30***	(1.45)	-18.66***	(1.95)
Dummy for fixed price contract	-7.60***	(0.44)	-6.04***	(0.64)
Dummy for music streaming	-3.87***	(0.70)	-0.11	(0.71)
Month dummies				
May 2011	0.00	(.)	0.00	(.)
June 2011	-1.28***	(0.05)	-0.62***	(0.05)
July 2011	-0.83***	(0.07)	-0.46***	(0.06)
Aug 2011	-0.66***	(0.05)	-1.87***	(0.08)
Sep 2011	-0.07	(0.10)	-1.88***	(0.06)
Oct 2011	0.38*	(0.18)	-2.33***	(0.11)
Nov 2011	-2.06***	(0.07)	-1.42***	(0.18)
Dec 2011	-0.90***	(0.12)	-1.67***	(0.16)
Jan 2012	-2.07***	(0.12)	-2.38***	(0.19)
Feb 2012	-2.06***	(0.21)	-3.35***	(0.26)
March 2012	-2.49***	(0.24)	-4.50***	(0.26)
Apr 2012	-3.98***	(0.23)	-5.34***	(0.24)
May 2012	-4.63***	(0.26)	-5.19***	(0.21)
June 2012	-5.54***	(0.28)	-5.62***	(0.19)
July 2012	-4.95***	(0.40)	-6.46***	(0.21)
Aug 2012	-4.56***	(0.42)	-6.82***	(0.25)
Sep 2012	-6.88***	(0.30)	-6.60***	(0.21)
Oct 2012	-5.44***	(0.19)	-7.63***	(0.25)
Nov 2012	-7.51***	(0.21)	-8.62***	(0.25)
Dec 2012	-7.07***	(0.22)	-8.59***	(0.27)
Jan 2013	-6.32***	(0.27)	-8.27***	(0.29)

Feb 2013	-7.97***	(0.20)	-10.02***	(0.33)
March 2013	-8.37***	(0.26)	-10.68***	(0.30)
Apr 2013	-8.83***	(0.18)	-9.45***	(0.25)
May 2013	-11.83***	(0.38)	-18.23***	(0.41)
June 2013	-12.18***	(0.35)	-16.76***	(0.47)
July 2013	-12.76***	(0.34)	-17.75***	(0.48)
Aug 2013	-14.34***	(0.31)	-19.36***	(0.61)
Sep 2013	-13.23***	(0.25)	-18.17***	(0.34)
Oct 2013	-14.38***	(0.23)	-18.14***	(0.30)
Nov 2013	-14.86***	(0.29)	-18.66***	(0.32)
Dec 2013	-15.36***	(0.32)	-18.03***	(0.32)
Jan 2014	-15.51***	(0.36)	-18.11***	(0.36)
Feb 2014	-17.10***	(0.55)	-18.44***	(0.39)
March 2014	-18.05***	(0.61)	-19.10***	(0.54)
Apr 2014	-17.72***	(0.48)	-19.75***	(0.73)
May 2014	-17.15***	(0.52)	-18.21***	(0.26)
June 2014	-16.57***	(0.45)	-18.59***	(0.38)
July 2014	-17.27***	(0.55)	-18.50***	(0.41)
Aug 2014	-17.01***	(0.48)	-18.00***	(0.36)
Sep 2014	-16.93***	(0.54)	-17.87***	(0.37)
Oct 2014	-19.48***	(0.65)	-20.91***	(0.37)
Nov 2014	-19.82***	(1.00)	-19.24***	(0.51)
Dec 2014	-19.38***	(0.67)	-19.24***	(0.52)
Constant	17.98***	(0.86)	17.36***	(1.73)
Observations	7306		7306	
R^2	0.74		0.85	

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

Data allowance reference group is zero allowance. Data allowances below 0.5 are grouped in data=0.5. Data allowance of 4GB are grouped with data allowance of 5GB. Data allowance of 7GB are grouped with allowance of 6GB. Data allowance of 0.5GB are grouped with allowance of 1GB for low-cost data allowance. Discount for 3G tariffs was introduced when 4G tariffs were launched

Table A.7 – Hedonic price regressions for classic and low-cost tariffs

	(1) WLS Classic tariffs		(2) WLS Low-cost tariffs	
Data allowance				
Data=0.5GB	7.98***	(0.36)		
Data=1GB	12.74***	(0.77)	5.96***	(0.87)
Data=2GB	20.62***	(0.52)	8.02***	(0.98)
Data=3GB	27.98***	(1.77)	10.39***	(0.20)
Data=5GB	38.12***	(1.38)	12.40***	(1.04)
Data=6GB	46.26***	(1.88)		
Data=10GB	87.88***	(15.67)		
Data=14GB	144.10***	(1.18)		
Bundle with fixed line				
Quadruple Play with broadband internet	24.69***	(0.42)	26.33***	(0.71)
Quadruple Play with fiber internet	27.47***	(0.58)		
Voice				
Voice allowance in minute if not unlimited	0.11***	(0.00)	0.02*	(0.01)
Dummy for unlimited national calls	25.71***	(0.88)	7.57***	(1.06)
Dummy for unlimited international calls	28.78***	(2.12)		
Other attributes				
Handset subsidy dummy	10.87***	(0.57)		
Commitment period of the mobile plan=12	-3.22*	(1.42)		
Commitment period of the mobile plan=24	-8.00***	(1.35)		
Discount 3G=1	-6.22***	(1.59)	1.56	(0.93)
Web-only mobile plan	0.00	(.)		
Dummy for fixed price contract	-6.27***	(0.56)	0.37	(0.22)
Dummy for music streaming	-1.26	(0.94)		
Month dummies				
May 2011	0.00	(.)		
June 2011	-0.84***	(0.04)		
July 2011	-0.74***	(0.04)		
Aug 2011	-2.28***	(0.07)		
Sep 2011	-2.17***	(0.07)		
Oct 2011	-2.65***	(0.10)	0.00	(.)
Nov 2011	-1.92***	(0.19)	2.56***	(0.50)
Dec 2011	-2.35***	(0.18)	-0.08	(0.32)
Jan 2012	-2.90***	(0.18)	-8.71***	(0.25)
Feb 2012	-3.91***	(0.27)	-8.52***	(0.64)
March 2012	-5.18***	(0.26)	-8.33***	(0.73)
Apr 2012	-5.97***	(0.24)	-8.23***	(0.78)
May 2012	-6.00***	(0.21)	-8.28***	(0.76)
June 2012	-6.43***	(0.18)	-8.42***	(0.70)
July 2012	-7.43***	(0.23)	-8.41***	(0.74)
Aug 2012	-7.90***	(0.26)	-8.52***	(0.68)
Sep 2012	-7.61***	(0.22)	-8.49***	(0.74)
Oct 2012	-7.80***	(0.25)	-11.16***	(0.96)
Nov 2012	-8.79***	(0.25)	-10.99***	(0.93)
Dec 2012	-8.72***	(0.27)	-11.00***	(0.93)
Jan 2013	-8.41***	(0.29)	-11.18***	(0.96)
Feb 2013	-8.98***	(0.26)	-13.51***	(0.80)
March 2013	-10.49***	(0.26)	-13.84***	(0.88)
Apr 2013	-9.53***	(0.25)	-12.37***	(0.77)
May 2013	-19.30***	(0.46)	-13.76***	(0.89)
June 2013	-18.49***	(0.56)	-13.98***	(0.89)

July 2013	-19.76***	(0.58)	-13.82***	(0.89)
Aug 2013	-21.18***	(0.72)	-13.84***	(0.90)
Sep 2013	-20.41***	(0.38)	-13.69***	(0.90)
Oct 2013	-20.37***	(0.34)	-13.54***	(0.90)
Nov 2013	-20.69***	(0.39)	-13.74***	(0.90)
Dec 2013	-20.39***	(0.35)	-13.63***	(0.90)
Jan 2014	-20.35***	(0.38)	-13.55***	(0.90)
Feb 2014	-20.73***	(0.41)	-14.02***	(0.89)
March 2014	-21.41***	(0.58)	-14.14***	(0.89)
Apr 2014	-21.54***	(0.76)	-14.09***	(0.90)
May 2014	-19.58***	(0.26)	-14.07***	(0.90)
June 2014	-20.21***	(0.40)	-14.14***	(0.90)
July 2014	-20.01***	(0.42)	-14.05***	(0.90)
Aug 2014	-19.70***	(0.36)	-14.76***	(0.99)
Sep 2014	-19.70***	(0.37)	-14.85***	(0.98)
Oct 2014	-23.43***	(0.38)	-14.28***	(0.91)
Nov 2014	-21.89***	(0.66)	-14.26***	(0.91)
Dec 2014	-22.00***	(0.66)	-14.30***	(0.92)
Constant	17.12***	(1.73)	16.46***	(1.28)
Observations	7094		212	
R^2	0.85		0.98	

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

There are only 39 periods of observation for low-costs tariffs as there were introduced in October 2011. Data allowance reference group is zero allowance. Data allowances below 0.5 are grouped in data=0.5. Data allowance of 4GB are grouped with data allowance of 5GB. Data allowance of 7GB are grouped with allowance of 6GB. Data allowance of 0.5GB are grouped with allowance of 1GB for low-cost data allowance. Discount for 3G tariffs was introduced when 4G tariffs were launched

Table A.8 – Hedonic price regressions for all tariffs year-by-year

	(1) 2011		(2) 2012		(3) 2013		(4) 2014	
Data allowance								
Data=0.5GB	8.13***	(1.47)	5.97**	(1.96)	0.48	(1.65)	0.48	(1.59)
Data=1GB	17.13***	(3.94)	8.02***	(2.03)	11.35***	(2.23)	4.37*	(1.70)
Data=2GB	18.78***	(1.70)	15.97***	(2.01)	12.22***	(2.84)	10.37***	(2.77)
Data=3GB	22.29**	(7.74)	30.38***	(3.24)	17.58***	(2.63)	10.96***	(1.46)
Data=5GB					29.72***	(3.94)	21.99***	(6.00)
Data=6GB					73.09**	(22.64)	33.25***	(3.30)
Data=10GB							82.06***	(19.77)
Data=14GB							131.78***	(2.07)
Bundle with fixed l.								
4Play with BB	22.61***	(3.43)	22.68***	(2.03)	26.57***	(1.15)	25.56***	(1.29)
4Play with Fiber	22.17***	(4.70)	26.12***	(1.65)	31.73***	(1.43)	28.11***	(1.95)
Voice								
Voice allowance	0.11***	(0.02)	0.09***	(0.02)	0.09***	(0.02)	0.05**	(0.02)
Unlimited calls (nat.)	53.08***	(5.43)	23.32***	(2.52)	18.66***	(2.68)	14.15***	(1.84)
Unlimited calls (inter.)	116.37***	(10.83)	60.01***	(17.31)	19.93*	(8.74)	13.35***	(2.73)
Other attributes								
Handset subsidy dummy	8.50***	(1.58)	14.04***	(2.24)	14.32***	(0.99)	10.96***	(1.13)
Commitment period =0	0.00	(.)	0.00	(.)	0.00	(.)	0.00	(.)
Commitment period =12	-6.22***	(1.31)	-7.45**	(2.45)	-0.55	(3.13)	0.42	(1.10)
Commitment period =24	-11.33***	(1.19)	-10.87***	(2.70)	-5.37	(3.17)	-4.41**	(1.42)
Discount 3G=1			-40.30*	(17.20)	0.07	(2.95)	3.20*	(1.36)
Web-only mobile plan	-34.64***	(6.18)	-24.60***	(2.83)	-14.70***	(3.59)	-9.51***	(1.36)
Fixed price contract=1	-10.24***	(1.69)	-7.74**	(2.81)	-3.85*	(1.54)	-1.79	(1.51)
Music streaming=1	2.35	(2.38)	1.75	(2.21)	-0.64	(1.46)	1.21	(1.21)
Month dummies								
May 2011	0.00	(.)						
June 2011	-0.28	(0.39)						
July 2011	-0.39	(0.50)						
Aug 2011	-1.17	(0.72)						
Sep 2011	-1.62	(0.95)						
Oct 2011	-2.47	(1.47)						
Nov 2011	-1.36	(1.40)						
Dec 2011	-0.98	(1.37)						
Jan 2012			0.00	(.)				
Feb 2012			-1.48*	(0.72)				
March 2012			-2.57*	(1.24)				
Apr 2012			-3.43*	(1.32)				
May 2012			-3.44*	(1.71)				
June 2012			-3.90*	(1.74)				
July 2012			-4.53*	(1.76)				
Aug 2012			-4.82**	(1.66)				
Sep 2012			-4.50*	(1.87)				
Oct 2012			-5.36**	(1.82)				
Nov 2012			-6.29***	(1.43)				
Dec 2012			-6.28***	(1.46)				
Jan 2013					0.00	(.)		
Feb 2013					-1.75	(1.11)		
March 2013					-2.95	(1.56)		
Apr 2013					-1.32	(1.25)		
May 2013					-8.88***	(1.83)		
June 2013					-7.19***	(1.65)		

July 2013					-7.93***	(1.57)		
Aug 2013					-8.69***	(1.60)		
Sep 2013					-9.02***	(1.50)		
Oct 2013					-9.32***	(1.52)		
Nov 2013					-10.10***	(1.59)		
Dec 2013					-9.30***	(1.54)		
Jan 2014							0.00	(.)
Feb 2014							-0.47	(0.45)
March 2014							-0.97	(0.60)
Apr 2014							-1.20	(0.81)
May 2014							-1.81	(1.22)
June 2014							-1.80	(1.29)
July 2014							-1.64	(1.26)
Aug 2014							-1.91	(1.32)
Sep 2014							-1.95	(1.34)
Oct 2014							-2.48*	(1.15)
Nov 2014							-2.68*	(1.35)
Dec 2014							-2.79*	(1.39)
Constant	21.36***	(2.29)	18.66***	(2.82)	10.16**	(3.51)	7.26**	(2.23)
Observations	1460		1959		2088		1799	
R^2	0.92		0.85		0.89		0.95	

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

1.7.2 Comparison with ARCEP and OECD Baskets

Table A.9 – Mobile services baskets

	2011		2012		2013		2014	
	Voice	Data	Voice	Data	Voice	Data	Voice	Data
National Regulator (ARCEP)								
Basket 1	421	137	400	236	382	418	480	695
Basket 2	421	27	400	67	382	100	480	179
Basket 3	421	32	400	24	382	37	480	66
Basket 4	84	137	98	236	114	418	123	695
Basket 5	84	27	98	67	114	100	123	179
Basket 6	84	32	98	24	114	37	123	66
Basket 7	24	137	22	236	28	418	33	695
Basket 8	24	27	22	67	28	100	33	179
Basket 9	24	32	22	24	28	37	33	66
OECD								
Basket 1	50	100	50	100	50	100	50	100
Basket 2	188	500	188	500	188	500	188	500
Basket 3	569	1000	569	1000	569	1000	569	1000
Basket 4	1787	2000	1787	2000	1787	2000	1787	2000
Basket 5	75	2000	75	2000	75	2000	75	2000

Voice is in minutes, Data in MB

Source: ARCEP website and BEREC Report on mobile broadband prices

Figure A.7 – Price of lowest-cost tariff for ARCEP baskets

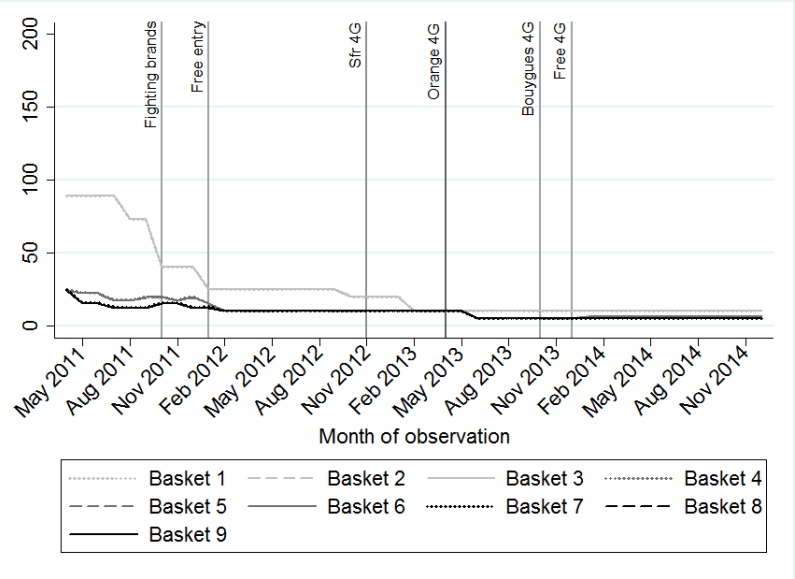


Figure A.8 – Price of lowest-cost tariff with handset subsidy for ARCEP baskets

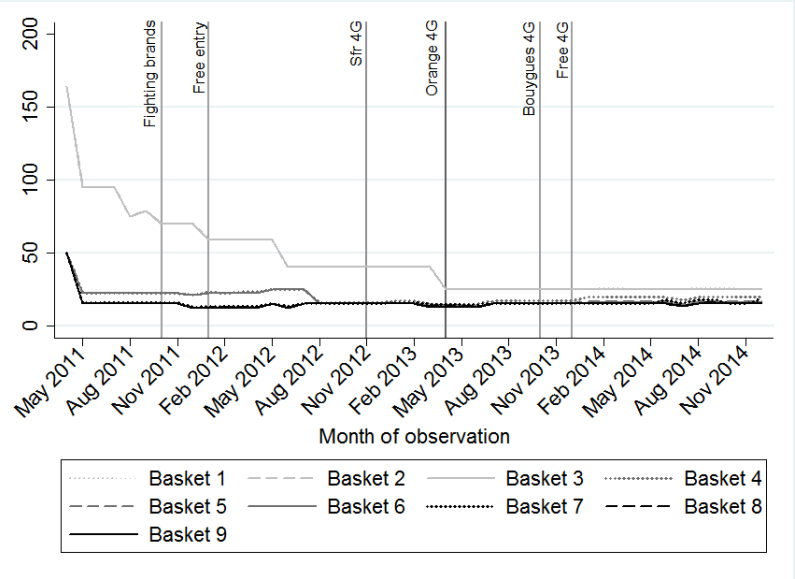


Figure A.9 – Price of lowest-cost tariff for OECD baskets

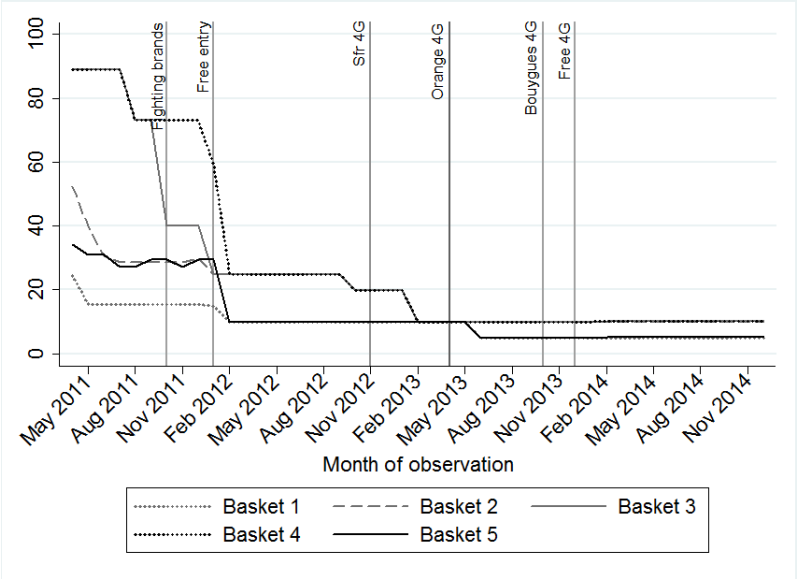
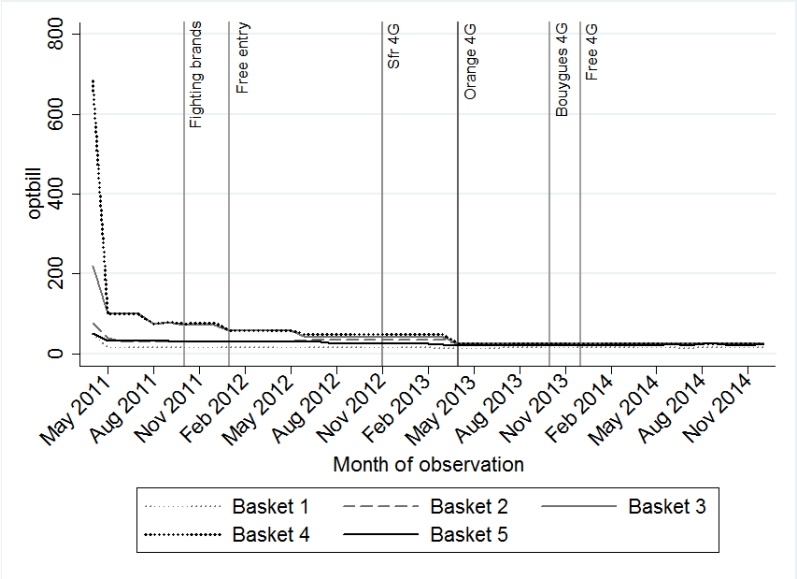


Figure A.10 – Price of lowest-cost tariff with handset subsidy for OECD baskets



Chapter 2

Consumer Myopia in Handset and Tariff Choices

This chapter is based on the article "Are Consumers Myopic? Evidence from Handset and Mobile Services Choices".[1]

Abstract This paper estimates a discrete choice model for combination of mobile tariffs and handsets using a cross-section of 16 743 subscribers of a European telecommunications carrier, observed between April 2011 and December 2014. The estimates are used to assess consumer's myopia in an original set-up, namely the trade-off between current and future expenses individuals make when choosing a handset and a mobile plan. We show that, under assumptions underlying the econometric model, consumer myopia decreases significantly over time, along with the introduction and adoption of sim-only plans and stabilizes around a value reasonably close to myopia estimated in other markets. This indicates that, on average, individuals tend to correctly trade-off current and future expenses when being offered suitable alternatives, in term of tariffs and handsets. We relate the emergence of these conditions to changes in the mobile market structure, leading to increased price competition and product differentiation.

[1]This article was presented during the Rising Star Session at the EARIE conference (Lisbon, Portugal), at the ITS Conference (Cambridge, UK) and at the 65th Annual Meeting of the French Economic Association (Nancy, France) in 2016; at the ZEW Summer Workshop for Young Economist (Mannheim, Germany) in 2017.

2.1 Introduction

Myopic consumers show limited ability to assess the future costs and benefits from a decision. They undervalue future payoffs and overvalue present ones. Myopic behavior may be observed in several contexts, for instance in a dynamic consumption framework (Strotz (1955)), when products come with add-on (Gabaix and Laibson (2006)) or more often when products require consumables complementary goods such as printer and cartridges.

Early articles estimate implied discount rates on purchase of air conditioners (Hausman (1979)), heating systems (Dubin and McFadden (1984)) and cars (Dreyfus and Viscusi (1995)). Some more recent articles focus on the measure of attention weight (Allcott and Wozny (2014); Grigolon et al. (2018); De Groote and Verboven (2016)) which distinguish the market interest rate from consumer's subjective valuation of future. Policy implication of these studies are mainly related to the functioning of policy towards markets such as energy market, in particular when the policy maker faces the possibility to implement a policy which affect current or future time periods. Short-sighted consumers may lead a policy implying future rewards -or penalty- to be less efficient or more costly compared to the alternative policy implying only a present cash flow.[2]

This article investigates the question of consumer myopia in a novel set-up, namely the choice of handset and mobile tariff. Handsets has long been in a large extent subsidized by mobile operator and scarce alternatives to this scheme were offered. The recent introduction of sim-only tariff and possibility to purchase the handset separately from the service makes the inter-temporal trade-off between current and future expenses relevant. Indeed, in numerous European countries, since the late 2000's, consumers may select a combination of a sim-only contract with a handset purchased at list price rather than a classical tariff with handset

[2]For example, in Grigolon et al. (2018), the Policy Maker can rather choose to implement a policy of upfront product tax on the less fuel efficient cars or, alternatively, to impose a fuel tax which affect future fuel cost for consumers. In De Groote and Verboven (2016), the Government faces the possibility to implement a program which involve upfront subsidy for solar photovoltaic system adoption or grant subsidies based on future electricity production. In the former case, fuel taxes were implemented and Grigolon et al. (2018) highlights that it actually targeted the right consumers -namely those with high mileage-. In the latter, the program involved future production subsidies and the authors are able to show that upfront subsidies rather than future electricity production subsidies would have enabled the public authority to reduce its expenditure by 51% for a similar level of adoption.

subsidy, incurring a lower upfront cost for the handset but a higher monthly bill for the commitment period.

Sim-only tariffs were introduced by operators in response to pressure from a new entrant, to cut down operational costs or to serve niche segments such as commitment-averse or highly price sensitive consumers. In markets such as UK, France and Spain, this significant transformation of tariff design also initiates changes in the handset distribution channel. Indeed, increasing freedom for consumers to purchase handset from the retailer of their choice generated economic space for development of second hand and refurbished devices markets, but also for low-cost brands which were not traditionally commercialized by operators. With the decline of traditional handset subsidy scheme also arose alternative financing schemes such as 0% credit, handset leasing and installment programs. In the same time, the regulatory framework constantly evolved to provide better transparency to consumers and reduce lock-in, in particular in reducing termination fees and commitment period of contracts. Some national regulators also encouraged -or required- operators to unbundle services and handsets or to provide more transparent information in displaying separate payments for service and repayment of the handset. In this context of both improved set of choice and quality of information, are consumers able to correctly value the discounted future monthly charges when choosing a tariff? How does the increased sim-only contracts availability impact future valuation of consumers? We attempt to provide answers to these questions in using a unique individual-level data of new subscribers from a European mobile operator, observed between April 2011 and December 2014. We estimate a discrete choice model to determine consumers valuation of tariff and handset characteristics, in particular tariff price and upfront cost of the handset. We replicate Allcott and Wozny (2014)'s strategy to compute average value of myopia from April 2011 to December 2014. We show that, under assumptions underlying the econometric model, consumer myopia decreases significantly, along with availability and adoption of sim-only plans and stabilizes around a value reasonably close to myopia estimated in other markets. This would indicate that, on average, individuals tend to correctly trade-off current and future expenses when being offered suitable alternatives, in term of tariffs and

handsets. We relate the emergence of these conditions to structural changes in the mobile market structure, leading to increased price competition and product differentiation.

The remainder of the paper is organized as follows: in the next section, we position this paper within the related literature. In section 3, we describe the data. Section 4 develops the econometric model. Section 5 provides details on the empirical estimations. Section 6 presents a discussion with results from alternative models. Section 7 concludes.

2.2 Related Literature

There is a large body of empirical research on consumer behavior in telecommunications markets which is focused on estimating choices of tariffs (Ben-Akiva et al. (1987)), price elasticities (Pereira and Ribeiro (2011)) and willingness to pay for service attributes (Rosston et al. (2010); Grzybowski and Liang (2015)). Dynamics of tariff choice has also been documented through empirical work on switching costs (Grzybowski (2008)) but also on consumer's learning in Miravete (2003).

As mobile telecommunications services and handset are complementary goods, these two have, since the early stage of the industry, been bundled within contracts involving a commitment period for the consumer, generally 24 months. Consumers are able to purchase a handset at a discounted price thanks to the operator's handset subsidy. Consequently, handset choice is often conditioned to -or at least influenced by- tariff choice, as only handsets offered by the service provider are subject to the handset subsidy and the level of this subsidy is proportional to the tariff price. Consequently, a large part of the research on handset choice is strongly related to the question traditional financing scheme. In particular, several papers evaluated how the ban of handset subsidies in some countries -Belgium, South Korea, Finland- impacted consumer adoption of a new technology (Han et al. (2006); Zhang and Huang (2009)), competition (Choi et al. (2001); Song and Kim (2001)) and welfare (Kim et al. (2004)). In this paper, we estimate simultaneously demand for tariff and handset, in a situation where both sim-only and traditional contracts are available to consumers. Apart from estimating consumer's valuation for characteristics of handsets and mobile tariffs, our model

enables to compute a value which captures how consumers tradeoff future expenses, namely the monthly recurring charge, compared to present expenses, namely the upfront cost of the device. This trade-off is similar to the trade-off between capital costs and operating costs when a firm has to make an investment decision, or between present and future consumption in the case of consumers choosing to save, lend or spend money. The latter was illustrated in Fisher (1930) which highlights existence of implicit discount rate for individuals, based on their level of initial and expected future stream of income. This work is followed by Samuelson (1937) who extended Fisher's two periods model into an infinite horizon model. These two papers both consider the trade-off between consuming and saving an available income. Discounted utility also applies to choices which involve trade-off between capital costs and operating costs, in particular in the energy field. Hausman (1979) computes implicit discount rate for air conditioners purchase. He finds an average rate of 20%, decreasing with household's level of income. This result suggests consumers may be biased towards present. Dubin and McFadden (1984) apply the same method for choice of heating and cooling systems and found similar values. More recent empirical work distinguish the market interest rate from consumer's subjective future valuation[3] in comparing implicit discount rates with observed interest rates. The extent of the gap between these two values is interpreted as consumer's *myopia* or limited *attention weight*. Consumer myopia has mainly been estimated in the car market, in US (Busse et al (2013), Allcott and Wozny (2014)) and in Europe (Grigolon et al (2018)). These studies share similar conclusion: consumer myopia is modest. This question has raised attention as implications are substantial, in particular with respect to accuracy of policies which are implemented in the markets. Indeed, if consumers are myopic, policies may be inefficient or too expensive. Grigolon et al (2018) find modest consumer undervaluation and conclude that fuel taxes are more effective in reducing fuel usage compared to product taxes. De Groote and Verboven (2016) show a significant undervaluation of future by households deciding to invest in photovoltaic systems, resulting in a too expensive subsidy

[3]Which echoes early work by Fisher (1930) who designates the gap between the market line -which captures the interest rate at which individuals may borrow or lend money- and the willingness line -which captures the rate at which individuals would actually accept to borrow or lend money- as an indicator of consumer's impatience.

policy.

European Commission published in 2007 a study on consumer detriment, highlighting the role of behavioral biases such as myopia, in choice of insurance policies, housing and investment goods but also in the case of bundled goods. In a more recent report, European Commission (2017) uses surveys to assess the magnitude of consumer's detriment in different markets in four EU countries. It shows that mobile services markets are among the most concerned by consumer detriment, at least in term of 'incidence', i.e. the share of consumers who declared having encountered a problem after purchase. Beyond simple 'incidence', the study also assesses the magnitude of this detriment, accounting for financial and psychological aspects. Although attempting to provide a general measure of consumer detriment, the study is limited by the design of the survey and provides no insight related to consumer myopia in particular.

This paper replicates Allcott and Wozny (2014)'s estimation strategy to investigate the question on consumer myopia in the mobile market. Thanks to our data which covers a period of three years, we are able to estimate a level of myopia for each quarter. We then relate evolution of myopia to changes in the mobile market. In particular, we suggest that increased competitive pressure in the market caused firms to differentiate their tariffs and offer better deals which benefited to consumers, whether consumers choose a traditional handset subsidy or a sim-only tariff.

2.3 The Data

The main data set we use consists in a cross-section of 16,743 new subscribers to a European operator, observed between April 2011 and December 2014. The original sample consists in a panel of 119, 729 consumers with post-paid contracts from which 21,608 new subscribers are extracted. We keep only the first observation so that the data set becomes a cross section. After keeping individuals aged between 18 and 75 years old, the sample consists of 20,611 observations. All tariffs with missing information are dropped. 19,732 consumers constitute the sample which includes complete information about the tariff chosen (price, call allowance,

data allowance, commitment period, handset subsidy option) and information about the consumer (age and gender). This data set is supplemented by the operator's handsets catalog which provides list price and level of subsidy for 283 unique models. Prices and subsidy may vary over time, what is recorded in this catalog. Amount of subsidy offered are given for ranges of tariff prices: the more expensive the tariff is, the bigger is the subsidy.[4] These 283 models represent about 82% of chosen handsets in the consumers data set. Since some of the handsets chosen by consumers are not listed in the operator's catalog, we have collected national public prices at release time.[5] We use this price as an approximation for the small share of handsets for which we do not have a price from the operator's catalog. We consider this price reasonable for the six months following the release. These handsets are, naturally, never associated with a subsidy. The interest of collecting these prices is two-fold: on the one hand, it enables to keep as much consumers as possible in the sample in not excluding the totality of individuals who chose a handset outside the operator's catalog. Thanks to this supplementary data, 87.3% of chosen handsets are associated with a price.[6] On the other hand, it also enables to include more diverse handset models in choice sets. After dropping all observations with missing information on handset price, our sample consists in 17,087 individuals. To finish, we use handset characteristics which are web-scrapped on gsmarena.com. It provides public information about the handset itself (year of release, operating system, screen size, autonomy, etc.). After merging this data set with the consumer sample with, the final sample consists of 16,743 individuals.[7]

Table B.1 provides an overview of main variables included in the dataset. Individuals are from 18 to 75 years old.[8] The average consumer is 41 years old. 51% of consumers are

[4]For example, in December 2014, the Apple's iPhone 4S was sold 492€ with a sim-only contract, 370€ with a tariff above 20€ per month, 340€ with a tariff above 30€, 239€ with a tariff above 43€, 99€ with a tariff above 55€ and 49.9€ with a tariff above 90€.

[5]This data was collected on an independent website which aggregate characteristics and price of handsets.

[6]Unfortunately, some of these handsets are chosen by consumers more than six months after their release in the market and we cannot infer a reasonable price beyond this. Consequently, we have to drop the observations.

[7]We have compared characteristics of consumers in final sample with consumers from the original sample, assumed unbiased, and found no significant difference. Nevertheless, despite particular attention paid to keep an unbiased sample, the original data itself consists of consumers from only one operator which offers particularly high quality of services and potentially a larger share of premium tariffs with higher level of subsidy compared to its competitors.

[8]We dropped consumers below or above these limits.

women. Monthly usage of voice is on average about 88 minutes and of data about 260 MB. Average price of tariff is 39€ and price of handset about 362 €. A large majority of chosen tariffs are mobile plans with handset subsidy (89%), with an average amount of subsidy of 209€. The average commitment period is about 21.4 months, witnessing the high share of consumers choosing 24 months contract. 23% of tariffs offers unlimited calls. The average data allowance is 1GB, ranging between 0 and 10GB.

Table B.2 shows evolution of tariffs selected by new consumers over time. Average tariff price declines by 13.2% between 2011 and 2014.[9] while list price of handset remains stable with a slight decline of 2.4%. Amount of subsidy granted to consumers with handset subsidy tariff decreases of 12.4%. This reduction may be surprising at first glance as we would expect subsidies to go up in a context of increasingly sophisticated handsets -and consequently increasingly expensive handsets-. Two opposite trends are reflected in this figure: on the one hand, in a context of intense competition, operators need to compete for premium consumers, namely those who are willing to pay for an expensive tariff associated with high-end smartphone. This would steer for higher amount of subsidy. But, on the other hand, prices of tariff with handset subsidy also declined: since amount of subsidies are computed on ranges of tariff prices, it mechanically declined too. A sharp take-off of sim-only contracts is observed between 2011 and 2014. It climbs from below 2.4% in 2011 to 30.3% in 2014. Handset's average price for these consumers decreases by 28% over the time period showing that they tend to choose cheaper devices when facing its full cost at purchase. Over the same time period, an increasing popularity of tariff with no commitment or short commitment period (12 months) is observed: share of the first is multiplied by 24 while share of the second has more than doubled between 2011 and 2014. No-commitment tariffs take-off is in a large extent driven by the growing demand for low-cost offers[10]: 98% of free of commitment subscribers are low-cost tariffs subscribers. Table B.2 also shows shares of observations by year. The significant drop observed between 2011 and 2014 is due to the extraction method used by the operator to construct the raw data. Indeed, individuals are selected among all customers of the firm based

[9] National price index for mobile tariffs shows a decrease of 38% between April 2011 and December 2014

[10] Low-cost offer is based on a simplified range of sim-only contracts with online subscription and online customer services

on their date of birth (day and month only). Over time, individuals churn but their phone number are potentially reallocated to other consumers so that new consumers are observed in the sample. High share for year 2012 corresponds to a period of net gain of consumers, mainly driven by low-cost tariff take-off. Despite this surprising pattern, we believe there is no selection bias since the construction process of the raw data is perfectly random.

Table B.3 presents shares of handset brands over the time. Four brands of handsets are the most widespread in our sample: Apple, Samsung, Nokia and BlackBerry. These shares are relatively stable in time, except for the brand Blackberry. Its share dropped from 12.8% in 2011 to 1.3% in 2014. The share of 'other' brands increased 3.6 times between 2011 and 2014, in particular because of the significant growth of an outsider low-cost brand which entered the market along with the new MNO. Generally, the penetration of sim-only tariffs enabled marginal brands -until then excluded from the mainstream retailing scheme- to gain market shares.

Table B.4 shows changes in prices of tariffs and handsets and highlights the differences between available alternatives and observed choices, per quarter. The time period studied in this paper witnesses the polarization of the mobile market with, on the one hand, premium tariff with handset subsidy and on the other hand, sim-only tariff. Consequently, we separate each type in the table. Average sim-only tariff price decreases by 35% between Q2 2011 and Q4 2014. The major price drop is observed early in 2012, when the new MNO enters the market. Average price of tariff with handset subsidy slightly increases by 8% over this time period. On handset prices, we compute a significant decline of 32% in price of chosen handsets for sim-only consumers, which confirms that they tend to choose cheaper handsets when facing the full cost of the device when contracting. On the contrary, price of handsets for consumers who choose a tariff associated with a subsidy increases of 10% between Q2 2011 and Q4 2014. In comparison to available alternatives, chosen sim-only tariffs are cheaper compared to what is available on the market. For example, the average price of available sim-only tariffs is 39.3€ while the average price of chosen sim-only tariff is 20.3€. We do not find such a significant gap for the tariff with handset subsidy, with an average of 45,2€ for

available and 41.2€ for chosen tariff.

2.4 Econometric Model

Our model relies on the assumption that individuals subscribe to a tariff and purchase a handset simultaneously. The price paid by the consumer for the handset equals the list price if the selected tariff is a sim-only tariff. Alternatively, if the tariff is a traditional tariff with handset subsidy, the consumer will pay the discounted price for the device.[11]

A discrete choice model framework is commonly used to analyze choices of telecommunication products. These models allow analyzing situations where an agent (a person, a firm) faces a choice or a series of choices over time, among a set of options. Each individual chooses with preferences depending on her characteristics (age, gender) and the product attributes (price, quality of services). A rational consumer chooses the alternative which maximizes her utility. Since the data set contains alternatives-specific variables, a conditional logit model is estimated. The first step of modeling is to define an exhaustive and mutually exclusive choice set. Consumers are assumed to choose a combination of tariff and handset among all the combinations available at current month. Each combination is constructed with a tariff from the list of available tariffs and a handset from the list of available handsets at current month.[12] Constructing an exhaustive choice set would have led to computational issues as each choice set would consist of more than 30,000 alternatives[13] and the final data set over 500 million of observations. The number of alternatives is limited by fixing a number of tariffs

[11] We are able to observe which handset is used at subscription time thanks the device's International Mobile Equipment Identity (IMEI), registered in the operator's information system. We do not have information about when the handset was actually purchased and no information about the price actually paid by the consumer to acquire the handset. Nevertheless, for consumers who subscribed to a tariff with handset subsidy (89% of observations in our sample), timing and price are correct as, by design, the handset is obtained at the subscription, at a price which depends on the chosen tariff and advertised in the operator's catalog. For the sim-only consumers, there is now way to be sure the handset was purchased at the time of subscription; consequently, we drop sim-only consumers using handsets which are not available on the market anymore, obviously not purchased new at consumer's subscription.

[12] Most of these handsets are listed in the operator's catalog. In this case, we use list price from this catalog. In reality, handsets may be purchased elsewhere but their prices are assumed equal to the operator's list price. For handsets outside of the operator's list, we use the official public price when released in the national market.

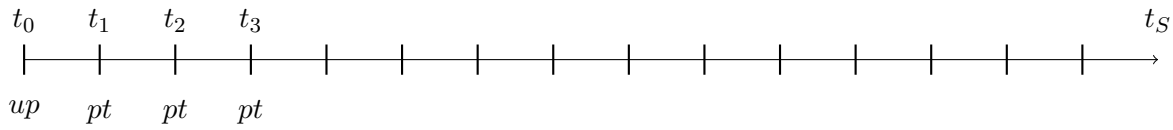
[13] Between 115 and 218 unique tariffs are observed, with an average of 165 tariffs per month. Between 103 and 237 unique handsets are observed, with an average of 184 handsets per month. If each handset is combined with each unique tariff, the choice set would consist in 165*184= 30,360 alternatives

and handsets randomly chosen, which is a standard approach in the discrete choice literature (see Ben-Akiva et al (1987)). Robustness and implications of this assumption are discussed in the section 2.5.2

The majority of available tariffs since April 2011 are offered with several options in terms of commitment period and handset subsidy. Prices differ in each of these situations. Commonly, the cheapest tariff is the tariff with no handset subsidy. These tariffs are offered free of commitment or with a 12-months commitment period, the latter being cheaper of about 5-10 euros compared to the no-commitment tariff. Tariffs with handset subsidy are associated with commitment period of 12 or 24 months. 24-months contracts are the cheapest among these two. In the choice set, in addition to the selected tariff, 10 randomly selected tariffs are added. Each tariff appears in all its available versions (handset subsidy, sim-only, with or without commitment). Consequently, number of unique tariffs in the choice set varies between 11 and 54. Similarly, 10 random handsets are added to the chosen handset. These handsets are combined with all tariffs selected as described previously. Handsets which are not listed in the carrier's catalog only appears in the choice combined with sim-only tariffs. Each choice set consists in between 209 and 506 alternatives per individual.[14] This variation is related to the difference in number of options available for a same randomly selected tariff.

Consumer's decision affects her inter-temporal budget constraint in two ways: on the one hand, the consumer pays a capital cost at t_0, namely the upfront cost of the chosen handset up_{jk}, and on the other hand, the consumer pays the present discounted value of recurring charges for mobile services PT_j [15], from t_1 to t_S.

Figure B.1 – Time horizon of a consumer decision



[14] All combination of tariffs and handset in the choice set are theoretically possible: the carrier's catalog gives a level of subsidy, even for very cheap handset corresponding with expensive tariffs. Nevertheless, some of them may not be reasonably chosen such as a premium tariff with 10GB of data charged 120€per month coming with a low-end feature phone, which costs 30€ without subsidy. Moreover, some combination may be more advertised than others. Unfortunately, we do not have information on this.

[15] We assume here that the amount paid by the consumer every month, the bill, is equal to the tariff price.

A standard linear utility specification is used for individuals $i = 1, ..., N$ over different tariffs $j = 1, ..., J$ and handsets $k = 1, ..., K$. Utility depends on tariffs and handset characteristics and on the observable and unobservable individuals' characteristics. The utility of individual i for tariff j and handset k is given by:

$$U_{ijk} = x'_{jk}\beta + \alpha(up_{jk} + \gamma PT_j) + \epsilon_{ijk} \tag{2.1}$$

where x'_{jk} is the vector which includes the following variables: a categorical variable for data allowance (500 MB, 1, 2, 4, 6 or 10 GB); a dummy for unlimited calls; a continuous variable for call allowance for tariffs which do not include unlimited calls; a dummy variable for fixed broadband option (DSL or FTTH); a categorical variable for tariff type (which combines handset subsidy option and commitment period); a dummy variable for each main brand of the sample; a dummy for smartphone; age of the handset model (in months); height, width, thickness (in mm), camera quality (in megapixels) and battery life (in hours) of the handset; a dummy variable for 4G handset when the tariff is compatible with 4G services. We interact our variables of interest (PT_j and up_{jk}) with quarter and age groups. Some characteristics (dummy for unlimited calls and tariff types) are also interacted with time. ϵ_{ijk} captures the unobserved variability generated, among others, from advertising, special discount or refund offers. The upfront cost of handset is denoted up_{jk} and is whether equals the full list price of the handset if a sim-only tariff is chosen or to the full price discounted by the subsidy granted by the operator if a classic tariff is chosen. PT_j is the present discounted value of expected future costs for mobile services. α is the marginal utility of income. γ is Allcott and Wozny (2014)'s attention weight which captures potential consumer's myopia. If γ equals zero, future costs do not have any weight in consumer's decision: she is fully myopic. If γ equals 1, consumer perfectly trade off the initial cost of the handset against present discounted value of future costs. If $\gamma > 1$, consumer overvalues future costs when making her decision. Net present value of future costs PT_j depends on tariff price pt_j, time horizon S and the market interest rate we denote r. We use the standard net present value formula to isolate the tariff price pt_j we observe in our data. highlight the capitalization coefficient ρ:

$$
\begin{aligned}
PT_j &= \frac{pt_j}{(1+r)^1} + \frac{pt_j}{(1+r)^2} + ... + \frac{pt_j}{(1+r)^S} && (2.2)\\
&= \sum_{s=1}^{S} (1+r)^{-s} pt_j && (2.3)\\
&= \frac{1}{r}[1-(1+r)^{-S}]pt_j && (2.4)\\
&= \rho pt_j && (2.5)
\end{aligned}
$$

We will refer to ρ as the capitalization coefficient. We now rewrite equation (2.1) in replacing PT_j by the expression we developed above.

$$U_{ijk} = x'_{jk}\beta + \alpha(up_{jk} + \gamma\rho pt_j) + \epsilon_{ijk} \tag{2.6}$$

We are able to estimate the following model:

$$U_{ijk} = x'_{jk}\beta + \alpha_1(up_{jk}) + \alpha_2(pt_j) + \epsilon_{ijk} \tag{2.7}$$

with α_1 denoting the price coefficient for capital cost up_{jk} and α_2 the price coefficient for future expenses.

Parameters γ and ρ cannot be estimated separately from pt_j. We are able to isolate γ based on the equivalence of Equ. 2.6 and Equ. 2.7.

$$\alpha = \alpha_1 = \rho\gamma\alpha_2 \tag{2.8}$$

$$\gamma = \frac{\alpha_1}{\alpha_2} \times \frac{1}{\rho} \tag{2.9}$$

While α_1 and α_2 are estimated, ρ will be computed, based on assumptions on the market interest rate r and time horizon S. For r, we use the average consumption credit rate granted by banks, which range from 5 to 6.15% over the period, in the country concerned by the

study. This value is very close to assumptions on r selected by Allcott and Wozny (2014) and Grigolon et al (2018) who both use $r = 6\%$ to compute the valuation of future payoffs in automobile market.[16] Alternative assumptions may be considered. Indeed r may take the value of the opportunity cost of funds, and, in this case, a national non-risky booklet interest rate may be considered. It varies from 1 to 2.25% . r may also takes value of consumption credit rate granted by specialized companies which offers revolving credit. This rate ranges between 12.8 and 15.2%. We compute myopia based on these two alternative assumptions and show its impact on γ is marginal and negligible in section 2.5.2. For S, which represents the time horizon consumers consider when trading-off present and future costs, we use the commitment period associated with the contract when it is different from zero. In the latter case, we assume S equals 19 months, which is the average time a non-committed consumer keeps her tariff in our data.[17] We compute myopia based on alternative assumptions on S and discuss its impact on γ in section 2.5.2. As r varies over time and S over consumers, depending on the length of chosen contract, ρ is time and individual specific.

Choice Probabilities and Estimation

An individual i chooses a combination n of a tariff and a handset it this maximizes her utility among all the available alternatives in her choice set. A part of this utility (V_{in}) is observable to the researcher.

$$U_{in} = V_{in} + \epsilon_{in} \tag{2.10}$$

[16] Allcott and Wozny (2014) and Grigolon et al (2018) use $r = 6\%$ as market interest rate to compute the valuation of future payoffs in automobile market. They use a weighted average of discount rate in the case of financed payment and cash payment. The value is calculated as follow:37% of the vehicles of the Allcott and Wozny's panel is financed at a real interest rate of 6.9% in average. 63% are purchased cash. In this case, the cost opportunity of funds is assumed to be equal to S&P 500 (Standard and Poors index) returns, i.e. at the time they did the study 5.8%. The weighted average is equal to 6.2. They use 6% for more convenience.

[17] Literature sets up this value as the durability of the good, its life time. Indeed, in the case of heating, cooling system or cars, goods may be sold at any moment; no contractual relationship bounds the consumer with the retailer who sold the good. In the framework of this study, the contrary is often the case. For instance, consumers willing to switch service supplier will be charged of a termination fee. Previously developed models in the field of energy took the average lifetime of the good as a reference for S. Ignoring the significant differences between configurations of bundles considered, one might take the average time period before handset is replaced. In this case, S would take a value close to 32 months which is the handset replacement cycle estimated by Recon Analytics in 2012. Nevertheless, this alternative does not make sense as the monthly recurring charge may vary over life time of the device.

The probability that individual i chooses a combination n is given by:

$$P_{in} = Prob(V_{in} + \epsilon_{in}) > Prob(V_{im} + \epsilon_{im}) \quad \forall m \neq n \tag{2.11}$$

The closed form expression derived from the previous equation, which is the classic logit probability, is given by:

$$P_{in} = \frac{e^{V_{in}}}{\sum e^{V_{im}}} \tag{2.12}$$

under the assumption of the error term ϵ having a standard Type 1 extreme value distribution, with cumulative distribution function

$$F(\epsilon_{im})) = exp^{-exp^{-\epsilon_{im}}} \tag{2.13}$$

This translates into the log-likelihood function:

$$\mathcal{L}_i(\theta) = \sum_n z_{in} ln(P_{in}) \tag{2.14}$$

Given that our data set includes information on individuals (age, usages) as well as on alternatives (tariff prices, handset price and various quality measures), we use both regressors which are alternative-specific and others which are interactions between case-specific variables -age groups, time of subscription- and alternative-specific variables. Consequently, we estimate a conditional logit model using the *clogit* command in Stata. This model fits maximum likelihood for each group, i.e. at each consumer decision level.

2.5 Estimation Results

2.5.1 Demand Estimation and Computation of Myopia

In this section, we comment on the estimation results and then discuss computation of myopia. Table B.5 shows results from the main model. Highly significant and reasonable coefficients for all variables of the model are found. In particular, we find, as expected, negative coefficients

for tariff price and upfront cost of the handset. Categories of data allowance are positively valuated, with coefficients ranging from 1.7 for 500MB to 10.6 for 10GB, which converts into a willingness to pay[18] ranging from 67€ per GB for the smallest allowance to 20.3€ per GB in the biggest allowance. Tariffs are offered whether with an unlimited call option or a limited call allowance, which range from 30 minutes to 900 minutes. The unlimited option is highly valuated, with a willingness to pay of 81€. This valuation has tendency to grow over time according to the interactions with quarters we included in the model. The option for fixed broadband which provide access to the fixed internet and telephony at home (DSL or FTTH) is also positively valuated, with a willingness to pay of about 24€, which is consistent with the premium charged for this option. We use as base outcome the most common tariff type, i.e. the 24-months contract with handset subsidy. Coefficients associated with other types are negative and significant, except for the low-cost type which is, in average, more valuated by consumers from our sample. We introduced dummy for main brands in our sample and their valuation is to be interpreted relatively to marginal brands which are our base outcome. We observe a strong valuation premium for Apple's products, followed by Blackberry. The dummy for smartphone is also positive and significant. Time since release which capture the age of the handset model is negative, meaning that on average, consumers prefer more recent models. Positive valuations for height and width show consumer's preference for large screen, while negative coefficient for thickness witnesses the disutility drawn from having a thick handset. Camera quality, which is measured in megapixels and battery life, measured by the stand-by autonomy are both positively valuated. Positive coefficient for 4G compatibility capture valuation for this recent technological advance.

To account for heterogeneity of usages, we introduced in the model the differences between observed individuals' consumption and allowances for voice and data.[19] We also interacted tariff price and upfront cost of handset with consumers age groups to account for differences in price sensitivity. Fig.B.6 shows that price sensitivity to the upfront cost of the handset

[18] To compute the willingness to pay for tariff attributes, we divide the coefficient for the attribute by the tariff price coefficient.

[19] We were not able to directly introduce usages in our estimation as chosen allowance and usages are strongly correlated.

differs across age groups. It varies from -0.005 for age groups 18-25 and 26-35, to about -0.007 for age groups 36-45, 46-55 and 56-65 and reaches -0.01 for the 66-75 group. This suggests that willingness to spend upfront for the handset (roughly) decreases with age of consumer, with the youngest age group being twice less price sensitive compared to the oldest group. Differences across age groups for tariff price are of a similar magnitude, with the least price sensitive being the age group 25-26, with a price coefficient of -0.023. The youngest consumers are more sensitive to tariff price compared to this group (-0.034), but less than the other age groups with an average price coefficient of -0.048 for 36-45, close to the coefficient estimated for age group 56-65. Age groups 46-55 and 66-75 are the most sensitive to tariff price with a coefficient of -0.052. Similarly, we interact tariff and upfront cost with quarter of subscription. Fig. B.6 shows evolution of price coefficients over time. Estimated price coefficients for upfront cost of handset are relatively stable compared to tariff price coefficients which sharply decrease from -0.052 in Q2 2011 to -0.128 by the end of 2014. We observe a peak at first quarter of 2012, when the new MNO enters the market, which corresponds to the beginning of a period of increased competitive pressure. These evolutions are accounted for in the computation of consumer myopia we discuss next.

Based on the results from our estimation, we are able to compute a coefficient for tariff price and upfront cost for each individual, based on her quarter of subscription and her age group. For example, for an individual between 18 and 25 years old, who subscribed in Q3 2011, the following tariff price coefficient α_2 is obtained: -0.052 (main coefficient) -0.006 (interaction with Q3 2011) + 0.018 (interaction with 18-25 yo age group), what gives -0.04. We also compute the capitalization coefficient ρ for each individual: r takes average national credit rate at the quarter of subscription and S depends on the commitment period of chosen tariff; 12 or 24 months. For individuals without commitment, we take 19 months as discussed in the econometric model description. Consequently, we are able to compute an individual value for γ which capture our estimation of myopia. Average values for price coefficients α_1 and α_2, rho, r, S and γ per quarter are shown on Table B.6.

Figure B.2 – Estimation for γ

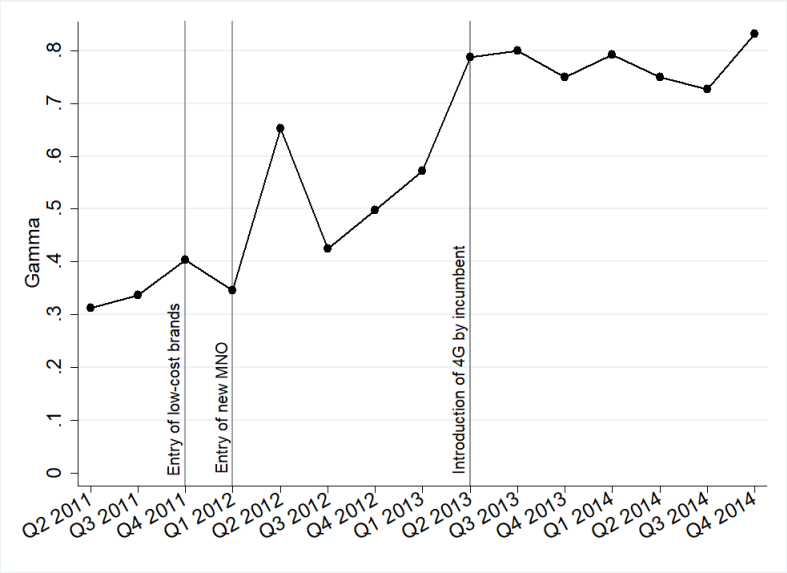


Fig.B.2 presents average values of γ over time. As a reminder, closer γ is to 1, the higher consumer's valuation of the future. Average value of myopia starts at 0.3 in Q2 2011 and stabilizes around 0.7 at Q4 2013. This value is below Grigolon et al's 0.88 in the framework of car purchase in Europe and Allcott and Wozny's 0.8 for cars in U.S. This is consistent with Strotz (1955) who suggests that consumers are more impatient when making short-run trade-offs than making long-run trade-offs. Besides the obvious difference in time horizon related to the replacement cycle and life-time of goods (2-3 years for handset, 15 years for a car), our case differs from the car set-up in term of magnitude of investment the initial purchase represents for consumers. This could explain the difference in estimated values of γ found.

Decline of consumer's myopia may intuitively be related to changes occurring in the market over the period 2011-2014. One quantitative approach to disentangle effects of events occurring at this time is to regress the estimated values of γ with variables capturing market changes. First, we use the Herfindahl-Hirschman Index (HHI) which is a commonly accepted measure of market concentration. We compute quarterly values for HHI based on market shares of MNO and MVNOs (See Fig. B.7). Then, we use a set of dummy variables which take value 1 after introduction of low-cost brands, entry of new MNO or introduction of 4G

by the main operator. Finally, we compute shares of available and chosen sim-only tariffs among all tariffs, at each quarter. Table B.7 shows the strong correlation between these variables. Consequently, we estimate several models using OLS to relate evolution of γ to each of these variables, separately. Results are presented in Table B.8 and indicate a strong significant impact of market concentration on γ: When HHI increases (indicating market is more concentrated), γ would decrease; meaning myopia increase. This would suggest that competition has a significant and positive impact on consumer's valuation of future. This effect may be complex and partially indirect: Indeed, if competition has directly impacted prices, it probably also encourages operators revising their tariff design strategy, in increasing the number of sim-only tariffs offered. This would be confirmed by the positive impact of an increase of sim-only tariff share on γ. We also note that entry of low-cost brands and entry of new MNO impact positively γ, reinforcing the hypothesis of a competition effect. The introduction of 4G also appears to be determinant of myopia reduction with a positive and significant impact of 4G on γ. Investments in this new technology and its commercial launch may be considered as a reaction of MNOs to an intensified competition, enabling to reinforce differentiation of the services they offer.

Another indirect effect of this increased competition is the growing availability of cheaper handsets, being itself the result of sim-only tariff increasing popularity. Handset subsidies have, for years, accustomed consumers to pay a low upfront price for their device and, as only the upfront cost was displayed and advertised, consumers were frequently not aware of the actual price of their handset. Unbundling handset and services implied list prices of handsets becoming salient to consumers; and this price may represent an obstacle, in particular in a time period witnessing a large number of first smartphone adoptions. We observed, along with sim-only penetration, the development of alternatives, cheaper handsets which offer an affordable equipment to combine with sim-only tariffs. In particular, a national-specific low-cost brand, created in 2011 and selling exclusively unbundled smartphones represented, mid 2014, a market share of 10-15% of national unbundled sales according to GfK, climbing to the second rank, just after Samsung. This also fostered emergence of alternatives financing

schemes such as leasing, short term consumption credit and spread repayment with no extra charge. Although no determinant may be isolated, decline of consumer myopia is very likely related to changes in market structure. Intensified competition related to the entry of a new player affected the market in leading to a generalized decline of tariff prices, a polarization between sim-only and classic tariff, resulting in an adapted handset market and a strong incentive to invest in a new technology to differentiate quality of services offered to consumers. To provide evidence of robustness of the specification we use, we explore some alternatives models and assumptions in the next section.

2.5.2 Robustness Checks

Computation of consumer's myopia in this paper relies on several assumptions we attempt to soften in estimating alternative models or computing results with alternative assumptions. An overview of these results is shown in Table B.10 and discussed in this section.

Alternative assumptions on r and S

First, we use estimation from the baseline model to compute alternative measures of myopia in changing parameters of the capitalization coefficient ρ, namely market interest rate r and S, time horizon of the tradeoff. Remind that, in the baseline computation, r equals the average rate of consumption credit granted by bank and is about 6%. We compute γ based on a lower rate $\approx$ 1.7% which is the interest rate of a non-risky booklet regulated by the State, representing the opportunity cost of capital. We also compute γ based on a higher market rate $\approx$ 14.3% which corresponds to the national average revolving credit rate. We observe that these alternative assumptions for r only slightly affect average values of gamma which now range from 0.35 with the low r to 0.39 with high r in 2011 and from 0.75 to 0.82 in 2014. We also test how changes on time horizon S affect our results. In our baseline computation, it may take three different values, depending on the consumer type: S=19 for non-committed subscribers, S=12 for 12-month contract subscribers and S=24 for 24-months contract subscribers. If we fix S=12 for all individuals, we see γ almost doubles compared to

the baseline computation and even exceeds 1 in 2013 and 2014, suggesting consumers would overvalue future. This scenario is not plausible as it would imply that all individuals from the sample expect to stick for 12 months on their contract and then switch. However, a large majority are committed 24 months to the operator and cannot switch, unless they pay a significant penalty. The results from the alternative computation considering all consumers are trading-off for 24 months is really close from our baseline estimation, in particular for the two first years. The last assumption for S, 32 months, would correspond to the scenario where the time horizon of the trade-off corresponds to the life-expectation of the handset. In this case, values for γ are significantly reduced, from 0.26 in 2011 to 0.5 in 2014.

Alternative choice sets

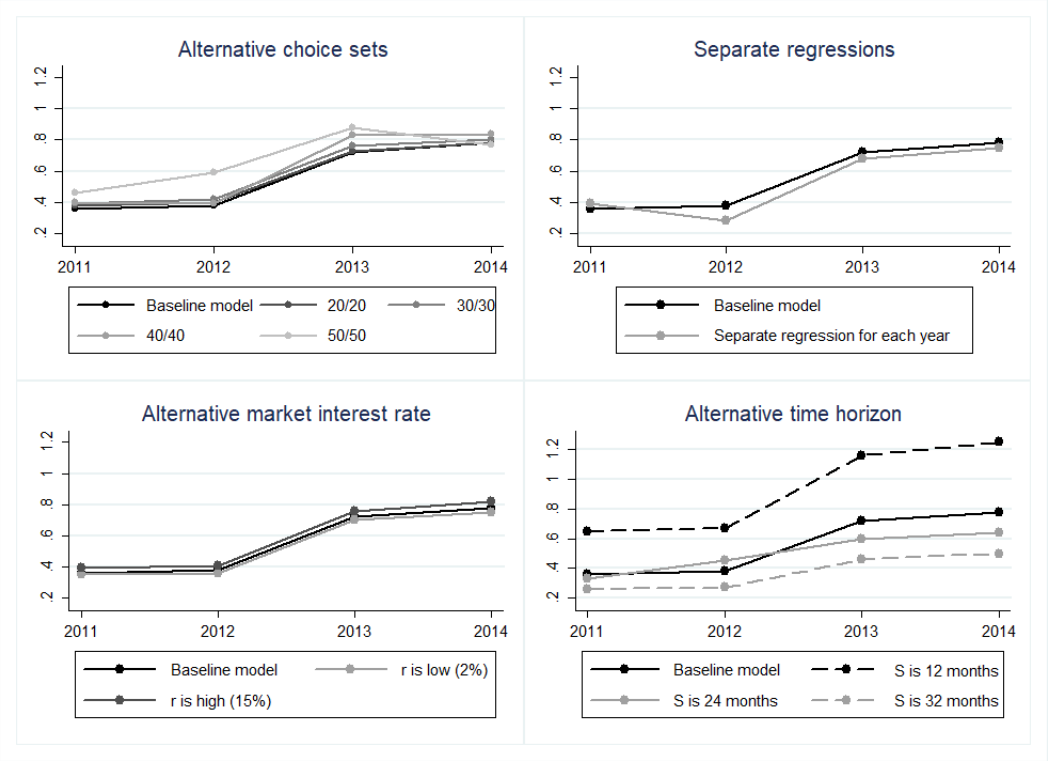
Second, we estimate our model based on alternative choice sets. More precisely, we increase the number of random tariffs and random handsets which constitute each individual choice set. In order to keep the size of the data set reasonable, we have to downsize the size of the sample proportionally to the growing size of choice sets.[20] Table B.9 shows the results for estimations on alternatives choice sets. We observe that coefficients for all variables are consistent and stable, regardless of the number of alternatives in choice sets. In particular, our variables of interest are not affected. To finish, we estimate alternative models, one with separate regression for each year, the other with random coefficients. Both shows our results are robust. To conclude, despite a high sensitivity of our model on assumption on time horizon accounted, S, our results are robust to alternative choice set constructions, assumption on market interest rate, separate regressions per year and random coefficients.

Alternative consumers sample

A potential concern may be raised about the correlation of myopia decrease and emergence of sim-only tariffs. We estimate our model based on two sub-samples of consumers to comment on myopia evolution for these groups specifically. As a first step, we restrict our analysis to consumers with commitment, i.e. consumers who subscribe to contract for 12 or 24 months.

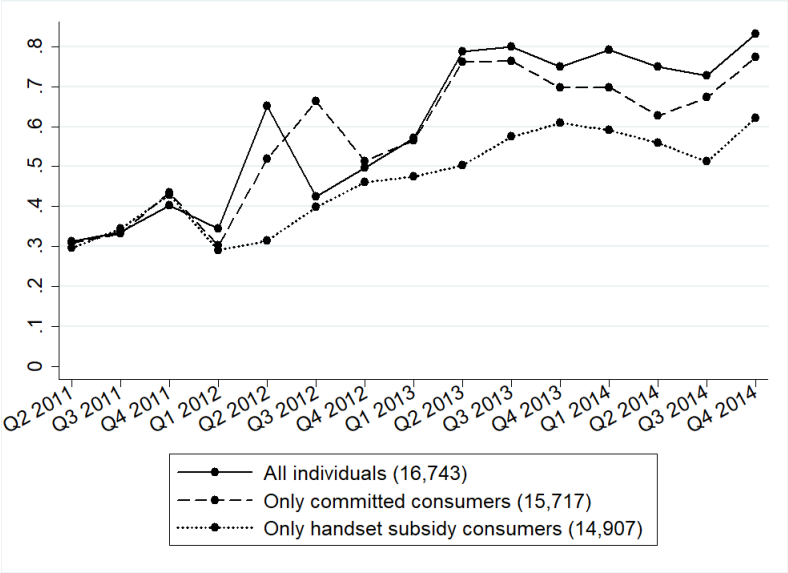
[20] Consumers are randomly selected among those from our original sample.

Figure B.3 – Alternative estimations for γ



12 months contracts may be sim-only tariffs or tariff with handset subsidy, while 24 months contracts are always related to a handset subsidy. These consumers represent 15,717 individuals out of the 16,743 individuals in the full sample. Computation of myopia for this sub-sample is of interest because it allows to consider a well-defined time horizon for the trade-off, and to relax the assumption of S being 19 months for a part of consumers for which this information is not available, namely the non-committed consumers. We estimate our model two times, once based on the full choice set, i.e. the choice which also include tariff without commitment, and, alternatively, based on choice set where only tariffs with commitment are included. We find no difference in estimation results. As a second step, we restrict our analysis to an even smaller sample of consumers, i.e. consumers who choose a contract with a handset subsidy. The sub-sample consists in 14,907 individuals who all chose a handset within the operator's catalogue and are committed for 12 or 24 months. This analysis allows to relax the S-assumption for not-committed consumers and also ensure that the handset price we

Figure B.4 – Alternative estimation for γ based on sub-sample of consumers



consider is valid, as we have for this sample the certainty of the price paid by consumers, as they necessarily purchased the handset at the operator' shop. We estimate our model two times, once based on the full choice set, i.e. the choice which also include sim-only tariffs, and, alternatively, based on choice set where only tariffs with handset subsidy are included. We find no difference in estimation results. Values for γ based on these alternative estimations are shown in Fig. B.4. We observe a significant increase of γ in the two alternative cases, with a magnitude similar to baseline model for committed-only consumers, and a smaller magnitude for handset subsidy consumers, with a smoother evolution over time. On the one hand, this suggests that the myopia decline we documented in our main specification is not driven by the increase of sim-only subscribers in our sample. On the second hand, it provides evidence of the market evolution being responsible for the myopia decline of all consumers, even consumers subscribing to handset subsidy tariffs.

2.6 Conclusion

In this chapter, we have estimated a discrete choice model to identify tariff and handset price valuations for a sample of mobile subscribers. We rely on these estimates to compute myopia

and relate its evolution to changes in the market structure and competitors' pricing strategies.

To estimate the demand model, we used detailed individual data of a cross-section of 16 743 subscribers of a European telecommunications carrier, observed between April 2011 and December 2014. In our set-up, individuals tradeoff between present and future expenses in selecting whether a sim-only tariff with a handset purchased at full price or a classic tariff with handset subsidy. We have emphasized the heterogeneity of price valuation among age groups and over time. We compute average consumer's myopia based on the estimates from the model. We show that, under assumptions underlying the econometric model, consumer myopia decreases significantly, along with availability and adoption of sim-only plans and stabilizes around a value reasonably close to myopia estimated in other markets. This would indicate that, on average, individuals tend to correctly trade-off current and future expenses when being offered suitable alternatives, in term of tariffs and handsets. We relate the emergence of these conditions to structural changes in the mobile market structure, leading to increased price competition and product differentiation. We provide evidence of this result not being driven by a mechanical effect of increasing number of subscribers to sim-only tariffs as an estimation restricted to subscribers to handset subsidy tariffs also suggest a decline of myopia, although of a smaller extent. This study offers a measure of one of the potential sources of detriment listed by the European Commission (2007) based on observed data. It suggests a significant and positive role of competition in reducing one of the source of consumer's welfare loss, i.e. myopia.

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2.7 Appendix

2.7.1 Descriptive Statistics

Table B.1 – Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Age of consumer	41.36	13.69	18	75	16743
Dummy female	0.51	0.5	0	1	16743
Voice consumption in minutes	88.56	290.32	0	12447.05	16743
Data consumption in GB	0.26	0.97	0	56.68	16743
Tariff price	38.96	21.59	4.9	175	16743
List price of the handset	361.79	178.78	19	800	16743
Option handset subsidy	0.89	0.31	0	1	16743
Amount of subsidy	209.64	118.57	0	649	16743
Commitment period	21.42	6.48	0	24	16743
Unlimited calls	0.23	0.42	0	1	16743
Data Allowance	0.99	1.24	0	10	16743

Table B.2 – Statistics per year

	2011	2012	2013	2014
Tariff price	39.3	42.8	31.7	34.1
List price of handset	357.6	382.2	337.7	348.7
Individuals with handset subsidy	355.7	381.8	343.3	364.4
Individuals with no handset subsidy	434.0	384.9	322.3	312.5
Amount of subsidy (if sub>0)	237.2	251.7	208.4	207.3
Upfront cost of handset	126.6	161.4	187.2	206.1
Individuals with handset subsidy	119.1	130.2	138.3	159.9
Individuals with no handset subsidy	434.0	384.9	322.3	312.5
Share of sim-only contracts (%)	2.4	12.2	26.6	30.3
Commitment period				
No	0.6	9.1	14.3	14.5
12 months	7.4	6.0	17.6	18.7
24 months	92.1	84.9	68.1	66.9
Share of observations	48.43	29.86	11.08	10.63
Individuals	8109	4999	1855	1780

These statistics are for selected tariffs.

Table B.3 – Share of brands (%)

	2011	2012	2013	2014
Apple	22.79	30.25	25.71	32.87
BlackBerry	12.85	8.98	6.04	1.29
HTC	2.92	2.18	2.37	2.02
LG	4.25	3.6	5.12	3.03
Motorola	1.7	1.78	1.02	0.34
Nokia	11.41	9.32	13.96	10.11
Samsung	38.17	37.77	31.72	31.91
Sony	0	0.42	7.92	11.74
Sony-Ericsson	4.14	3.78	1.83	0.28
Others	1.76	1.92	4.31	6.4
Total	100	100	100	100

Table B.4 – Average prices of tariffs and handsets, per quarter

	Chosen						**Available**			
	Tariff price			Handset price			Tariff price			Handset price
Quarter	All	Sim -only	Handset subsidy	All	Sim -only	Handset subsidy	All	Sim -only	Handset subsidy	All
Q2 2011	40.1	30.3	40.2	366.5	438.3	365.4	43.8	44.1	43.7	305.8
Q3 2011	40.4	24.8	40.7	338.0	407.7	336.7	45.3	39.9	47.3	297.2
Q4 2011	38.0	29.8	38.3	369.2	444.9	366.6	43.3	41.9	44.0	297.0
Q1 2012	44.1	19.7	47.3	390.5	398.3	389.4	44.9	42.7	46.0	296.8
Q2 2012	37.8	18.8	44.0	310.8	305.7	312.5	41.9	36.8	45.2	286.4
Q3 2012	36.9	23.4	39.5	281.4	212.3	294.4	43.8	38.0	47.1	267.7
Q4 2012	32.9	17.9	34.7	337.2	334.5	337.6	40.8	37.3	42.5	284.9
Q1 2013	34.0	18.2	38.4	344.4	338.5	346.0	40.9	37.0	43.2	290.3
Q2 2013	31.6	17.9	36.7	345.3	343.6	345.9	40.0	33.5	44.2	276.7
Q3 2013	29.7	18.3	34.3	326.4	334.6	323.1	39.2	32.7	43.4	269.9
Q4 2013	31.5	18.8	36.5	335.3	279.9	357.5	40.5	32.9	45.4	273.1
Q1 2014	30.9	19.3	36.0	334.7	298.7	350.5	38.5	32.0	42.8	267.3
Q2 2014	31.9	18.3	36.8	334.1	336.9	333.1	40.7	32.8	45.7	262.4
Q3 2014	36.1	22.7	41.3	347.8	330.0	354.9	41.3	33.5	46.3	255.7
Q4 2014	35.8	19.6	44.1	367.7	298.1	403.7	40.3	32.0	45.7	262.3
Total	39.0	20.3	41.2	361.8	352.0	363.0	43.3	39.3	45.2	291.0

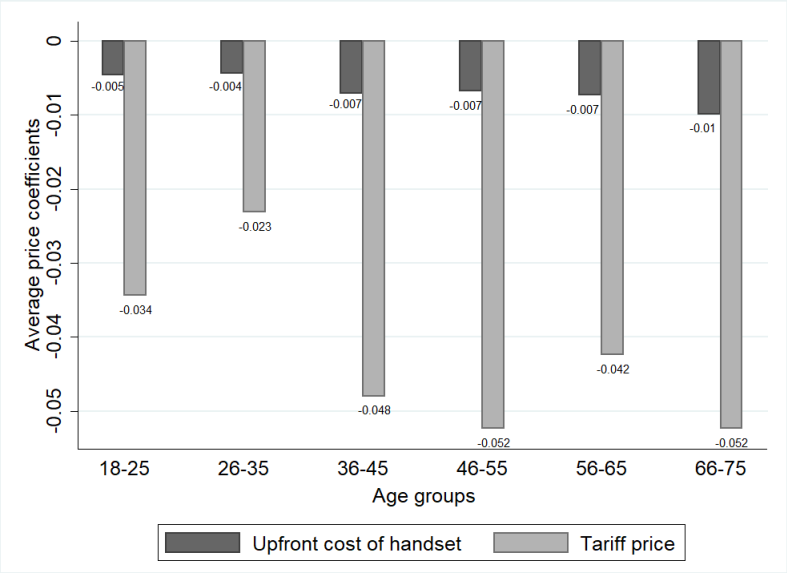
2.7.2 Estimation Results

Table B.5 – Results from model estimation

	Conditional Logit	
Prices		
Tariff price	-0.0524***	(0.00)
Upfront cost of handset	-0.00680***	(0.00)
Tariff characteristics		
Data allowance		
500 MB	1.754***	(0.03)
1 GB	2.049***	(0.05)
2 GB	3.635***	(0.09)
4 GB	4.438***	(0.18)
6 GB	8.215***	(0.25)
10 GB	10.64***	(1.08)
Unlimited calls	4.286***	(0.78)
Call allowance (minutes)	0.00395***	(0.00)
Fixed broadband	1.238***	(0.04)
Type 1: Tariff with handset subsidy, 24 months	0	(.)
Type 2: Tariff with handset subsidy, 12 months	-2.459***	(0.03)
Type 3: Sim-only, no commitment	-4.174***	(0.24)
Type 4: Sim-only, 12 months	-1.679***	(0.05)
Type 5: Sim-only, 24 months	-1.792***	(0.07)
Type 6: Low cost tariff, no commitment	0.934***	(0.05)
Handset characteristics		
Dummy Apple	6.002***	(0.07)
Dummy Blackberry	2.633***	(0.06)
Dummy HTC	0.286***	(0.07)
Dummy LG	0.607***	(0.06)
Dummy Motorola	0.900***	(0.08)
Dummy Nokia	1.271***	(0.06)
Dummy Samsung	1.934***	(0.05)
Dummy Sony	1.135***	(0.08)
Dummy Sony Ericsson	0.828***	(0.07)
Dummy smartphone	0.625***	(0.03)
Time since handset release	-0.0275***	(0.00)
Height	0.00927***	(0.00)
Width	0.0152***	(0.00)
Thickness	-0.0508***	(0.01)
Camera Quality	0.0473***	(0.00)
Standby autonomy in hours	0.00170***	(0.00)
4G access if handset is 4G compatible	1.099***	(0.06)
Consumer usages and age		
Data usage - allowance	0.505***	(0.03)
Voice usage - allowance	0.00370***	(0.00)
Tariff price*Age groups	Yes	
Upfront cost of handset*Age groups		
Evolution over time		
Unlimited calls*Quarter	Yes	
Tariff price*Quarter	Yes	
Upfront cost of handset*Quarter	Yes	
Observations	5490726	
Log Likelihood	-67894.6	

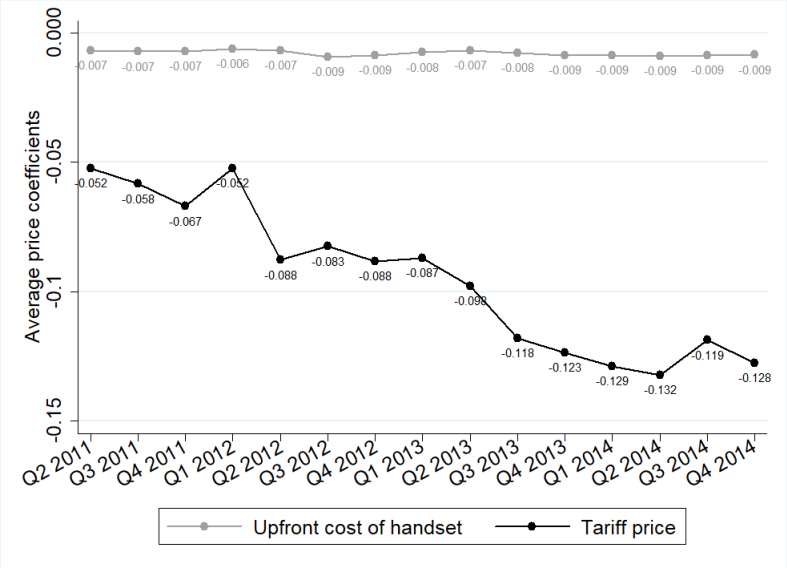
Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure B.5 – Price coefficients by age groups



Quarter=Q2 2011

Figure B.6 – Price coefficients over time

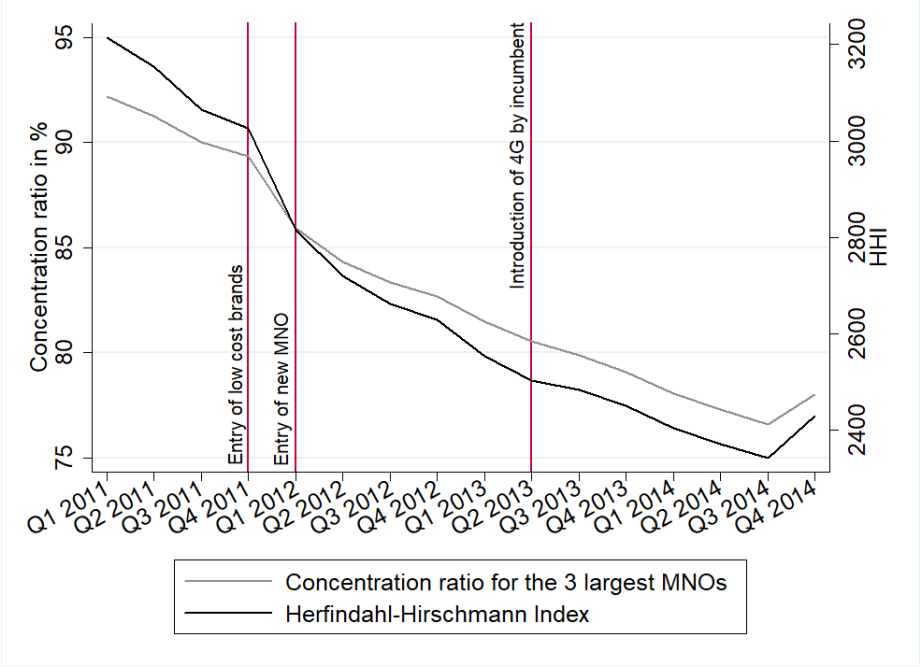


Age group=45-55

Table B.6 – Average values per quarter

	α_1	α_2	$\rho\gamma$	r	S	ρ	γ
Q2 2011	-0.006	-0.042	6.592	6.286	23.055	21.752	0.31
Q3 2011	-0.007	-0.049	7.132	6.231	23.140	21.842	0.34
Q4 2011	-0.007	-0.058	8.528	6.155	23.065	21.789	0.40
Q1 2012	-0.006	-0.042	7.340	6.191	22.980	21.711	0.35
Q2 2012	-0.006	-0.078	12.351	5.887	21.275	20.206	0.65
Q3 2012	-0.009	-0.071	8.186	5.792	21.587	20.508	0.42
Q4 2012	-0.008	-0.074	9.818	5.835	21.970	20.849	0.50
Q1 2013	-0.007	-0.074	11.061	5.977	21.529	20.425	0.57
Q2 2013	-0.006	-0.084	14.514	5.761	20.747	19.744	0.79
Q3 2013	-0.007	-0.107	15.197	5.591	21.147	20.143	0.80
Q4 2013	-0.008	-0.110	14.334	5.650	21.228	20.209	0.75
Q1 2014	-0.008	-0.115	15.178	5.933	21.269	20.198	0.79
Q2 2014	-0.008	-0.119	14.751	5.630	21.634	20.586	0.75
Q3 2014	-0.008	-0.107	13.749	5.373	21.099	20.136	0.73
Q4 2014	-0.008	-0.115	15.225	5.233	20.476	19.582	0.83
Total	-0.007	-0.061	9.085	6.064	22.581	21.365	0.45

Figure B.7 – Concentration measures



Source: Own computation based on data from ARCEP and Yankee Group

Table B.7 – Correlation matrix

	HHI	Entry low cost	Entry MNO	Intro 4G	% available sim	% chosen sim
HHI	1.00					
Entry low cost brands	-0.72	1.00				
Entry MNO	-0.86	0.78	1.00			
Introduction 4G	-0.78	0.37	0.47	1.00		
% available sim-only	-0.93	0.72	0.80	0.81	1.00	
% chosen sim-only	-0.93	0.66	0.81	0.80	0.89	1.00

Table B.8 – OLS with average computed γ

	(1)	(2)	(3)	(4)	(5)	(6)
HHI	-0.000647***					
	(0.00)					
Entry low cost brands		0.316*				
		(0.13)				
Entry MNO			0.310**			
			(0.10)			
Introduction 4G				0.334***		
				(0.05)		
Share of chosen sim-only tariffs					0.0163***	
					(0.00)	
Share of available sim-only tariffs						0.0274***
						(0.00)
Constant	2.307***	0.324*	0.351**	0.443***	0.274***	0.0753
	(0.25)	(0.12)	(0.09)	(0.03)	(0.03)	(0.10)
Observations	15	15	15	15	15	15
R^2	0.778	0.329	0.437	0.789	0.903	0.718

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B.9 – Estimation results based on alternative choice sets

	(1)		(2)		(3)		(4)		(5)	
	10 random tariffs 10 random handsets 16743 individuals Av. 335 alternatives $\in [209, 506]$		20 random tariffs 20 random handsets 6992 individuals Av. 1200 alternatives $\in [777, 1596]$		30 random tariffs 30 random handsets 3996 individuals Av. 2590 alternatives $\in [1705, 3348]$		40 random tariffs 40 random handsets 2500 individuals Av. 4480 alternatives $\in [3321, 5658]$		50 random tariffs 50 random handsets 1699 individuals Av. 6687alternatives $\in [3854, 8415]$	
Prices										
Tariff price	-0.0524***	(0.00)	-0.0524***	(0.00)	-0.0547***	(0.00)	-0.0538***	(0.00)	-0.0590***	(0.01)
Upfront cost of handset	-0.00680***	(0.00)	-0.00674***	(0.00)	-0.00696***	(0.00)	-0.00656***	(0.00)	-0.00664***	(0.00)
Tariff characteristics										
Data allowance										
500 MB	1.754***	(0.03)	1.721***	(0.04)	1.706***	(0.05)	1.836***	(0.07)	1.784***	(0.08)
1 GB	2.049***	(0.05)	1.996***	(0.08)	2.077***	(0.10)	2.074***	(0.13)	2.269***	(0.15)
2 GB	3.635***	(0.09)	3.635***	(0.13)	3.490***	(0.17)	3.777***	(0.21)	3.757***	(0.26)
4 GB	4.438***	(0.18)	4.475***	(0.27)	3.616***	(0.40)	4.674***	(0.47)	4.616***	(0.57)
6 GB	8.215***	(0.25)	8.198***	(0.36)	7.743***	(0.47)	8.640***	(0.60)	8.460***	(0.73)
10 GB	10.64***	(1.08)	-3.599	(2118.80)	-2.784	(1005.66)	-1.811	(2231.88)	-0.571	(743.65)
Unlimited call	4.286***	(0.78)	4.926***	(1.16)	4.260**	(1.53)	5.368**	(1.83)	8.976***	(2.43)
Call allowance (minutes)	0.00395***	(0.00)	0.00485***	(0.00)	0.00453**	(0.00)	0.00598**	(0.00)	0.00947***	(0.00)
Fixed broadband	1.238***	(0.04)	1.213***	(0.06)	1.368***	(0.07)	1.183***	(0.09)	1.470***	(0.11)
Type 1: Handset sub, 24 m	0		0		0		0		0	
Type 2: Handset sub, 12 m	-2.459***	(0.03)	-2.503***	(0.05)	-2.460***	(0.07)	-2.345***	(0.08)	-2.389***	(0.10)
Type 3: Sim-only	-4.174***	(0.24)	-4.039***	(0.36)	-4.830***	(0.71)	-3.961***	(0.58)	-4.818***	(1.00)
Type 4: Sim-only, 12 m	-1.679***	(0.05)	-1.772***	(0.07)	-1.572***	(0.09)	-1.792***	(0.13)	-1.833***	(0.14)
Type 5: Sim-only, 24 m	-1.792***	(0.07)	-1.787***	(0.11)	-1.832***	(0.16)	-1.738***	(0.19)	-1.356***	(0.18)
Type 6: Low cost tariff	0.934***	(0.05)	0.869***	(0.07)	0.730***	(0.10)	0.969***	(0.12)	0.370*	(0.15)
Handset characteristics										
Dummy Apple	6.002***	(0.07)	5.865***	(0.10)	5.695***	(0.13)	5.828***	(0.16)	5.891***	(0.20)
Dummy Blackberry	2.633***	(0.06)	2.642***	(0.09)	2.482***	(0.12)	2.494***	(0.15)	2.673***	(0.19)
Dummy HTC	0.286***	(0.07)	0.197	(0.11)	-0.0872	(0.15)	0.115	(0.18)	0.437*	(0.22)
Dummy LG	0.607***	(0.06)	0.657***	(0.10)	0.469***	(0.13)	0.545***	(0.16)	0.710***	(0.20)
Dummy Motorola	0.900***	(0.08)	1.070***	(0.12)	0.777***	(0.16)	0.867***	(0.20)	1.045***	(0.25)
Dummy Nokia	1.271***	(0.06)	1.261***	(0.09)	1.092***	(0.11)	1.112***	(0.14)	1.310***	(0.18)
Dummy Samsung	1.934***	(0.05)	1.917***	(0.08)	1.755***	(0.10)	1.804***	(0.13)	1.938***	(0.17)
Dummy Sony	1.135***	(0.08)	1.139***	(0.12)	1.057***	(0.15)	0.638**	(0.22)	1.119***	(0.25)
Dummy Sony Ericsson	0.828***	(0.07)	0.813***	(0.11)	0.634***	(0.14)	0.716***	(0.17)	0.898***	(0.21)
Dummy smartphone	0.625***	(0.03)	0.642***	(0.04)	0.629***	(0.05)	0.556***	(0.07)	0.637***	(0.08)
Time since handset release	-0.0275***	(0.00)	-0.0282***	(0.00)	-0.0273***	(0.00)	-0.0298***	(0.00)	-0.0311***	(0.00)
Height	0.00927***	(0.00)	0.00595*	(0.00)	0.00712*	(0.00)	0.0102**	(0.00)	0.00831	(0.00)
Width	0.0152***	(0.00)	0.0105**	(0.00)	0.00799	(0.01)	0.00908	(0.01)	-0.000124	(0.01)
Thickness	-0.0508***	(0.01)	-0.0780***	(0.01)	-0.0759***	(0.01)	-0.0577***	(0.02)	-0.0750***	(0.02)
Camera Quality	0.0473***	(0.00)	0.0454***	(0.01)	0.0634***	(0.01)	0.0551***	(0.01)	0.0198	(0.02)
Standby autonomy in hours	0.00170***	(0.00)	0.00177***	(0.00)	0.00186***	(0.00)	0.00188***	(0.00)	0.00188***	(0.00)
4G access if handset is 4G	1.099***	(0.06)	1.063***	(0.09)	1.129***	(0.12)	0.847***	(0.15)	0.948***	(0.18)
Consumer usages and age										
Data usage - allowance	0.505***	(0.03)	0.537***	(0.05)	0.465***	(0.07)	0.577***	(0.08)	0.522***	(0.10)
Voice usage - allowance	0.00370***	(0.00)	0.00425***	(0.00)	0.00369*	(0.00)	0.00471**	(0.00)	0.00843***	(0.00)
Tariff price*Age groups	Yes		Yes		Yes		Yes		Yes	
Upfront*Age groups	Yes		Yes		Yes		Yes		Yes	
Evolution over time										
Unlimited calls*Quarters	Yes		Yes		Yes		Yes		Yes	
Tariff price*Quarters	Yes		Yes		Yes		Yes		Yes	
Upfront*Quarter	Yes		Yes		Yes		Yes		Yes	
Observations	5490726		8242572		10184796		11067729		11180200	
Log Likelihood	-67894.6		-36697.6		-23893.3		-16234.8		-11694.4	

Standard errors in parentheses

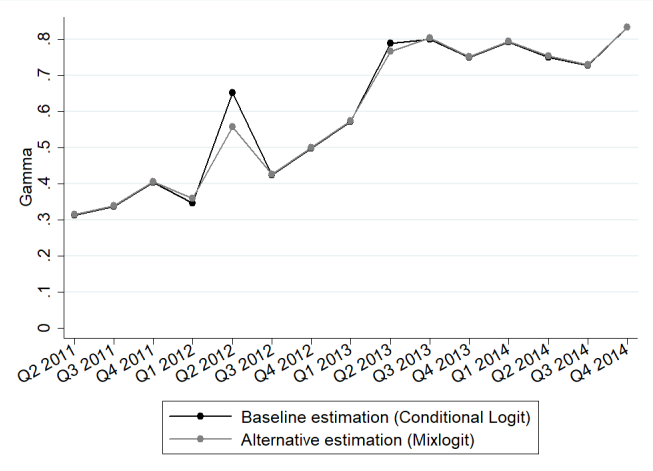
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B.10 – Alternative average values of γ

	$\hat{\gamma}_{2011}$	$\hat{\gamma}_{2012}$	$\hat{\gamma}_{2013}$	$\hat{\gamma}_{2014}$
Baseline model	0.36	0.37	0.72	0.78
20 tariffs, 20 handset	0.38	0.4	0.73	0.78
30 tariffs, 30 handsets	0.39	0.42	0.76	0.8
40 tariffs, 40 handsets	0.40	0.39	0.83	0.84
50 tariffs, 50 handsets	0.46	0.59	0.88	0.77
r is low (2%)	0.35	0.36	0.7	0.75
r is high (15%)	0.39	0.4	0.76	0.82
time horizon 12 months	0.65	0.67	1.16	1.25
time horizon 24 months	0.34	0.35	0.6	0.64
time horizon 32 months	0.26	0.27	0.46	0.5
Separate regression for each year	0.41	0.27	0.66	0.79
Estimation on committed consumers	0.37	0.33	0.69	0.70
Estimation on handset subsidy consumers	0.37	0.31	0.54	0.57
Random coefficients	0.36	0.38	0.72	0.78

Baseline model results are computed with the medium interest rate r which is approx. 5.9%. Time horizon S used in the baseline computation is the commitment period of the selected tariff for committed consumers and 19 months for non-committed consumers. Results from alternative choice sets are based on similar assumptions for r and S.

Figure B.8 – Alternative estimation for γ with random coefficients



Chapter 3

Consumer Inertia in Smartphone Choice

This chapter is based on the article "Estimating Consumer Inertia in Repeated Choices of Smartphones", which is a joint work with Lukasz Grzybowski.[1]

Abstract In this paper, we use a unique database on switching between mobile handsets in a sample of about 5,000 subscribers using tariffs without commitment from a single mobile operator on monthly basis between March 2012 and December 2014. We estimate discrete choice model in which we account for disutility from switching to a different operating systems and handset brands and for unobserved time-persistent preferences for operating systems and brands. Our estimation results indicate presence of significant state-dependency in the choices of operating systems and brands. We find that it is harder for consumers to switch from iOS to Android and other operating systems than from Android and other operating systems to iOS. Moreover, we find that there is significant time-persistent heterogeneity in preferences for different operating systems and brands, which also leads to state-dependent choices. We use our model to simulate market shares in the absence of switching costs and conclude that the market share of Android and smaller operating systems would increase at the expense of the market share of iOS.

[1]This article was presented at the IIOC Conference (Indianapolis, USA), during the Poster Slam of the Munich Summer Institute (Munich, Germany) and at the 2nd doctoral workshop on the Economics of Digitization (Paris, France) in 2018.

3.1 Introduction

The total number of smartphones sold to end users worldwide reached 1,495 millions by 2016, which is an increase by more than 1200% from 122 million in 2007.[2] During this period, the market of mobile smartphones has been inherently dynamic with new market players rapidly gaining global market shares and others being driven out of the market. In particular, Apple and Samsung entered the market in 2008 and within three years by 2011 reached joint market share of about 50% globally. Since then their global market shares are in decline, but they still remain the largest global market players in this industry.[3] At the same time, BlackBerry which was one of the most prominent smartphone vendors early on with sales peaking at 85 million worldwide in September 2013, lost its dominant position due to the success of the Android and iOS platforms. In March 2016, the number of BlackBerry subscribers fell to 23 million.[4] Since 2010, the global market shares of Asian manufacturers such as LG, Huawei, ZTE and Lenovo are on the rise pushing out of the market manufacturers such as HTC and Motorola and eroding the position of Apple and Samsung.

Smartphones are sold with pre-installed operating system (OS), thus the sales of smartphones determine global market shares of operating systems. The big winner is Android with market share growing from zero in 2009 to about 85 percent of all smartphones sold to end users globally in the first quarter of 2017. The second dominant operating system is iOS with market share of 14.7% as of first quarter 2017. The other operating systems including Microsoft, RIM, Bada and Symbian have a negligible total market share of 0.3%.[5] The success of smartphone manufacturers is intertwined with the success of operating system.

Due to the role which smartphones started to play in our daily lives and their increasing role as a platform for distribution of products and services, there is an immense interest in what drives the evolution and success in this industry. Fierce competition for the market between iPhone and Galaxy smartphones has already led to a series of ongoing lawsuits between Apple Inc. and Samsung Electronics with respect to the design of smartphones and

[2]Source: www.statista.com
[3]Source: www.businessinsider.com
[4]Source: Blackberry financial statement from April 2016.
[5]Source: www.idc.com

tablet computers. Moreover, the extremely high concentration in operating systems market and the winner-takes-all feature of this market has drawn attention of the policy makers. In 2016, the European Commission charged Google with unfairly using Android to promote its own services over those of its rivals. The Commission also looked into the relationships of Google with some of the world's biggest manufactures of mobile handsets, which have helped expand the reach of Android.[6]

In this paper, we shed light on competition between smartphone manufacturers and operating systems by revealing some facts with respect to consumer behavior in this market. We estimate consumer choices of smartphone models using a database of subscribers to a single mobile operator in a European country on monthly basis between March 2012 and December 2014. Since the choice and use of handset is inherently linked to mobile tariff and consumers tend to switch both tariff and handset at the same time, we model these two choices in parallel. However, in the estimation, we consider consumers who only use newly launched tariffs without commitment to avoid the problem of dealing with the issues of handset subsidies and possible lock-in due to commitment period.[7] Moreover, we only focus on consumers and observations in which handset switching takes place. Thus, our estimates are conditional on the decision to switch handset.

In our model the choice set consists of a combination of all tariffs without commitment which are available to consumers in a given month and mobile handsets without subsidy which are available in handset catalogues of the operator published on quarterly basis. We focus on the dynamics of consumer decision problem and estimate consumer inertia with respect to the choice of tariff and handset. Of particular interest for us is whether consumers face frictions when switching between different brands of smartphones, especially Samsung and Apple, and between two main operating systems: Android and iOS.

Our estimation results indicate that there is significant state-dependency in the choices of operating systems and smartphone brands. In general, we observe that it is harder for consumers to switch from iOS to other operating systems, except Blackberry. These higher

[6]Source: europa.eu

[7]The issue of consumer myopia when making choices of tariff plans and handset subsidies is studied by Nicolle (2017).

switching costs may be also linked to the cost of changing the whole ecosystem build by Apple around iPhone. Switching from Android to iOS and Windows is also costly but the switching costs in this direction are lower than average. It is also easier than average to switch from Blackberry to iOS. There is no difference from average in switching from Windows to different operators systems. Smartphones made by Blackberry and Apple have proprietary operating systems and the state-dependency between operating systems and brands cannot be separated. Moreover, we find that there is significant time-persistent heterogeneity in preferences for different smartphone brands and operating systems, which also leads to state-dependent choices. Our estimation results indicate presence of significant state-dependency in the choices of tariffs without commitment. Thus, consumers who decided to switch handset tend to continue using the same tariff due to preferences or switching costs. We use our model to simulate market shares in the absence of OS and brand-specific switching costs and conclude that the market share of Android and smaller operating systems would increase at the expense of the market share of iOS.

The literature on the choice and use of smartphones is still very short and recent, which is due to the fact that the industry essentially exists only since 2007. The second reason is availability of data which is suitable for such modelling. This paper is the first empirical analysis of repeated consumer choices of smartphones and the first attempt to estimate state-dependency in choices of operating systems and handset brands.

Our paper is related to the stream of empirical literature on switching costs between mobile providers and tariffs. Among papers on switching costs between mobile providers, Cullen and Shcherbakov (2010) use U.S. survey data from 2005-2009 to estimate a model for myopic consumers and develop a framework which allows including the introduction of persistent unobserved consumer heterogeneity in tastes for handset-carrier combinations. They find that consumers have significant switching costs associated with a change of provider amounting to approximately $230 USD. In another paper on provider-level, Weiergraeber (2017) uses survey data of U.S. consumers for years 2006-2010 to estimate dynamic demand model with both switching costs and network effects. He estimates switching costs to range from $40

USD to $88 USD. Switching costs are also found to lead to state-dependency in choices of tariffs. Grzybowski and Liang (2015) use consumer-level information on monthly basis for year 2013 from a single mobile provider in an European country to estimate switching costs between mobile tariffs. They find significant switching costs which reduce consumer surplus on average by 48-55 Euros per month. To the best of our knowledge there is only one paper so far by Sinkinson (2014) which estimates a structural model of demand for smartphones and carriers at the same time. He uses monthly market-level dataset of US consumer decisions over 2008-2010 and estimates both price elasticities for smartphones and carriers in order to study the implications of exclusive contracts for smartphones. Based on counterfactual simulations he concludes that AT&T had the highest willingness to pay for exclusivity with Apple and that this exclusivity increased entry incentives for rivals. In another recent paper, Park and Koo (2016) attempt to estimate switching costs between smartphones in Korea but the analysis is based on a single cross-sectional survey data and declarations of consumers about switching smartphones in the past.

The remainder of this paper is organized as follows. Section 3.2 presents the data used in the estimation. Section 3.3 introduces the econometric framework. Section 3.4 presents the estimation results. Finally, Section 3.5 concludes.

3.2 The Data

This analysis is based on three datasets which we combine together. The first database at the starting point consists of about 115,000 mobile subscribers to a single carrier in a European country who are observed on monthly basis between April 2011 and December 2014. This database includes only consumers with contracts, i.e., there are no prepaid users, and do not include any business customers. From this sample we select subscribers to tariffs without commitment and handset subsidy. These may be either new subscribers who did not have contract with the operator before or consumers who switched from tariffs with commitment and handset subsidy during the time period of our data. There are approximately 16,000 such consumers in our database. They can quit their contracts at any time without additional

charges.[8] We focus on consumers using tariffs without commitment to avoid dealing with the issue of handset subsidies which are linked to commitment. Consumer decision problem can be greatly complicated when in addition to the choice of handset we would need to consider a large number of tariffs with 12 or 24 months commitment and different level of subsidy. We observe in the data that only few consumers who decide to use a tariff without commitment switch back to a tariffs with commitment (less than 1% of the sample). The vast majority of consumers either keep using initially selected tariff or switch between tariffs without commitment. We drop from the analysis consumers who switched back to tariffs with commitment. We focus therefore on consumers who make a choice between tariffs without commitment and purchase a handset at a full price.

Next, we select only months in which consumers switched handset. In the time period considered, we observe 7,146 instances of handset switching by 4,983 unique customers. We are therefore not modeling the decision of a consumer to switch handset but the choice of specific handset conditional that a consumer had already decided to switch handset. We can observe that the handset was changed because the SIM card automatically detects and registers a new device, which is recorded in the data. It is possible that a consumer uses the SIM card in a few different handsets during a single month. Handset type is registered in the information system thanks to its International Mobile Equipment Identity (IMEI) twice a week on Monday and Thursday. Our database contains the last handset used by a consumer at the end of each month.

The second database includes the characteristics of all tariffs without commitment, which were available to consumers each month between March 2012 and December 2014. These characteristics are minutes and data allowances included in the tariff price and whether DSL broadband connection is part of the offer. Fiber-to-the-Home (FttH) broadband connection was not bundled with these tariffs.

The third database consists of prices and names of handsets which were advertised by the operator in its catalogues published on quarterly basis between March 2012 and December

[8]Tariffs without commitment and handset subsidy were first launch in October 2011. But due to a small number of users of these tariffs and also a small number of switchings between handsets in the first months we start our analysis from March 2012.

2014. Subscribers could purchase these handsets at listed prices without subsidy. For these handsets we have collected from online sources a long list of characteristics including the release date in the country considered. For 30.5% of observations in subscribers database, consumers switch to or from older handsets which are not listed in the catalogues. We do not have information on prices and other characteristics for these handsets and the observations on subscribers who use them are dropped from the analysis. This leads to bias towards newer handsets and smartphones and a higher share of iPhones and Apple than in the country population.

Switching between smartphone brands and operating systems

Before moving to econometric estimation we first compute some statistics to illustrate how consumers switch between different handset brands and operating systems. Table C.1 illustrates switching between feature phones and smartphones with different operating systems, where feature phones are broadly defined as handsets without operating system, i.e., not smartphones. We observe that 47% of switching takes place from Android to Android and 72% from iOS to iOS. There is therefore substantial inertia towards using the same operating system. This inertia is not present among users of Windows among whom only 19% switch to another smartphone running on Windows. Similarly, only 16% of Blackberry users switch to another Blackberry device. Users of Windows tend to switch more to iOS (36%) than to Android (28%). Also, users of Blackberry switch more to iOS (37%) than to Android (23%). Users of 'other' operating systems switch more to Android (32%) than to iOS (28%). Only 4.7% of them switch to a device which also relies on 'other' operating system. Finally, 41% of users of feature phones switch to another feature phone. The higher popularity of Android among users of feature phones may be due to a greater range of offers of Android smartphones both in terms of brands and specific models. But iPhones are also in general more expensive, hence first time smartphone users may opt for cheaper models to get their first experience. Among 59% who switch to a smartphone, 51% choose Android versus 27% opting for iOS. The adoption of smartphones is on the rise but there are still many smartphone users who

switch back to feature phones. The smallest share of switchers to feature phones represent users of iOS (6.4%), followed by Windows (9.7%) and Android (13.9%). The highest share of smartphone users who switch to feature phones are among users of devices running on 'other' operating systems (21.9%) and Blackberry (16.5%). The observed switching patterns indicate that the operating systems market evolves rapidly towards duopoly of Android and iOS with the remaining operating systems and feature phones losing market shares.

Table C.2 illustrates switching between different handset brands. As above, we observe that 72.5% of consumers switch from iPhone to iPhone. Furthermore, 37% of Blackberry users and between 17.8% to 27.7% of users of the other brands switch to iPhone. We also observe that 47% of users of Samsung switch to Samsung, where the percentage of users of other brands based on Android who switch to Samsung ranges between 27.7% for Sony to 42.3% for LG. At the same time 15.8% of iPhone users and 25.5% of Blackberry users switch to Samsung. The percentage of consumers who switch within the same brand relative to switching to the other brands is also higher for the remaining brands. This indicates that there is consumer inertia when switching between smartphone brands, which varies depending on brand and operating system.

Choice Set

We use the tariff and handset data sets to create choice set in each month. The choice set is a combination of tariffs and handsets which are available to consumers in a given month. The choice set of a particular consumer must also include tariff which he uses, even if it is not available to other consumers. Because of this, the set of tariffs which are included in the choice set in a given month may differ among consumers. On the other hand, the handsets included in the choice set in a given month are the same for all consumers. This is because we estimate the choice of handsets conditional on the decision to switch, and the continuation to use the same handset is not an option.

The choice set includes all handsets which were chosen by at least one consumer in a given month.[9] We do not consider that consumers purchase second hand handsets, which

[9]In alternative model specification, we include in the choice set all handsets offered at a full price in the

assumption is supported by market research.[10] The choice set ranges between 474 and 1,224 alternatives in a month, where consumers choose between 3 to 10 unique tariffs per month and between 71 to 194 unique handsets. These handsets belong to 16 different brands.

3.3 Econometric Model

We estimate a discrete choice model to analyze consumer choices of handsets and tariffs. Consumers are free to combine any non-subsidized handset with any non-commitment tariff available on the market in a given month and choose the combination which maximizes their utility. We use a standard linear utility specification which depends on tariff and handset characteristics including prices. We also account for the heterogeneity in preferences for operating systems and brands by means of random coefficients. The utility of individuals $i = 1, ..., N$ derived from handset $j = 1, ..., J_t$ and tariff plan $k = 1, ..., K_t$ which are available in month t is given by:

$$U_{ijkt} = X_j\beta_h^i - \alpha_h p_{jt} + X_k\beta_p - \alpha_p p_k + s_{ijkt}\gamma + \epsilon_{ijkt} = V_{ijkt} + \epsilon_{ijkt}. \tag{3.1}$$

where the price of handset is denoted by p_{jt} and the price of tariff plan is denoted by p_k. The valuations of handset attributes are denoted by β_h^i and the attributes vector X_j includes the following variables: (i) brand of the handset; (ii) operating system; (iii) handset measures: height, thickness and weight; (iv) battery life; (v) screen size; and (vi) camera resolution. The valuations of tariff characteristics are denoted by β_p and the characteristics vector X_k includes the following variables: (i) voice allowance in minutes if not unlimited;[11] (ii) a dummy for unlimited voice minutes; (iii) data allowance in Gigabytes (GB); (iv) a dummy for ADSL broadband. The characteristics and prices of tariff plans do not change over time but instead new plans are introduced and older ones are withdrawn. The characteristics of handsets also

catalogue of the operator in a given month, even if they were not chosen by any consumer, which results in greater choice set. The estimation results are comparable.

[10] According to Technical Market Index (TEMAX) from the market research firm GfK, only 15% of handsets sold in 2012 were second hand handsets. Moreover, according to Technology, Media and Telecommunications (TMT) Predictions from consultancy firm Deloitte, in 2015 only about 10% of customers from this country considered a purchase of a second hand handset.

[11] This variable takes value zero if the tariff includes unlimited calls

do not change over time but the catalogue price may change from one quarter to another.

The vector of switching dummies is denoted by s_{ijkt} and coefficients γ represent the disutility from switching which approximates switching costs. We consider four types of switching dummies. First, we use a dummy variable for switching tariff, which takes a value zero if consumer i in the previous month $t-1$ used the same tariff k, and value one otherwise. Second, we use a dummy variable for switching from a feature phone to smartphone. Third, we use a dummy variable for switching from a smartphone to feature phone. Fourth, we estimate an average switching costs between operating systems and a set of dummy variables which are specific switching costs between pairs of operating systems. In this way, we allow the disutility from switching to vary depending on the OS from which consumers switch and the OS to which they change. In the case of iPhone and Blackberry, which have proprietary operating systems, switching costs between operating systems and brands are equivalent. For smartphones which operate on Android, Windows and other smaller OS, we estimate in addition average switching costs between brands.

We use random coefficients on brand and operating system dummy variables. Our data is unbalanced panel, where for some consumers who switch more than once we have multiple observations, as shown in Table C.7. This table shows the number of consumers who switched handsets once, twice, three times and more. Thus, the random coefficients account for unobserved individual time-persistent preferences for particular brands and operating systems, which may result in state-dependent choices. We can denote the random coefficient as $\beta^i = \beta + \nu^i$, where β is a vector of mean valuations and $\nu^i \sim N(0, \Sigma)$ is a randomly drawn vector from a joint normal distribution. Here, Σ represents a diagonal matrix, in which the diagonal elements are standard deviations around the mean valuations. In this analysis, we do not use any observable individual characteristics which influence valuations of handset and tariff attributes because such information is confidential.

Finally, ϵ_{ijkt} is the individual-specific valuation for handset j, tariff k at time t, i.e., the "logit error term". It is assumed to be identically and independently distributed over tariffs and individuals according to type I extreme value distribution.

Choice Probabilities and Estimation

An individual i chooses in period t a handset m and a tariff n with the highest utility among all the available alternatives, i.e., if $U_{imnt} = \max_{jk \in C_{it}} U_{ijkt}$, where C_{it} is individual i's choice set in month t. Hence, the probability that individual i with random coefficients β^i makes a sequence of handset and tariff choices $mn = \{mn_1, mn_2, ..., mn_T\}$ is given by:

$$\begin{aligned} l_{imn}(\theta_i) &= \prod_{t=1}^{T} \Pr\left(U_{imn_t t} = \max_{jk \in C_{it}} U_{ijk_t t}\right) \\ &= \prod_{t=1}^{T} \frac{\exp(V_{imn_t t})}{\sum_{jk \in C_{it}} \exp(V_{ijkt})} \end{aligned}$$

where the second line follows from the distributional assumptions of the logit error term ϵ_{ijkt}.

When selected coefficients are allowed to be individual-specific, the estimated model is mixed logit model with unobserved time-persistent heterogeneity among individuals. We need to integrate of the conditional choice probability $l_{imn}(\theta_i)$ over the joint distribution of θ_i:

$$P_{imn}(\theta, \Sigma) = \int_{\theta_i} l_{imn}(\theta_i) f(\theta_i) d\theta_i. \tag{3.2}$$

where θ and Σ are the parameters to be estimated. In the special case when Σ is a matrix of zeros, there is no unobserved individual heterogeneity and we estimate the conditional logit model.

The probability that each individual in the sample chooses the sequence of alternatives as observed can be written as the log-likelihood function:

$$\mathcal{L}(\theta, \Sigma) = \sum_{i=1}^{N} \log(P_{imn}(\theta, \Sigma)) \tag{3.3}$$

To approximate the integral entering the choice probabilities $P_{imn}(\theta, \Sigma)$ in (3.2), we use simulation method, where following Train (2003) we take R draws for vector ν from the joint

normal distribution to obtain the average choice probability per individual:

$$\widehat{P}_{imn}(\theta, \Sigma) = \frac{1}{R} \sum_{r=1}^{R} \prod_{t=1}^{T} \frac{\exp\left(V^r_{imn_t t}\right)}{\sum_{jk \in C_{it}} \exp\left(V^r_{ijkt}\right)} \tag{3.4}$$

The maximum simulated likelihood estimator are the values of parameters θ and Σ which maximizes the likelihood function $\mathcal{L}$ given by equation (3.3) after substituting into it probability function (3.4).[12]

3.4 Estimation Results

3.4.1 Demand Estimation

The estimation results for conditional and mixed logit models are shown in Table C.8. In Model I, we estimate average switching costs between brands and operating systems. In Model II switching costs are allowed to vary between pairs of OS. In Model III, in addition we estimate random coefficients on handset brands and OS, which account for unobserved time-persistent preferences of consumers. The coefficient estimates in all three regressions are comparable. The log-likelihood values indicate that the model with OS-specific switching costs is preferred to the model with average switching costs between OS and brands. Moreover, the model with unobserved brand and OS preferences is preferred to the other two models. We therefore interpret the estimates of Model III below. We must stress again that we estimate the models for a sample of consumers who decided to switch handsets, and hence our estimates are interpreted conditional on handset switching.

The coefficient estimates can be divided into tariff characteristics, handset characteristics, switching costs and unobserved heterogeneity. The estimates of tariff characteristics and tariff price are highly significant. The price coefficient is estimated at -0.132. The coefficients of tariff characteristics are easier to interpret in terms of willingness to pay (WTP), i.e., by dividing the coefficients on particular tariff characteristic by tariff price. The willingness to pay

[12]The algorithm for estimating a mixed logit model is explained in detail in Train (2003). We estimate the mixed logit model using Stata procedure mixlogit with 50 Halton draws. See Hole (2007) for estimation details.

for DSL broadband as part of the tariff plan is about 1.851/0.132=14.0€, the willingness to pay for unlimited calls rather than for standard 2 hours allowance is 7.5€. Each gigabyte of data is valued at 4.2€. There is also a substantial switching costs between tariffs without commitment for consumers who had decided to switch handsets which cost can be approximated at about 38.6€.

The estimate of handset price is highly significant at -0.001, which yields a lower price elasticity of demand for handsets than for tariffs in our sample of consumers. Only some handset characteristics are significant and can be interpreted in terms of willingness to pay, i.e., by dividing their estimated coefficients by the coefficient on handset price.

Height is significant and positive with consumer willingness to pay of 8€ per millimeter. Consumers do not like thick handsets since the coefficient on thickness is significant and negative at -0.029. The coefficient on weight is also significant and negative at -0.003, which implies that consumers are willing to pay 3€ for each additional gram less. The coefficients on camera quality in pixels and battery talk time are not significant. Similarly, the coefficient on screen size is insignificant but it is correlated with the other handset measurements.

There are significant differences in the valuation of main brands relative to less popular brands which are not included in the model.[13] The most valued brand is Apple, followed by Blackberry, Samsung and Nokia. At the same time, HTC, Sony and LG are less valued than other smaller base brands. Since Apple and Blackberry have exclusive operating systems, their valuation also includes the value of their OS. Furthermore, the operating systems which are used by more than one brand, Android and Windows, are valued more than other less popular and older operating systems such as Symbian, Bada and Linux, as reflected by significant dummy variables for Android and Windows. Still the combined value of say Samsung and Android of 1.223+0.743 is less than the value of iPhone and iOS represented by 3.680.

We find that there are significant switching costs between operating systems and brands, which vary across OS pairs. The average switching costs between different operating systems are estimated at -0.966. The disutility from switching between brands on the same operating system is estimated on average at -0.287. In terms of willingness to pay, these numbers

[13]The other brands include Acer, Huawei, Icephone, Motorola, Sagem and some country-specific brands.

translate to approximately 966€(=-0.966/-0.001) and 287€, which are substantial monetary switching costs. Switching costs from feature phone to smartphone and from smartphone to feature phone are not significant.

The cost of switching varies greatly between operating systems and brands. In particular, switching from iOS to other operating systems and brands is much harder. The highest cost of switching is estimated from iOS to other operating systems such as Symbian, Bada and Linux followed by the cost of switching to Windows and Android. Surprisingly, it is not much harder than average to switch from iOS to Blackberry.

It is also harder to switch from Android to other smaller operating systems: Symbian, Bada and Linux. The cost of switching from Android to Windows and Blackberry is close to average. On the other hand, the cost of switching from Android to iOS is below average at (-0.966+0.400)=-0.566. For the other two larger operating systems, Windows and Blackberry, the cost of switching to other operating systems is close to average, except that it seems to be easier to switch from Blackberry to iOS, as reflected by significant and positive coefficient estimated at 0.392.

There is therefore asymmetry in the cost of switching from iOS to Android and from Android to iOS. The higher cost of switching from iOS may be due to the fact that iPhone users may have other devices from Apple, such as tablets and laptops, which are incompatible with other brands. Thus, the higher switching cost for iPhone may be the cost of switching the whole ecosystem. Figure C.5 compares switching costs between pairs of operating systems in monetary terms based on willingness to pay calculation.

Finally, we estimate significant heterogeneity in consumer preferences for brands and operating systems, as reflected by significant standard deviations on all brand coefficients, except Apple. The estimates of heterogeneity vary across brands with the highest estimates of standard deviations for Sony and HTC, and the lowest for Sony Ericsson and Blackberry (apart from Apple with insignificant standard deviation). There is also significant unobserved heterogeneity for Android, as reflected by significant estimate of standard deviation on the dummy variable for Android.

3.4.2 Conterfactual

We use the model to simulate market shares of brands and operating systems in the absence of switching costs. To do this we set the estimates of switching costs between brands and OS to zero, but keep non-zero switching costs between tariffs. The simulated market shares of operating systems for the whole time period are shown on Figure C.6. Since we estimated the highest disutility from switching from iOS to other operating systems, in the absence of switching costs iOS and Apple lose market share, while Android's market share increases, as shown on Figure C.7. As of December 2014, in the absence of switching costs the market share of iOS in our sample would drop from 56% to 42.1%. At the same time, the market share of Android would increase from 28.5% to 38.2%, with the smaller OS gaining market shares as well (see Figure C.6). Our sample is highly skewed towards iOS but we can expect a similar change in market shares at the country-level. We can therefore conclude that the market position of Android would be even stronger towards monopoly in the absence of switching costs between operating systems and brands.

3.5 Conclusions

This is the first paper which relies on detailed consumer-level data on choices of handsets over time to shed light on consumer inertia in choices of smartphone brands and operating systems. Our analysis contributes to understanding the role which state-dependency plays in the evolution of shares of market players and competition between iOS and Android.

We estimate consumer choices of smartphone models using a database of subscribers to a single mobile operator in a European country on monthly basis between March 2012 and December 2014. In the estimation, we only consider consumers who use newly launched tariffs without commitment to avoid the problem of dealing with the issues of handset subsidies and possible lock-in due to commitment period. Moreover, we only focus on consumers and time events in which handset switching takes place. Thus, our estimates are conditional on the decision to switch handset.

Our estimation results indicate that there is significant state-dependency in the choices

of operating systems and smartphone brands. In general, we observe that it is harder for consumers to switch from iOS to other operating systems, except Blackberry. These higher switching costs may be also linked to the cost of changing the whole ecosystem build by Apple around iPhone. Switching from Android to iOS and Windows is also costly but the switching costs in this direction are lower than average. It is also easier than average to switch from Blackberry to iOS. There is no difference from the average in switching from Windows to different operators systems. Smartphones made by Blackberry and Apple have proprietary operating systems and the state-dependency between operating systems and brands cannot be separated. Moreover, we find that there is significant time-persistent heterogeneity in preferences for different smartphone brands and operating systems, which also leads to state-dependency of choices.

We use our model to simulate market shares of brands and operating systems in the absence of switching costs. Since we estimated the highest disutility from switching from iOS to other operating systems, in the absence of switching costs iOS and Apple lose market share, while Android's market share increases. We can conclude that the market position of Android would be even stronger towards monopoly in the absence of switching costs between operating systems and brands.

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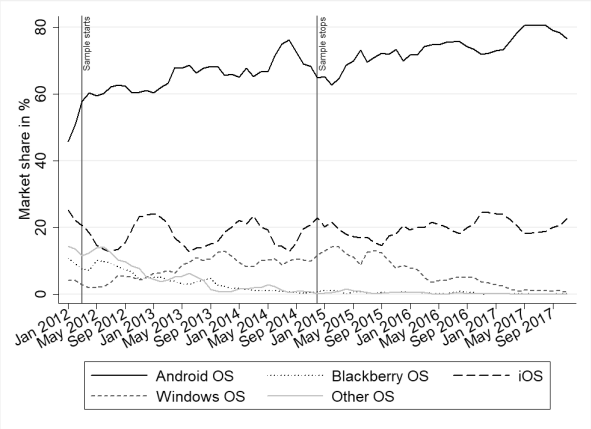
3.6 Appendix

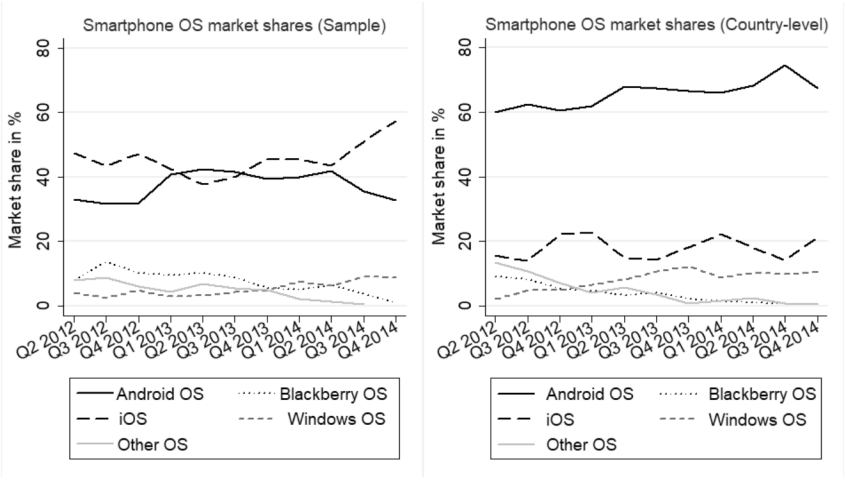
3.6.1 Descriptive Statistics

Figure C.1 – Smartphone OS market shares at the country-level



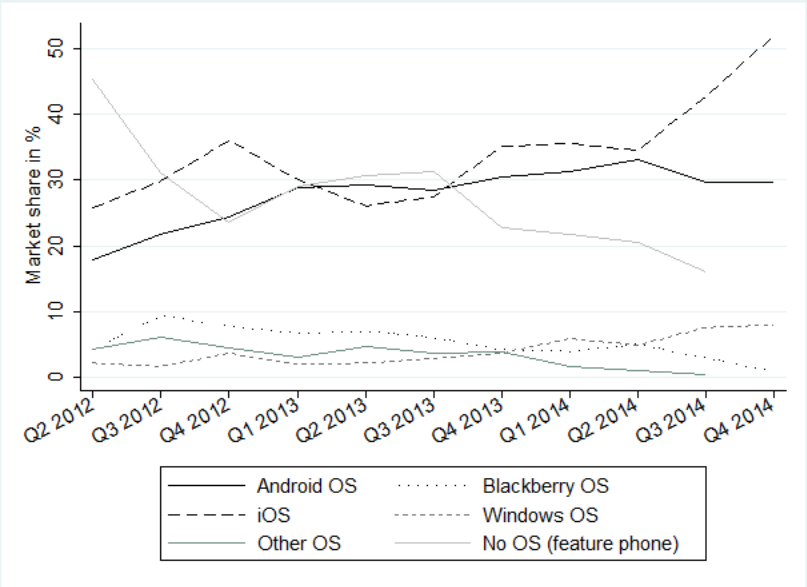
Source: Kantar Worldwide Panel

Figure C.2 – Smartphone OS market shares in the sample and at the country-level



See Figure C.3 for market shares including feature phones. Source for country-level data: Kantar Worldwide Panel

Figure C.3 – Handset market shares (smartphones and feature phones)



See Figure C.2 for smartphones market shares.

Figure C.4 – Main brands in the sample (smartphones and feature phones)

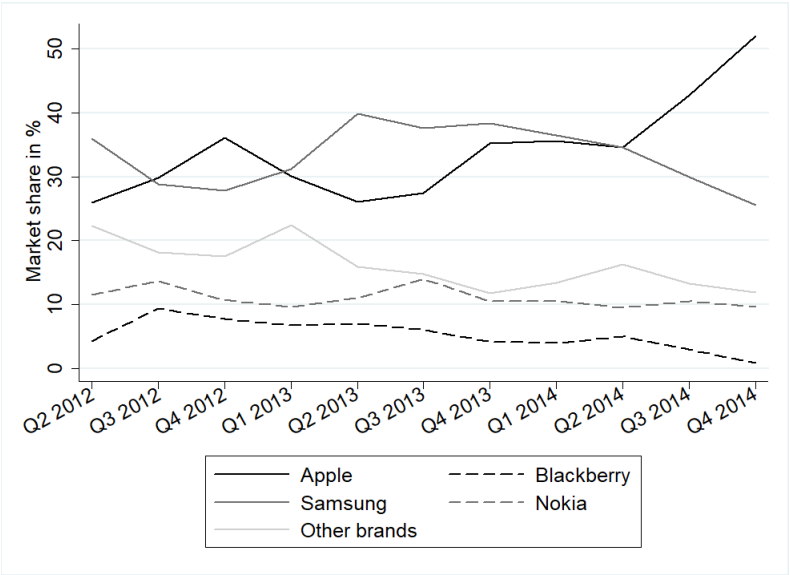


Table C.1 – OS before and after switching handset (% of observations of individuals)

		After switching						
		Android	Blackberry	Windows	iOS	Other	Feature phone	Total
Before switching	Android	46.94	4.02	5.99	27.55	1.59	13.9	100
	Blackberry	23.17	16.28	4.59	37.16	2.29	16.51	100
	Windows	28.41	4.55	18.75	35.8	2.84	9.66	100
	iOS	15.13	2.91	2.1	72.46	0.97	6.44	100
	Other	32.38	4.7	7.83	28.46	4.7	21.93	100
	Feature phone	29.97	4.53	4.65	15.96	4	40.9	100
	Total	29.3	4.7	4.76	36.43	2.55	22.26	100

Table C.2 – Brand before and after switching handset (% of observations of individuals)

		After switching								
		Apple	BBerry	HTC	LG	Nokia	Samsung	Sony	Son.Eric.	Other brands	Total
Before switching	Apple	72.46	2.91	0.97	0.87	3.47	15.79	1.94	0.72	0.87	100
	BlackBerry	37.16	16.28	1.38	3.44	9.4	25.46	2.98	1.61	2.29	100
	HTC	25.25	4.04	8.59	2.02	9.6	40.91	5.56	2.02	2.02	100
	LG	17.79	5.53	3.95	4.74	13.83	42.29	3.56	1.98	6.32	100
	Nokia	20.12	4.36	2.18	3.37	22.79	35.08	3.07	1.59	7.43	100
	Samsung	22.73	3.66	1.38	4.02	10.76	46.76	4.02	1.25	5.4	100
	Sony	27.66	2.13	1.06	1.06	10.64	27.66	26.6	1.06	2.13	100
	Sony-Ericsson	19.14	5.12	1.89	4.58	12.94	35.85	9.16	7.55	3.77	100
	Other brands	20.2	6.62	1.36	5.26	13.92	34.63	4.07	1.87	12.05	100
	Total	36.43	4.7	1.69	3.09	10.83	33.19	3.85	1.6	4.62	100

Table C.3 – OS before and after switching handset (observations of individuals)

		After switching						
		Android	Blackberry	Windows	iOS	Other	Feature phone	Total
Before switching	Android	736	63	94	432	25	218	1568
	Blackberry	101	71	20	162	10	72	436
	Windows	50	8	33	63	5	17	176
	iOS	296	57	41	1418	19	126	1957
	Other	124	18	30	109	18	84	383
	Feature phone	787	119	122	419	105	1074	2626
	Total	2094	336	340	2603	182	1591	7146

Table C.4 – Brand before and after switching handset (observations of individuals)

		After switching									
		Apple	BBerry	HTC	LG	Nokia	Samsung	Sony	Son. Eric.	Other brands	Total
Before switching	Apple	1418	57	19	17	68	309	38	14	17	1957
	BlackBerry	162	71	6	15	41	111	13	7	10	436
	HTC	50	8	17	4	19	81	11	4	4	198
	LG	45	14	10	12	35	107	9	5	16	253
	Nokia	203	44	22	34	230	354	31	16	75	1009
	Samsung	509	82	31	90	241	1047	90	28	121	2239
	Sony	26	2	1	1	10	26	25	1	2	94
	Sony-Ericsson	71	19	7	17	48	133	34	28	14	371
	Other brands	119	39	8	31	82	204	24	11	71	589
	Total	2603	336	121	221	774	2372	275	114	330	7146

Table C.5 – Average prices of handsets and tariffs, and share of smartphones/iPhone per quarter

Quarter	Handset price	Tariff price	Smartphone (%)	iPhone (%)
Q1 2012	300.73	14.16	0.67	0.11
Q2 2012	334.34	17.17	0.55	0.26
Q3 2012	373.86	17.58	0.69	0.30
Q4 2012	419.73	17.40	0.76	0.36
Q1 2013	384.79	17.51	0.71	0.30
Q2 2013	364.25	16.70	0.69	0.26
Q3 2013	330.50	15.37	0.69	0.27
Q4 2013	357.17	15.99	0.77	0.35
Q1 2014	352.28	16.44	0.78	0.36
Q2 2014	343.72	16.32	0.79	0.35
Q3 2014	369.03	17.40	0.84	0.43
Q4 2014	408.13	18.31	0.91	0.52
Total	368.15	16.87	0.78	0.36

Table C.6 – Tariff and handset characteristics

Variable	Mean	Std. Dev.	Min.	Max.	N
Unlimited calls (0/1)	0.78	0.42	0	1	7146
Data allowance (GB)	1.65	1.4	0	5	7146
Quad. with DSL fixed line (0/1)	0.03	0.17	0	1	7146
Height (mm)	117.97	13.55	67	172	7146
Width (mm)	59.69	7.25	26	85.90	7146
Thickness (mm)	10.94	3.09	6.7	40	7146
Screen size (inch)	3.5	1	1	10.1	7146
Battery life: Talk time (hrs)	8.87	3.61	2.8	24	7146
Battery life: Stand by (hrs)	413.52	176.26	150	920	7137
Camera quality (mpixels)	5.38	3.59	0	41	7146

Table C.7 – Switching per individual

Switchings	Freq.	Percent	Cum.
1	3,637	72.99	72.99
2	902	18.1	91.09
3	267	5.36	96.45
4	98	1.97	98.41
5	32	0.64	99.06
6	24	0.48	99.54
7	8	0.16	99.7
8	2	0.04	99.74
9	5	0.1	99.84
10	2	0.04	99.88
11	2	0.04	99.92
12	3	0.06	99.98
13	1	0.02	100
Total	4,983	100	

3.6.2 Estimation results

Table C.8 – Estimation results

	(1) Clogit		(2) Clogit		(3) Mixlogit	
Main						
Tariff characteristics						
Tariff price	-0.132***	(0.02)	-0.132***	(0.02)	-0.132***	(0.02)
Unlimited calls	0.993***	(0.13)	0.993***	(0.13)	0.993***	(0.13)
Data allowance in GB	0.563***	(0.09)	0.563***	(0.09)	0.563***	(0.09)
Quad. with DSL fixed line	1.851***	(0.50)	1.851***	(0.50)	1.851***	(0.50)
Handset characteristics						
Handset price	-0.001***	(0.00)	-0.001***	(0.00)	-0.001***	(0.00)
Apple	4.067***	(0.11)	3.637***	(0.13)	3.680***	(0.14)
BlackBerry	1.694***	(0.11)	1.459***	(0.14)	1.224***	(0.19)
HTC	-0.473***	(0.11)	-0.472***	(0.11)	-1.129***	(0.29)
LG	0.165	(0.09)	0.165	(0.09)	-0.511*	(0.24)
Nokia	0.912***	(0.07)	0.923***	(0.07)	0.498***	(0.12)
Samsung	1.209***	(0.06)	1.227***	(0.06)	1.223***	(0.07)
Sony	0.191*	(0.09)	0.194*	(0.09)	-0.579*	(0.23)
Sony Ericsson	0.127	(0.11)	0.127	(0.11)	-0.717*	(0.33)
Other brands	0.000	(.)	0.000	(.)		
Battery life: Talk time	0.007	(0.00)	0.007	(0.00)	0.007	(0.00)
Screen size	-0.031	(0.04)	-0.031	(0.04)	-0.033	(0.04)
Height	0.008***	(0.00)	0.008***	(0.00)	0.008***	(0.00)
Weight	-0.003***	(0.00)	-0.003***	(0.00)	-0.003***	(0.00)
Thickness	-0.027**	(0.01)	-0.028**	(0.01)	-0.029**	(0.01)
Camera quality in mpixels	-0.009	(0.01)	-0.009	(0.01)	-0.009	(0.01)
Android Os	0.892***	(0.09)	0.784***	(0.11)	0.743***	(0.11)
Windows Os	0.923***	(0.10)	0.754***	(0.13)	0.694***	(0.15)
Switching costs						
Switching from feature phone to smartphone	-0.273**	(0.10)	-0.116	(0.14)	-0.140	(0.15)
Switching from smartphone to feature phone	0.021	(0.09)	-0.339	(0.18)	-0.377*	(0.19)
Switching cost for changing o.s.	-1.212***	(0.04)	-1.097***	(0.13)	-0.966***	(0.14)
Switching cost for changing brand	-0.513***	(0.05)	-0.457***	(0.05)	-0.287***	(0.06)
Switching cost for changing tariff	-5.098***	(0.07)	-5.098***	(0.07)	-5.098***	(0.07)
Switching from Android to iOS			0.435**	(0.15)	0.400*	(0.16)
Switching from Android to Blackberry OS			0.186	(0.20)	0.184	(0.21)
Switching from Android to other os			-0.389	(0.28)	-0.406	(0.28)
Switching from Android to Windows OS			0.325	(0.19)	0.331	(0.20)
Switching from iOs to Android			-0.621***	(0.15)	-0.742***	(0.16)
Switching from iOs to Blackberry OS			-0.340	(0.20)	-0.414	(0.21)
Switching from iOs to other os			-1.122***	(0.30)	-1.183***	(0.30)
Switching from iOs to Windows OS			-0.969***	(0.22)	-1.031***	(0.23)
Switching from Blackberry OS to Android			-0.376*	(0.19)	-0.338	(0.20)
Switching from Blackberry OS to iOs			0.421*	(0.18)	0.392*	(0.19)
Switching from Blackberry OS to other			-0.642	(0.38)	-0.622	(0.38)
Switching from Blackberry OS to Windows OS			-0.330	(0.28)	-0.285	(0.30)
Switching from Windows OS to Android			-0.125	(0.24)	0.003	(0.27)
Switching from Windows OS to iOs			0.309	(0.24)	0.394	(0.26)
Switching from Windows OS to Blackberry OS			0.002	(0.41)	0.151	(0.44)
Switching from Windows OS to other			-0.117	(0.51)	-0.108	(0.51)
SD						
Apple					-0.185	(0.27)
BlackBerry					0.750***	(0.18)
HTC					1.192***	(0.25)
LG					-1.265***	(0.22)
Nokia					1.172***	(0.14)
Samsung					0.576***	(0.12)
Sony					1.400***	(0.21)
Sony Ericsson					1.393***	(0.28)
Android Os					0.554***	(0.14)
Windows Os					0.282	(0.27)
Observations	6169592		6169592		6169592	
Log Likelihood	-30062.6		-29996;5		-29909.5	

The sign of the estimated standard deviations is irrelevant: interpret them as being positive

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure C.5 – Estimated switching costs between operating systems (in terms of WTP)

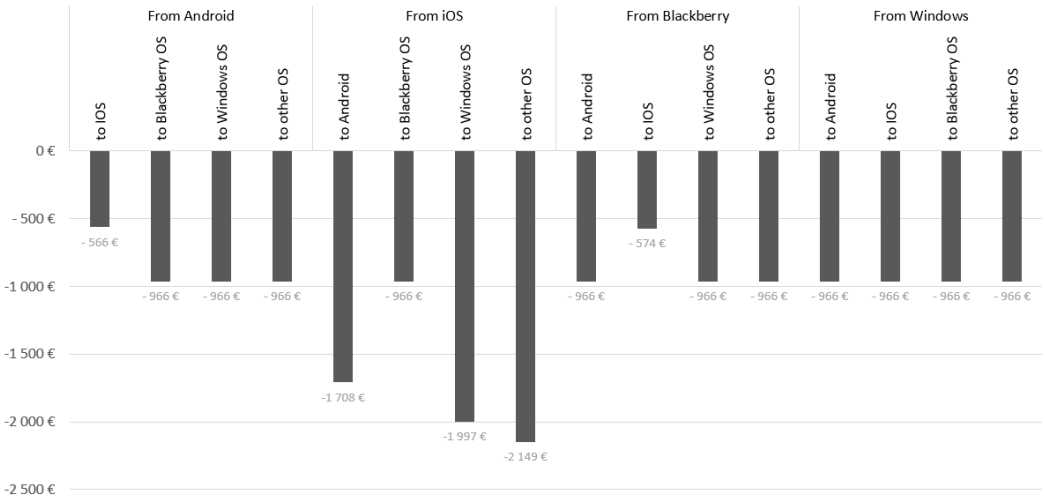


Figure C.6 – Simulation results for iOS in December 2014

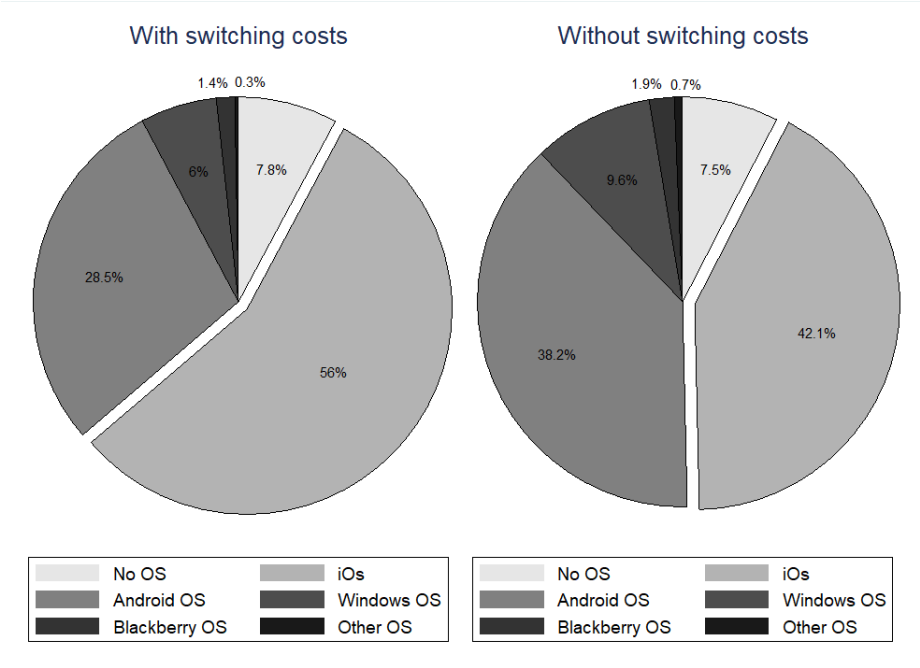
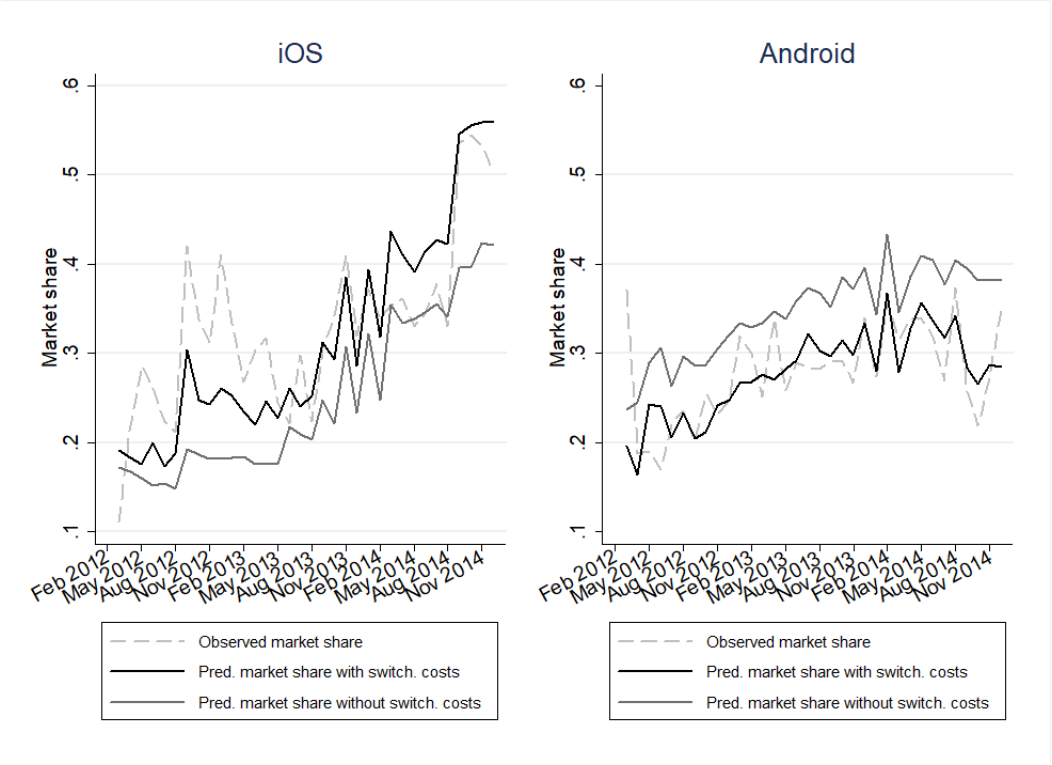


Figure C.7 – Simulation results for iOS and Android between March 2012 and December 2014



General conclusion

This thesis aims to contribute to the understanding of mobile telecommunications markets, on demand and supply sides. In this general conclusion, we recap the main results and their policy implications. Then, we discuss limitations of this work and potential future research.

The first chapter investigates the role of competition, introduction of a novel technology and regulation on mobile tariffs prices. In a first step, we use a hedonic price regression which allows to isolate the quality-adjusted prices. In a second step, we relate the evolution of these quality-adjusted price to changes in the market structure, introduction of 4G by the firms and its competitors and evolution of regulated wholesale prices. First, we show that introduction of 4G by Orange is the major determinant for price decrease. Then, we highlight that competition is also responsible for a large part of the observed price price. To finish, we provide evidence of regulation also having an impact but marginal. Policy implications derived from these results are first that the introduction of a novel technology may contributes significantly to the price decrease. Comparison with results from baskets used by ARCEP and OECD highlights that our methodology based on hedonic price regression offers a more detailed picture of the evolution of price, and especially captures the impact of introduction of 4G, which is missed by the baskets. Consequently, the methodology of baskets may not be valid, in particular in a market with regular innovation and quality improvement such as the mobile market.

The second chapter explores the question of consumer myopia in a novel set-up, namely individual's choice of handset and tariff. In a first step, we estimate demand for a combination of mobile tariffs and handsets using a discrete choice model. In a second step, we compute Allcott and Wozny (2014)'s attention weight to assess the level of consumer myopia for each

quarter between 2011 and 2014. We find that it increases significantly, from an average value of 0.3 for the second quarter of 2011 -which can be interpreted as a relatively high level of myopia- to an attention weight of between 0.7 and 0.8 in 2014, which is a much more modest level of myopia. We relate this myopia decline to the context of intense competition in the market and the increased differentiation of tariffs, in particular the growing availability of sim-only tariffs. This study offers a measure of one of the potential sources of detriment listed by the European Commission (2007) based on observed data. It also shows that innovation in the design of tariff, caused by the changes in market structure, have generally benefited to consumers.

The third chapter estimates consumer's inertia in choice of smartphone operating systems. Using individual-level data of consumers switching their handset, we are able to estimate switching costs between brands and operating systems. Our results suggest significant state dependance in individuals' choices and, in particular that it is harder for consumers to switch from iOS to Android and other operating systems than from Android and other operating systems to iOS. We then conduct simulation of our model without inertia. According to our counterfactual, as of December 2014, in the absence of switching costs the market share of iOS in our sample would drop from 56% to 42.1%. At the same time, the market share of Android would increase from 28.5% to 38.2%, with the smaller OS gaining market shares as well. We conclude that the market position of Android would be even stronger towards monopoly in the absence of switching costs between operating systems and brands.

The two main limitations of these studies are related to the data sample we use and to the assumption we make to model consumer's behavior. On the one hand, tariffs and handset prices we rely on are from a single operator, and, despite the good representativeness of these prices at the national level, we cannot exclude that differences may be observed. On the other hand, demand models we estimate rely on assumptions. In particular, we assume consumers are utility-maximizer and make decision based on a choice set which may not represent the complete set of alternatives they face. For example, in the framework of handset choice, individuals may consider second-hand devices, which are excluded from our analysis, because

of missing prices.

Changes in market structure and subsequent evolution in prices and design of tariffs have significantly affected consumer set of choices, as we described in the second chapter of the thesis. A relevant research question would be to assess how it impacted consumers' welfare. We discussed in the thesis how increased competition may drive prices down and encourage operators to introduce new forms of tariffs, such as the sim-only tariffs. One of the benefits of these tariffs is the possibility for consumers to replace their device less or, on the contrary, more frequently. In the case of France, sim-only tariffs also introduced more à la carte choices, with the possibility to unbundle unlimited voice and large data allowances which were traditionally bundled in tariffs. This may also results in gain of welfare. On the other hand, the increased variety and differentiation of tariffs may lead to consumers' confusion. Moreover, the introduction of mobile broadband in tariffs, which is relatively recent, may have reinforce the complexity of choice for consumers. Economic theory predicts consumers are able to converge, over time, towards a tariff which maximize their utility. Descriptive statistics on our sample shows this may not be the case as systematic differences between allowances and usages are observed. Several causes may be at play, on both demand and supply sides, and deserve to be disentangled.

The fifth generation of mobile networks is expected to bring significant gains in speed and quality of mobile services; how will prices be affected by this new technology? Will tariffs be redesigned by service providers? In particular, we may expect a quality differentiation of tariffs. What will be consumer's willingness to pay for incremental quality? How will competition be affected? Will the infrastructure-sharing pointed out as a potential revolution brought by 5G radically change the market structure? Compatibility of consumers devices will also be part of the challenges. Indeed consumers will probably have to upgrade their handsets to benefit from the 5G announced technological disruption. Will we witness a new golden age for handset subsidies? How will regulatory framework adapt? We can reasonably expect research questions investigated in this thesis being still relevant.

Résumés en Français

Résumé de la thèse

Cette thèse a pour objectif de contribuer à la compréhension des marchés de télécommunications mobiles, en offrant un éclairage sur la façon dont la structure de marché, les investissements technologiques des acteurs et la règlementation ont affectés les prix des services, mais également en mesurant l'ampleur de l'inertie et de myopie du consommateur dans un environnement en mutation rapide. Le premier chapitre explore les déterminants de la baisse des prix en France entre 2011 et 2014. Basée sur une régression prix hédoniques, cette étude montre que l'introduction d'une nouvelle technologie et la concurrence sont à l'origine de la majeure partie de cette baisse des prix. Le deuxième chapitre questionne la façon dont la disponibilité croissante des offres sans terminal associé -sim-only- a affecté l'arbitrage intertemporel des consommateurs lors de leurs choix de forfait et de mobile. En estimant un modèle de choix discret basé sur un ensemble de combinaisons de forfaits et de terminaux, il est possible de capturer une mesure de la myopie des consommateurs. Les résultats obtenus suggèrent que le niveau de myopie moyen a fortement diminué avec l'émergence des offres sim-only et converge vers une valeur proche de celles estimées pour des marchés différents, c'est-à-dire un niveau qui témoigne d'une sous-évaluation très modérée du futur. Le troisième chapitre propose une estimation de l'inertie des consommateurs lors de leurs choix de terminaux mobiles. En se basant sur un échantillon de consommateurs sim-only et en observant leurs choix de changement de terminal entre 2012 et 2014, un modèle de choix discret permet d'estimer les coûts de changement entre marques de terminaux mais aussi entre systèmes d'exploitation. Un

contrefactuel est ensuite réalisé pour simuler les parts de marchés de ces derniers en l'absence d'inertie des consommateurs. Celui-ci indique que la part de marché d'Android et celles des systèmes d'exploitation mineurs augmenteraient aux dépends de la part de marché d'IOS.

Résumé du Chapitre 1 : Impact de la concurrence, des investissements et de la réglementation sur le prix des services mobiles : le cas de la France

Dans cet article, nous évaluons l'impact de la concurrence, des investissements et de la réglementation sur le prix des services mobiles en France. Nous estimons une régression prix hédoniques à partir de données concernant les forfaits proposés par le principal opérateur de télécommunications mobiles en France entre mai 2011 et décembre 2014. Au cours de cette période, l'indice des prix ajusté par la qualité a diminué d'environ 42,8% alors que l'indice sans ajustement par la qualité n'enregistre qu'une baisse de 8,7 %. Dans un deuxième temps, nous cherchons à faire le lien entre l'évolution de l'indice de prix ajusté par la qualité et un ensemble de variables qui capturent les évolution des investissements, de la règlementation et du contexte concurrentiel. Nous constatons que le lancement des réseaux 4G par les opérateurs mobiles a été le principal facteur responsable de la réduction des prix des forfaits classiques avec engagement. Les prix des forfaits « bon marché » sans engagement, lancés pour anticiper l'arrivée d'un nouveau concurrent sur le marché, ont également diminué à son arrivée. De plus, nous montrons que la réglementation, ici représentée par le niveau des terminaisons d'appel mobile et les plafonds tarifaires de l'itinérance internationale pour la voix et les données, a un impact considérable sur les prix ajustés par la qualité. En termes de pourcentage, la concurrence est responsable d'environ 23,4% de la baisse totale des prix, contre 56,1% pour les investissements dans la 4G. Nous concluons que la réduction des prix ajustés par la qualité au cours des dernières années est principalement imputable à la concurrence entre les opérateurs pour une nouvelle technologie 4G et à l'arrivée d'un quatrième opérateur ayant une stratégie basée sur des forfaits "bon marchés".

Résumé du Chapitre 2 : Les consommateurs sont-ils myopes ? Étude sur les choix de terminaux et services mobiles

Cette étude repose sur l'estimation d'un modèle de choix discret composé de combinaisons de forfaits et terminaux mobiles, basé sur des données en coupe de 16 743 abonnés d'un opérateur de télécommunications européen, observés entre avril 2011 et décembre 2014. Les résultats de l'estimation permettent d'évaluer l'étendue de la myopie des consommateurs dans une configuration jamais encore explorée : l'arbitrage entre les dépenses courantes et futures effectué par les consommateurs qui choisissent terminal et forfait mobile. Cette étude permet de montrer que, en considérant les hypothèses sous-jacentes au modèle économétrique utilisé, la myopie des consommateurs a diminué de façon significative, parallèlement à la disponibilité et l'adoption grandissante des offres sim-only. Cette valeur semble se stabiliser autour d'une valeur proche de celle estimées sur des données d'autres marchés. Cela semble indiquer qu'en moyenne les individus tendent à arbitrer correctement entre dépenses présentes et futures s'ils ont à leur disposition des alternatives qui leur permettent de faire de tels choix. Ces conditions ont émergé sur le marché que nous considérons, notamment suite à des changements structurels importants, qui ont menés à une plus grande concurrence sur les prix et à une plus grande différentiation des produits.

Résumé du Chapitre 3: Estimation de l'inertie des consommateurs dans une situation de choix répétés de smartphones

Dans cet article, nous utilisons une base de données unique concernant les changements de terminaux mobile d'un échantillon de 5 000 abonnés ayant souscrit à une offre sans engagement d'un opérateur mobile européen. Nous observons ces abonnés mensuellement, entre mars 2012 et décembre 2014. Nous estimons un modèle de choix discret dans lequel nous prenons en compte la perte d'utilité générée par le changement de système d'exploitation et de marque de terminal mais aussi pour l'hétérogénéité non-observées et persistante dans le temps des préférences pour les systèmes d'exploitation et les marques. Nos résultats indiquent la présence d'une dépendance d'état significative dans les choix de systèmes d'exploitation et

de marque. Nous mettons en lumière qu'il est plus difficile, en moyenne, de passer du système d'exploitation iOS vers Android et les autres systèmes que d'Android et autres systèmes vers ios. De plus, nous montrons qu'il existe une hétérogénéité des préférences pour les systèmes d'exploitation et les marques significative, qui contribue à la dépendance d'état des choix que nous observons. Nous utilisons notre modèle pour simuler les parts de marché en l'absence de coûts de changement et nous montrons que la part de marché d'Android et des systèmes d'exploitations marginaux augmenterait aux dépends de la part de marché d'ios.

RÉSUMÉ DE LA THÈSE EN FRANÇAIS

Cette thèse a pour objectif de contribuer à la compréhension des marchés de télécommunications mobiles, en offrant un éclairage sur la façon dont la structure de marché, les investissements technologiques des acteurs et la règlementation ont affecté les prix des services, mais également en mesurant l'ampleur de l'inertie et de myopie du consommateur dans un environnement en mutation rapide. Le premier chapitre explore les déterminants de la baisse des prix en France entre 2011 et 2014. Basée sur une régression prix hédoniques, cette étude montre que l'introduction d'une nouvelle technologie et la concurrence sont à l'origine de la majeure partie de cette baisse des prix. Le deuxième chapitre questionne la façon dont la disponibilité croissante des offres sans terminal associé -*sim-only*- a affecté l'arbitrage intertemporel des consommateurs lors de leurs choix de forfait et de mobile. En estimant un modèle de choix discret basé sur un ensemble de combinaisons de forfaits et de terminaux, il est possible de capturer une mesure de la myopie des consommateurs. Les résultats obtenus suggèrent que le niveau de myopie moyen a fortement diminué avec l'émergence des offres *sim-only* et converge vers une valeur proche de celles estimées pour des marchés différents, c'est-à-dire un niveau qui témoigne d'une sous-évaluation très modérée du futur. Le troisième chapitre propose une estimation de l'inertie des consommateurs lors de leurs choix de terminaux mobiles. En se basant sur un échantillon de consommateurs *sim-only* et en observant leurs choix de changement de terminal entre 2012 et 2014, un modèle de choix discret permet d'estimer les coûts de changement entre marques de terminaux mais aussi entre systèmes d'exploitation. Un contrefactuel est ensuite réalisé pour simuler les parts de marchés de ces derniers en l'absence d'inertie des consommateurs. Celui-ci indique que la part de marché d'Android et celles des systèmes d'exploitation mineurs augmenteraient aux dépends de la part de marché d'IOS.

RÉSUMÉ DE LA THÈSE EN ANGLAIS

This thesis aims to contribute to the understanding of mobile telecommunication markets, in exploring how structure, technological investments of players and regulation have affected prices of services; but also in measuring the magnitude of consumer inertia and myopia in a rapidly evolving environment. The first chapter investigates determinants of mobile services price drop in France between 2011 and 2014. Based on a hedonic price regression, this study provides evidence of introduction of a new technology and competition being responsible for most of the price reduction. The second chapter questions how inter-temporal trade-off of consumers selecting a handset and a tariff has been affected by the increasing availability of sim-only contracts. Estimating a discrete choice model based on choice sets which combine extensive number of tariffs and handsets, it is possible to capture an average level of consumer's myopia. Results show myopia decreased along with emergence of sim-only contracts and converge towards a value which is close to what has been estimated in other markets, meaning consumers only exhibit a modest undervaluation of future. The third chapter measures the magnitude inertia in repeated choice of smartphones. Exploiting data of handset switchings between 2012 and 2014 of sim-only consumers, we estimate discrete choice models to estimate switching costs between brands and operating systems. We then rely on our model to simulate market shares without inertia and show that the market share of Android and smaller operating systems would increase at the expense of the market share of iOS.