IMPACT OF COMPETITION, INVESTMENT, AND REGULATION ON PRICES OF MOBILE SERVICES: EVIDENCE FROM FRANCE

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Impact of competition, investment and regulation on prices of mobile services: Evidence from France *

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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 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.

Key Words: *Mobile telecommunications; hedonic price regression; regulation; investments; entry*

JEL Classification: L13, L50, L96

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.[1] 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 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.[2] 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

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

[2] 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.

mobile technologies and increased popularity of bundled offers affect prices and draw attention of the policy makers.[3]

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[4]. 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 tariff plans offered by the leading mobile telecommunications operator in France, Orange, on monthly basis between May 2011 and December 2014.[5] 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,

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[3]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.

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

[5]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.

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 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.[6]

Among studies on the impact of regulation on prices of telecommunications services, 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,[7] which they call the "waterbed" effect.[8] 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

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[6]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).

[7]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.

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

of the industry, whereby mobile-to-mobile traffic surpassed fixed-to-mobile traffic.[9] 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 2 discusses the main changes in mobile telecommunications industry in France. Section 3 presents the data used in the estimation. Section 4 introduces the econometric framework. Section 5 presents the estimation results. Finally, Section 6 concludes.

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,

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[9]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).

except for a number of entries and exits of MVNOs.[10] 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 pre-empt 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 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.[11] 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 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

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[10]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.

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

Figure 1: Timeline of deployment of 4G services in France
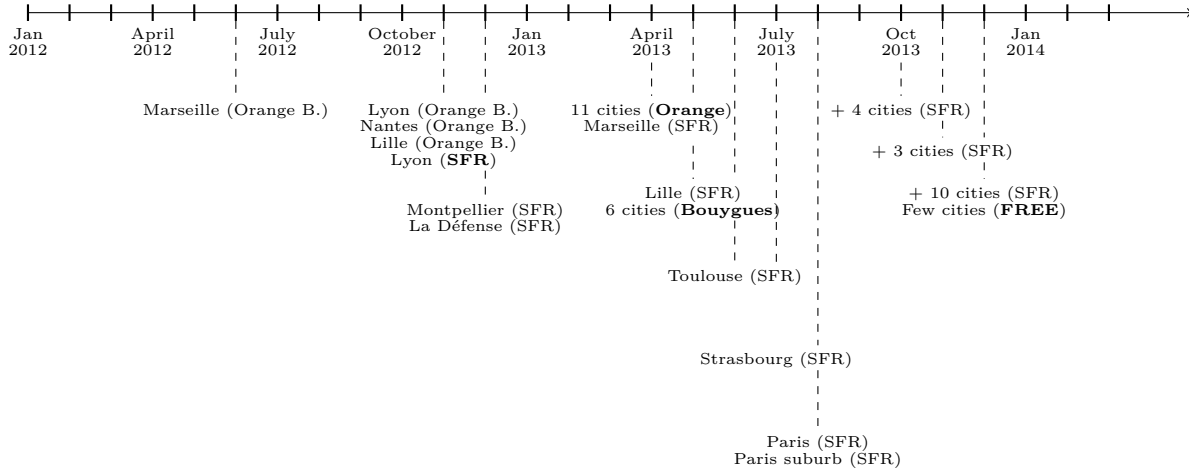
'Orange B.' denotes Orange Business offers. The bold text denotes the date of official launch of commercial 4G services by each operator.

roaming charges by the European Commission, impacted quality-adjusted prices.[12] 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 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).[13] As shown in

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[12]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.

[13]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

Figure 2, the M2M termination rates declined over time.

Figure 2: Mobile-to-mobile termination rates in France
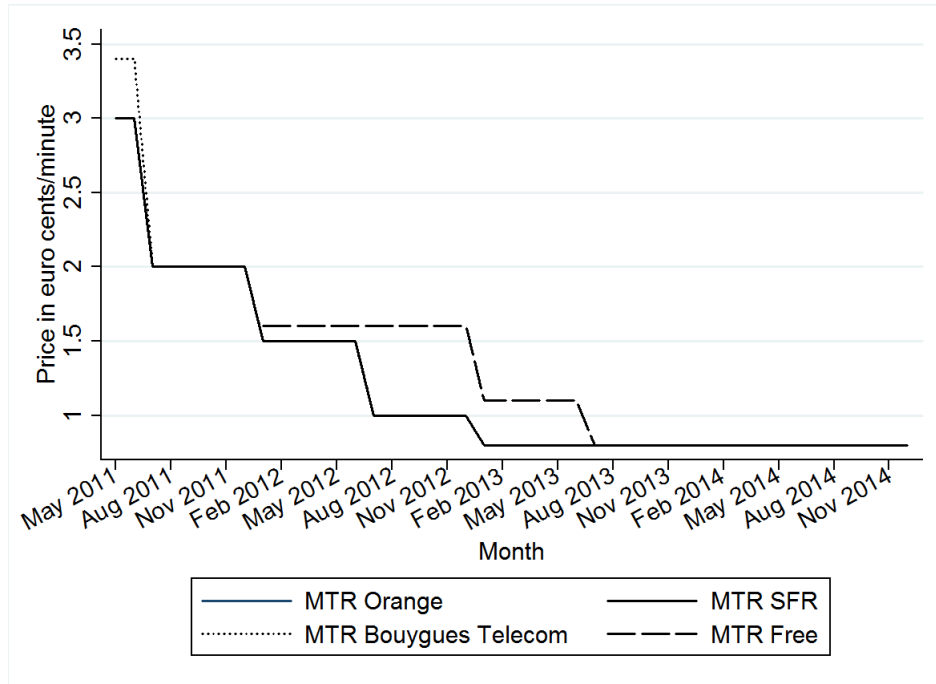
Source: ARCEP

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 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.

for Industry, Competition and Consumers (07/05/2009)".

Figure 3: Euro-tariffs and wholesale roaming price caps in the EU
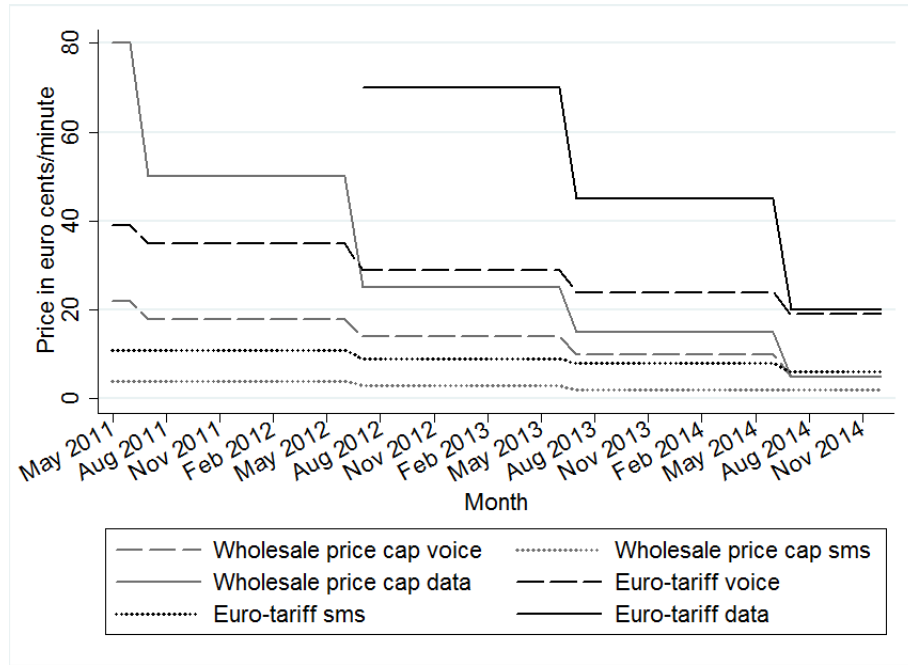
Source: European Commission

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.[14] Even though we use price information for a single firm, we can demonstrate that our price index is representative for the whole industry.[15]

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)

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[14]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.

[15]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.

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 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.

Table 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.

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 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.

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:

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

where y_{it} denotes the list price in Euros of tariff i which was available in month t.[16] 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 contract;[17] (viii) a dummy variable for a discount of 5 Euros for 3G tariffs at the time of launching 4G tariffs.[18]

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.[19]

In a next step, we regress the quality-adjusted price index δ_t on a set of competition, invest-

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

[17]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.

[18]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.

[19]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.

ment and regulation variables:

$$\delta_t = \gamma + Z_t\eta + R_t\lambda + \varepsilon_t \tag{2}$$

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.

5   Estimation Results

We show our estimation results in two parts. We start with the estimation results of the hedonic price equation (1) in Subsection 5.1 and then provide the estimation results of the quality-adjusted price equation (2) in Subsection 5.2. Finally in Subsection 5.4, we compare our results to other price indices which are constructed using the consumer usage basket methodology. These indices are commonly used by the OECD, European Commission and national regulators including ARCEP in France.

5.1   Hedonic Price Regressions

Table 2 shows the estimation results for the hedonic price equation (1) based on all tariffs using OLS in column (1) and WLS in column (2).[20] 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

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[20]The estimates of 44 monthly dummy variables for these two regressions are shown in Table A.1 in the Appendix A due to space constraints.

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.[21] 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 selected tariffs.

We plot the estimated coefficients of the monthly dummy variables for both OLS and WLS regressions in Figure 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.[22] 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.

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

[22]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.

Table 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 steaming	-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.

We notice that prices seem to react with 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.

Figure 4: Monthly coefficients (+ weighted average price in May 2011) for all tariffs
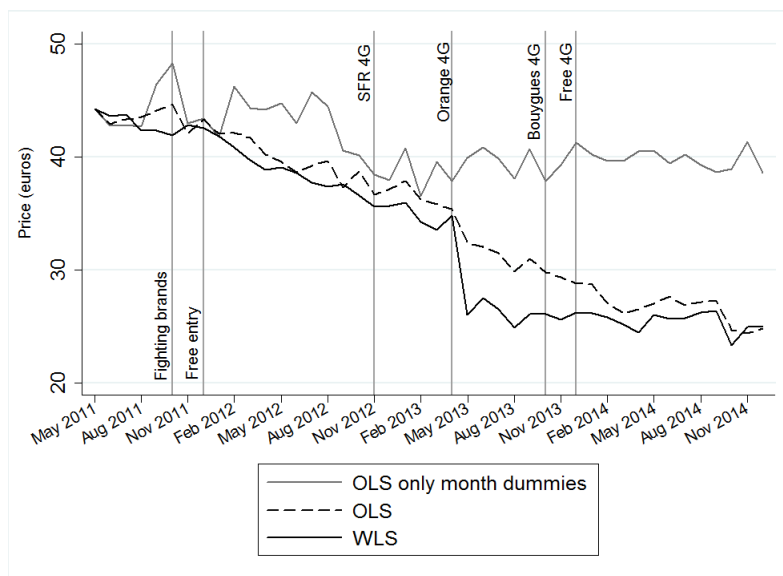
Note: The weighted average price of all tariffs in May 2011 was 44.2€.

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 3 shows the estimation results based on WLS.[23] 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 5 shows 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

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[23]Again, due to space constraints we show the estimated coefficients of monthly dummy variables for these regressions in Table A.2 in the Appendix A.

Table 3: Hedonic price regressions for classic and low-cost tariffs (WLS)

	(1)		(2)	
	Classic tariffs		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 steaming	-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.

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.

Figure 5: Monthly coefficients (+ weighted average price in the first period) for classic and low-cost tariffs
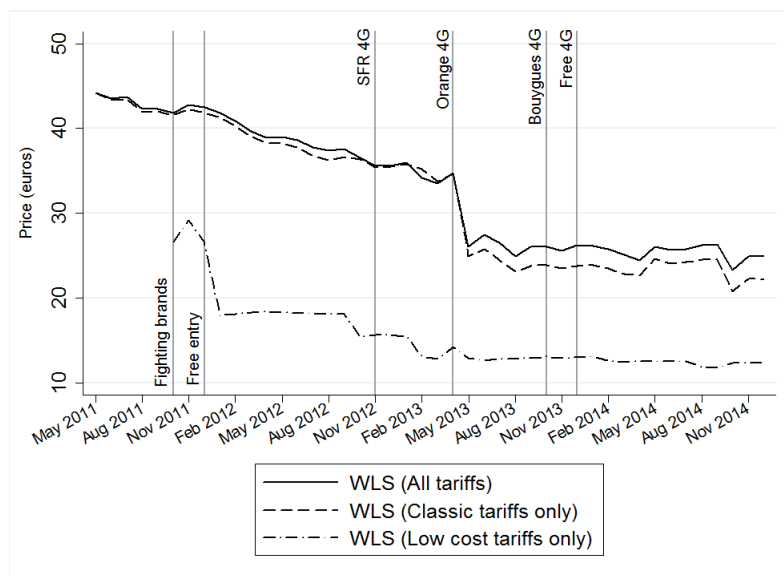
Note: The weighted average price of tariffs in May 2011 was 44.2€. The weighted average price of low-cost tariffs was 26.6€ in October 2011

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.1 and then the estimates which we obtain from the separate regressions for classic and low-cost tariffs from Table A.2 in the Appendix A. 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 and wholesale roaming

price caps for voice and data. As shown in Figures (2) and (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.[24] 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 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 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

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

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 lunch 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.[25]

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 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

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[25]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.

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%.[26]

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 ic 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.

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.3 in Appendix A. 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 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 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.

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[26]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 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
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 6: Monthly coefficients for year-by-year regressions (+ average weighted price in the first month for all tariffs
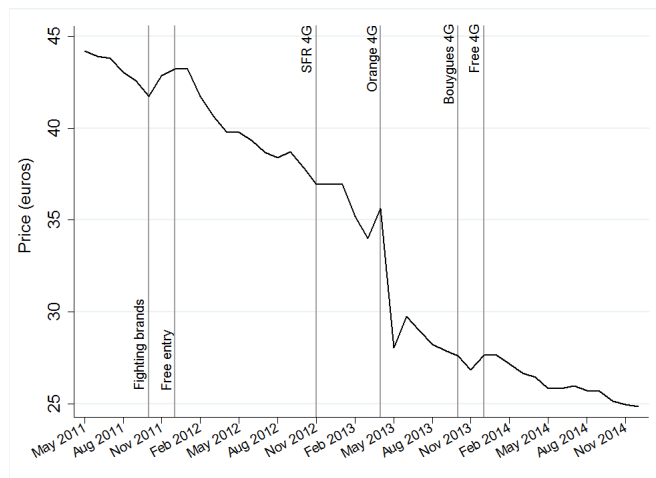
Note: The average weighted price of all tariffs in May 2011 was 44.2€.

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 C.1 in the Appendix B 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.[27]

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[27]Figures (C.1) and (C.2) in the Appendix B 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 (C.3) and (C.4) also in the Appendix B show analogous price indices for OECD baskets.

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

To compare the baskets approach with our quality-adjusted price indices, we now regress selected OECD and ARCEP baskets on competition, investment and regulation variables. The estimation results are shown in Table 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.

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 responsible

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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A   Appendix: Hedonic Price Regressions

Table A.1: 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 steaming	-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

Discount for 3G tariffs was introduced when 4G tariffs were launched

Table A.2: 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 steaming	-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	

There are only 39 periods of observation for low-costs tariffs as there were introduced in October 2011

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.3: 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 line								
Quadruple Play with BB	22.61***	(3.43)	22.68***	(2.03)	26.57***	(1.15)	25.56***	(1.29)
Quadruple Play with Fiber	22.17***	(4.70)	26.12***	(1.65)	31.73***	(1.43)	28.11***	(1.95)
Voice								
Voice allowance if not unlimited	0.11***	(0.02)	0.09***	(0.02)	0.09***	(0.02)	0.05**	(0.02)
Dummy for unlimited calls (nat.)	53.08***	(5.43)	23.32***	(2.52)	18.66***	(2.68)	14.15***	(1.84)
Dummy for 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)
Dummy for fixed price contract	-10.24***	(1.69)	-7.74**	(2.81)	-3.85*	(1.54)	-1.79	(1.51)
Dummy for music steaming	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

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

B Comparison with ARCEP and OECD Baskets

Table C.1: 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 C.1: Price of lowest-cost tariff for ARCEP baskets
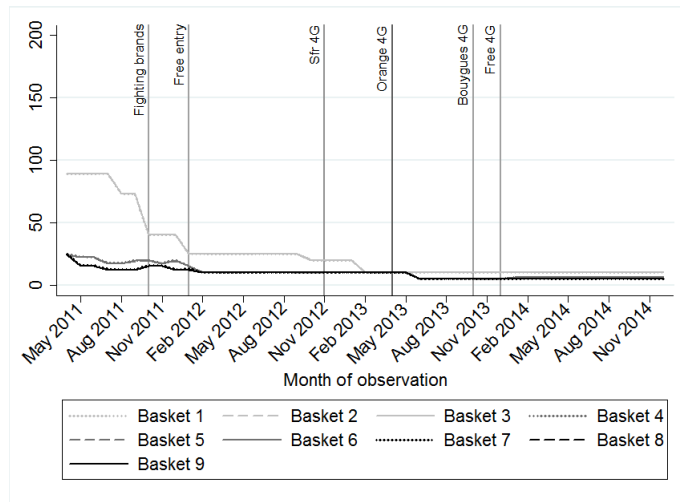

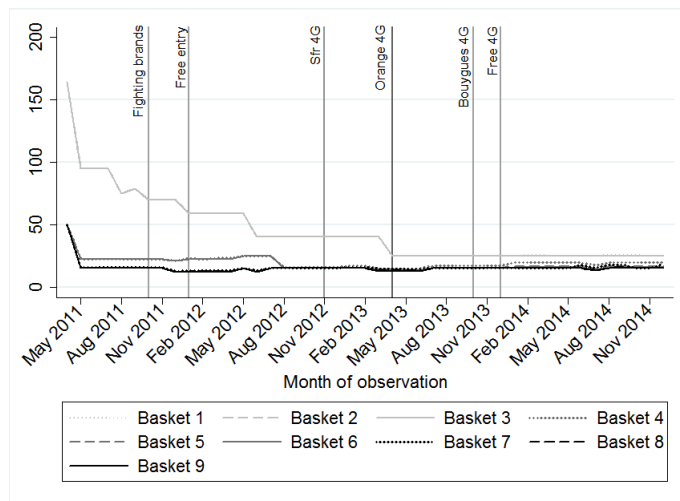Figure C.2: Price of lowest-cost tariff with handset subsidy for ARCEP baskets

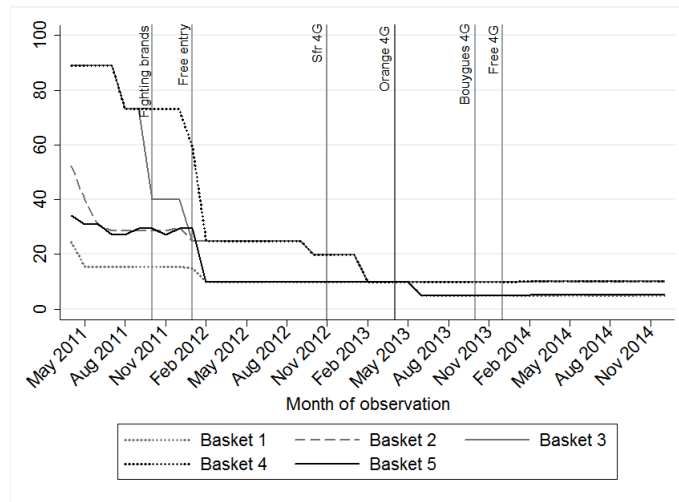Figure C.3: Price of lowest-cost tariff for OECD baskets

Figure C.4: Price of lowest-cost tariff with handset subsidy for OECD baskets