The Effects of Market Concentration on the Price of Wireless Communications Services*

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Abstract

In a dynamic framework where firms invest in cost-reducing innovation, price would fall with market concentration if the magnitude of the dynamic efficiencies outweighed the static's one. In this paper, I test whether this prediction holds in the wireless markets where the dynamic efficiencies might be significant, particularly for wireless data. The empirical test exploits the change in the market concentration induced by the entry of a fourth wireless operator in France, and the merger between the third and the fourth wireless operators in Austria. Using a hedonic price model and a matching estimation, I find that the price per Gigabyte of wireless data more than doubles with the entry in France; but decreases by 19% with the merger in Austria. The reverse holds for the price per hour of wireless voice. These results suggest a tradeoff between static efficiencies, in favor of wireless voice, and dynamic efficiencies, in favor of wireless data.

Keywords: Dynamic efficiencies, Merger Evaluation, Hedonic Model, Nearest-Neighbor Matching, Wireless Communications.

JEL Classification: D43, L11, L13.

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1 Introduction

Static models of industrial organization predict that more competition decreases prices. However, in a dynamic framework where firms invest in cost-reducing technologies, a rise in competition may end up increasing prices if the magnitude of the dynamic efficiencies is larger than the static's one. This outcome typically emerges when the investment in cost-reducing technologies decreases with the market concentration as emphasized by Schumpeter (1942) and formally proven by Vives (2008).

In the wireless industry, the dynamic efficiencies stem from the investment in the network infrastructure and translate into a subsequent fall in the marginal cost of production. For instance, the provision of an additional Gigabyte of wireless data requires investment in order to avoid network congestion. The cost of this investment falls regularly due to the technological progress.[1] The static efficiencies, on the other hand, stem from the reduction of firms' market power or the costs related to their physical distribution shops.

Both types of efficiencies are affected by the intensity of competition, which is strongly determined by government intervention on the market concentration. This intervention raises the question as to what extent the change in the market concentration affects the price of wireless communications services in the short and the long run. This question is currently at the heart of the policy debate in Europe, regarding whether mergers from four to three wireless operators should be cleared.[2]

This paper aims at contributing to this debate by testing the significance of the dynamic efficiencies in the wireless industry. In particular, it evaluates the impact of market concentration on the price of wireless communications services. The evaluation takes advantage of the change in the market concentration induced by the entry of the fourth wireless operator in France and the merger between the third and the fourth largest wireless operators in Austria. It relies on a detailed tariff database which allows to distinguish between voice telephony, a mature technology, and wireless data, a service driven by a strong technological progress (Amaya & Magee, 2008).

The tariff dataset provides information about the price and the characteristics of

[1] According to estimates by Amaya & Magee (2008), the cost of investment in wireless data services halves every year.

[2] On the one hand, a report by the OECD recommends that increasing the number of wireless operators would lowers prices and raises investment (OECD, 2014). On the other hand, another report by the GSMA suggests the contrary (Bohlin *et al.* , 2013).

each wireless plan in 40 national wireless markets between the first quarter of 2013 and the third quarter of 2014. Unfortunately, the price data before the change in the market structure was not available. I therefore employ a matching estimation following Szucs (2014) and similar to the "yardstick approach" used in the quantification of antitrust damages.[3]

The information about the characteristic of the plan is useful to make the distinction between the price of voice and data communications when both services are sold in package. It is also useful to estimate the actual price attached to each attributes of a plan. I exploit these features of the dataset by estimating a hedonic price model following Griliches (1961) and Karamti & Grzybowski (2010). The design of the hedonic price model assumes that the observed monthly tariff can be represented by a two-part tariff, on top of a bundling discount or premium. Thus, the hedonic price model identifies the parameters of the mobile tariff, namely the stand-alone access price, the price per unit, as well as their corresponding bundling discounts. It compares the slope of the tariff parameters between the treated market and the matches.

It turns out that the impact of the change in the market concentration in France and Austria is consistent with the prediction of the static models for voice communication services, a mature technology for which less dynamic efficiencies are expected. More precisely, the price of voice services declines with the entry in France ; but rises with the merger in Austria. On the contrary, the impact of the change in the market concentration on the price of wireless data suggests that the magnitude of the dynamic efficiencies may be larger than the static efficiencies for data communications. As a matter of fact, the entry of the fourth wireless operator in the French market has raised the access price as well as the price per Gigabyte of wireless data. Meanwhile, the merger in Austria has lowered the access price as well as the price per Gigabyte of wireless data.

These results provide an empirical contribution to the literature on the effect of competition in a dynamic environment. As in Schmutzler (2013), much of this literature deals with the impact of competition on investment. This paper makes a step further by testing directly the significance of the dynamic efficiencies in the wireless industries. There is an emerging strand of the literature which endogenizes the dynamic efficiencies in structural models of merger analysis as in Coublucq *et al.* (2013). However, this paper is much closer to Seim & Viard (2011) which evaluates

[3]See for instance Friederiszick & Roller (2010) and van Dijk & Verboven (2007) for a presentation of this approach along others.

the impact of entry in the US market on the prices of wireless communications services between 1996 and 1998, a period over which no wireless data services were commercialized. Thus, it also finds that entry has lowered the price of wireless voice services. By making the assessment in presence of wireless data, this paper is able to highlight the fact that dynamic efficiencies might largely surpass static efficiencies for wireless data.

The rest of the paper is organized as follow. Section 2 presents some background information about the entry, the merger and the specific features of the mobile telecoms industry that could explain the findings of this paper. Section 3 lays out the empirical strategy, particularly the description of the dataset and the formalization of the matching estimation. Section 5 presents and discusses the results along with some robustness checks. Section 6 concludes.

2 Background Information

2.1 Innovation and nonlinear pricing in the wireless industry

The wireless industry is characterized by significant rate of technological progress. This feature makes it particularly suitable to test the dynamic efficiencies over a relatively short period. According to Koh & Magee (2006), the annual rate of technological progress in the transmission of information was 35 percent between 1940 and 2006. This is far greater than the annual rate of technological progress in energy transportation (13.2 percent) (Koh & Magee, 2008). Every year, equipment providers innovate and release new technologies of mobile telecommunications networks. The adoption of these new technologies by wireless operators reduces their marginal cost of production due to the reduction of the cost of the equipment, as a result of the technological progress.

This technological progress drives the type of tariffs proposed by wireless operators. Historically, mobile telecommunications services mainly consist of the supply of voice services, including short or multimedia messages services. These services can be purchased under a prepaid or a postpaid contract. Under a prepaid contract, the customer typically pays for an allowance of voice before consuming. The set of prepaid contracts proposed by a firm is equivalent to a menu of pairs of quantity and tariff, without any loyalty commitment required from the customer. Under a postpaid contract, the customer pays a tariff periodically (monthly in general)

for a given allowance, with a minimum duration of commitment for loyalty. Some postpaid plans include unlimited voice or data services, sold separately (standalone) or in package (bundle). For mobile plans with limited voice allowance, the customer pays a price per unit to use the service in excess of the initial allowance. Because of these features, the tariff structure of a mobile plan is in general considered as a three-part tariff (Lambrecht *et al.* , 2007). The first part is an access price meant to recover the fixed cost of investment or to extract consumer surplus. The second part corresponds to the usage allowance and the third part is a variable price charged for every additional unit of the service consumed in excess of the allowance.

More recently, innovations in new generations of wireless networks, notably the third and the fourth generations (3G and 4G), have spurred the supply and demand for mobile data services. For instance, the share of mobile data in the revenue of Western European wireless operators has tripled from 15% in 2007 to almost 45% in 2013. This emergence of mobile data services has been accompanied by the bundling of both mobile voice and data services. As of the first quarter of 2014, half of the European Union mobile users purchase voice and data services in bundle (E-communications surveys N^0 414).

On top of these features, a postpaid mobile contract may also include several add-ons such as a subsidy for the handset, a premium quality services for business customers, international roaming services, and inter-temporal discount. Overall, this complexity of mobile tariffs makes it difficult to compare average price across firms or markets. The OECD has developed a methodology to account for this complexity (OECD, 2012). It involves the construction of a set of usage baskets that represent consumers' profiles. Then the price comparison across time and space is made by holding the basket fixed, thus controlling for the characteristics of the plans. However, even though the basket is regularly revised to account for the change in the characteristics of the new plans, the comparison still fails to incorporate the evolution of the allowances.

2.2 The changes in the market concentration: Entry in France and merger in Austria

Entry into the wireless market strongly depends on the allocation of radio frequency bands by the regulator. In the French market, three mobile network operators (MNO) were active in the early 2000s. Then, the regulator proposed four packages of frequency bands dedicated to the provision of the third generation of mobile network

(3G) in order to accommodate a fourth entrant. However, only the incumbent MNOs compete for the licenses, leaving one package unsold. As of December 2009, *Free*, a fixed broadband network operator, won the fourth license for the provision of wireless communications services based on the 3G.[4] Meanwhile, the other three MNOs also won additional frequency licenses for the provision of the 2G and 3G mobile network technology, conditionally on providing access to their network to *Free*. Additional frequency licenses were granted to the four MNOs in September 2011 and in January 2012. The fourth MNO, *Free* began supplying its commercial services in January 2012.

Following its entry, *Free* offered two mobile plans with no handset subsidy (SIM-Only), one for 2 euros including 1 hour of voice calls, the other for 20 euros including unlimited voice calls and 3 Gigabytes of data. The 2 euros plan was then the cheapest in the market, leading to a substantial switching of the customers from the incumbent wireless operators. Some weeks prior to the entry, the incumbent MNOs released comparable mobile plans but their prices remain slightly higher than the cheapest plan of *Free*. Three years later, the voice allowance of the 2 euros mobile plan rises by 1 hour and includes 50 Megabytes of data. The 20 euros plan remains with the same allowances although the customer can now have access to the fourth generation of mobile network (4G) which supports faster download and upload speeds. The new entrant also offers bundling discounts for its fixed broadband customers.

In the Austrian market, Hutchison, the fourth operator in terms of subscribers market share, acquired Orange, the third operator, in December 2012, following a notification to the European Commission (EC) in May 2012. This notification underwent a thorough review by the EC, after which the clearing was made under the conditions that Hutchison divests its radio spectrum to a potential new entrant and provides wholesale access for mobile virtual network operators (MVNOs). The MVNOs typically target specific segment of the market, for instance low-valuation consumers. In the aftermath of the merger, the newly formed operator *Hutchison Drei Austria* maintained the lowest tariff previously proposed by Orange. Two years later, it removes this cheapest plan from its offers.

[4]Note that the entry of the fourth wireless operator was strongly supported by the regulators as they substantially lessen the conditions of entry: reduced price of 3G license, obligation from the incumbents to provide nation-wide roaming for voice telephony services, and a formal warning from the competition authority that it would enforce a binding roaming agreement if no commercial roaming offer were proposed to the new entrant. In addition, the circumstances were favorable to the new entrant as the mobile number portability already exists, reducing the customers' switching cost, and as the regulated mobile termination rate was also the lowest in Western Europe.

The figure below presents the evolution of the Herfindahl-Hirschman Index (HHI) in France and Austria. The market concentration index (HHI) drops by 800 units within the three years following the entry of the fourth operator in France. This fall is rather significant compared to the overall decline by 66 units over 6 years before the entry. In Austria, the merger has led to a jump of the HHI by 500 units.

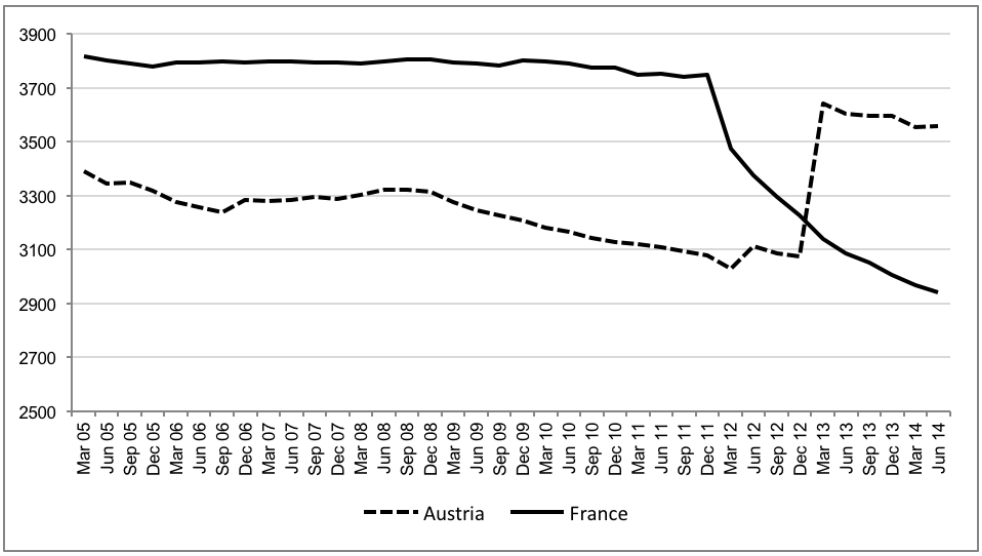

Figure 1: Herfindahl-Hirschman Index of market concentration

Source: Own's graphical representation using estimates from the Wireless Intelligence Database, GSMA.

Note: The sum of the squares of market share by connections for all MNOs in a market. The number of connections is typically larger than the number of subscribers in the sense that one subscriber can have several connections (SIM cards).

3 Data and descriptive statistics

The empirical framework relies on a detailed tariff dataset which allows identifying the parameters of the tariffs through a hedonic price model. The causal identification of the impact of the change in the market concentration on price uses a matching estimator. The details of the empirical test are provided in the following sections.

3.1 Description of the tariff dataset

I build a new dataset on mobile plans using information from various sources including the Teligen price benchmarking and the Wireless Intelligence databases.[5] The Teligen database is a key input in the cross-country comparison of telecommunications prices endorsed by the OECD and the European Commission.[6] It covers the OECD member States including 6 non-OECD countries. It provides quarterly information about the characteristics of each wireless plan. The information about the characteristic of the plan is important for two reasons. Firstly, they are useful to make the distinction between the price of voice and data communications when both services are sold in bundles. Secondly, they allow the estimation of the price per unit of each service; thus accounting for the dynamic efficiencies which typically work through the allowance included in each plan.

However, the plan is collected from the largest wireless operators that made up at least 50% of the market size. As a result, the plans proposed by the new entrants are generally not available in the database. The outcome of the estimation will strictly be valid for the two largest incumbent operators. To the extent that these operators are less sensitive to the competition than the smallest, I will underestimate the impact of the market structure on the average price in the market. The size of this underestimation depends on the segmentation of the market among operators. However, this is not the case from a supply side point of view, for the spectrum of mobile plans proposed by the largest operators includes the ones proposed by the smallest firms.

The Teligen database provides information about both fixed and wireless plans; but the estimation will be made on the wireless plans, as the change in the market concentration only occurs on the wireless market.[7] The information provided by the Teligen database allows the distinction of three types of wireless plans, namely postpaid, prepaid and pay-as-you-go.

The pay-as-you-go plans cannot be used in the estimation as they do not provide any information about the voice or data allowance. Regarding the prepaid plans, they are not representative of the pricing and consumption of a given consumer as

[5]The Teligen database is compiled by Strategy-Analytics and the Wireless Intelligence database is compiled by the GSMA. These are proprietary data purchased by Orange Group. I am grateful to Orange for having provided access to these databases.

[6]See for instance the OECD Communication Outlook.

[7]The change in the market concentration of the mobile market may also affect the pricing of the fixed telecommunications plans. A robustness check that includes the fixed telecommunications plans into the dataset finds no effect of the change in the mobile market structure on their pricing.

they can be purchased several times within a given period or consumed later after the purchase. For these reasons, the estimation relies upon postpaid plans. The omission of the prepaid plans is expected to underestimate the impact of market structure if prepaid consumers are more price sensitive than postpaid consumers. The other observed characteristics of a postpaid mobile plan are the monthly allowances, namely the number of minutes, the volume of data along with the download speed. Additional information includes the contract duration (in months), whether the plan is bundled with a mobile terminal and whether it is targeted to business or residential consumers.

The information on the market structure is retrieved from the Wireless Intelligence database managed by the GSMA.[8] This database provides the information on the wireless operators in each national market; in particular, their date of entry, merger or exit, if applicable.

The price is converted into the Q1-2013 US dollars purchasing power parity (PPP) to ensure the comparability across markets and quarters.[9] The voice and data allowances are expressed in hours and Gigabytes respectively. The unlimited voice and data plans have been converted into limited plans by imputing the following allowances for simplicity: 20 hours for unlimited standalone or bundled voice plan, 50 Go for unlimited standalone data plan and 15 Go for unlimited bundled plan. The results are not sensitive to these choices.

3.2 Descriptive statistics

Tables 1 and 2 below present the characteristics of the postpaid mobile plans in France and in Austria from the first quarter of 2013 to the third quarter of 2014. The three panels of each table present respectively the characteristics of standalone mobile voice, standalone mobile data and bundles of mobile voice and data plans.

In France, there is a downward trend in the price of standalone mobile voice plans, falling from 52 to 45 dollars.[10] Meanwhile, their voice allowance has remained flat around 9 hours on average. Taken together, these two observations imply that the

[8]The GSM Association is a consortium of most of the wireless operators worldwide.

[9]The purchasing power parity is an index that represents the relative price of the same basket of goods and services between two countries. The PPP index used in the estimation uses the US as reference and the basket was update in 2011. It is produced under the OECD-Eurostat Programme. See Eurostat-OECD (2012) for a detailed presentation of the calculations of the PPP.

[10]The high level of the average price is due to the preponderance of standalone mobile voice plans targeted to business customers.

price per hour of standalone mobile voice has fallen in France following the entry of the fourth wireless operator. Besides, there is an increase in the number of standalone mobile voice plans from 16 to 18. This increase stems from the introduction of new plans and the removal of old ones. The sample of tariffs is therefore affected by attrition and creation.

The price of the standalone mobile data plans has risen until the end of 2013 before declining afterwards. The allowance of mobile data follows a similar trend. There seems to be a gradual removal of expensive standalone mobile data plans particularly in the third quarter of 2014. Some of these plans include terminal equipment such as tablets, modems and dongles for access to the mobile broadband internet.

Regarding the bundled plans, their monthly prices were also declining from 45 to 32 dollars. On average, the voice allowance is larger in the bundles than in the standalone mobile voice plans. This is due to the importance of unlimited mobile voice plans in the bundles. On the other hand, the data allowance is much smaller in bundles than in standalone mobile data plans. This feature makes mobile data more expensive in bundles than in standalone plans. More importantly, the allowance has been falling over the period of observation, corresponding to a rise in the price per Gygabyte of mobile data in bundles. In addition, there is a general trend towards the introduction of more mobile bundles.

	Quarter	Q1-13	Q2-13	Q3-13	Q4-13	Q1-14	Q2-14	Q3-14
Voice	Monthly Price	52	49	47	47	47	45	45
	Hours included	8	8	8	8	8	9	9
	Number of plans	16	16	17	17	17	18	18
Data	Monthly Price	29	31	31	32	29	27	24
	Gigabytes included	13	13	15	14	6	6	6
	Number of plans	116	108	113	93	71	77	45
Bundle	Monthly Price	45	47	43	34	35	34	32
	Hours included	15	16	15	14	14	13	12
	Gigabytes included	13	16	12	3	4	3	3
	Number of plans	39	47	62	40	46	52	56

Table 1: Evolution of the characteristics of the average mobile plan in France

Note: Prices are expressed in constant 2013 US dollars PPP. Sample of the plans proposed by the two largest wireless operators. These plans may be bundled with fixed broadband, TV and fixed voice as bundles. Average estimates based on postpaid mobile plans. The unlimited voice and data plans have been converted into limited plans by imputing the following allowances for simplicity: 20 hours for unlimited standalone or bundled voice plan, 50 Gb for unlimited standalone data plan and 15 Gb for unlimited bundled plan.The standalone mobile data plans include dongles for tablets and mobile phones and USB wireless modem.

In Austria, the picture is quite different. There is rather a fall in the average price of standalone mobile voice plans from 27 to 11 dollars following the merger. However, the voice allowance has also fallen from 18 to 17 hours. This is due to the substantial removal of standalone voice plans and the introduction of more bundles. A similar trend is observed for mobile data in standalone. Regarding the bundles, their average price has increased from 21 to 31 dollars; but meanwhile there is also a rise in their allowance of voice and data.

	Quarter	Q1-13	Q2-13	Q3-13	Q4-13	Q1-14	Q2-14	Q3-14
Voice	Monthly Price		27	32	35	6	6	11
	Hours included		18	18	19	8	17	17
	Number of plans		7	10	10	1	1	1
Data	Monthly Price	25	25	25	26	25	24	23
	Gigabytes included	25	25	25	18	18	18	12
	Number of plans	16	16	16	18	18	18	23
Bundle	Monthly Price	21	16	15	17	26	29	31
	Hours included	16	15	17	18	19	20	20
	Gigabytes included	2	1	1	1	3	3	3
	Number of plans	13	4	5	11	20	18	18

Table 2: Evolution of the characteristics of the average mobile plan in Austria

Note: Prices are expressed in constant 2013 US dollars PPP. Sample of the plans proposed by the two largest wireless operators. These plans may be bundled with fixed broadband, TV and fixed voice as bundles. Average estimates based on postpaid mobile plans. The unlimited voice and data plans have been converted into limited plans by imputing the following allowances for simplicity: 20 hours for unlimited standalone or bundled voice plan, 50 Gb for unlimited standalone data plan and 15 Gb for unlimited bundled plan.The standalone mobile data plans include dongles for tablets and mobile phones and USB wireless modem.

An alternative way of assessing the change in the price of wireless service is to fix some baskets of usage profiles and examine the evolution of the price of the least expensive plan from each basket. This is typically the methodology used by the OECD and adopted by the national regulators.[11] Figures 2 and 3 below present the evolution of the price of the least expensive plan in France and Austria respectively. Four baskets of usage profile has been considered: standalone voice plans, standalone data plans, bundles of voice with less than 500 Mo of data, and bundles of voice with more than 500 Mo of data. Consistently with the outcome of the tables 1 and 2 above, prices have been falling in France; whereas in Austria they have been rising.

These trends are consistent with the claims by the regulators about the impact of the change in the market concentration on the prices of wireless communications. One limitation of the basket methodology is that it fails to account for the evolution of the allowances that change along with the price of the plan. Another limitation is the failure to distinguish between the price of data and voice when both are sold in

[11]See the evolution of the mobile price index computed by the regulators. These price indexes,calculated irrespective of voice and data services shows a decline in the price of mobile plans in France and a rise in Austria. Check the following links: French (http://www.arcep.fr/index.php?id=12614L=0) and Austrian (https://www.rtr.at/en/inf/alleBerichte).

bundle. Moreover, a change in the market concentration may also affect the other characteristics of the mobile plans such the terminal subsidy. For instance, the entry of the fourth operator in France has triggered the popularity of low-cost mobile plans without terminal subsidy or commitment. The introduction of these plans could also explain the fall in the monthly price of mobile plans observed in France. In the following section, the econometric identification strategy takes advantage of the availability of both standalone and bundle plans, as well as the information on the characteristics of the plans, to estimate a hedonic price model that will help identify the parameters of each mobile tariffs.

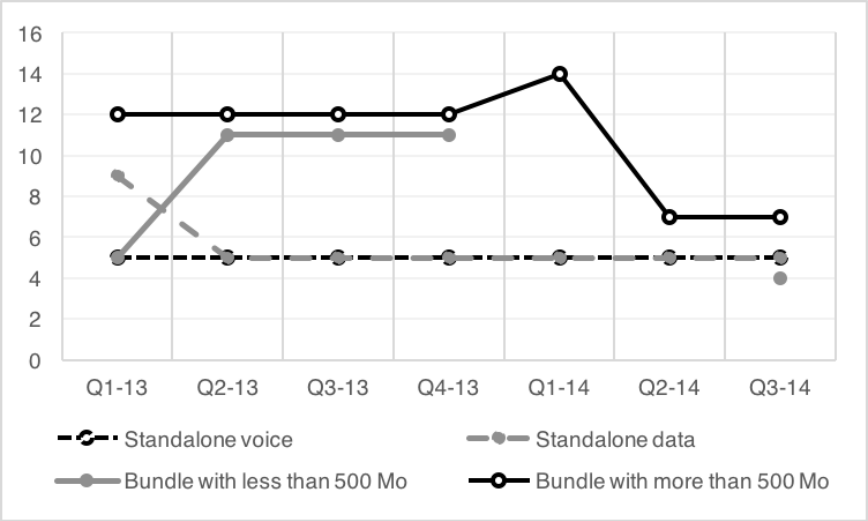

Figure 2: Evolution of the price of the least expensive plan in France (Orange and SFR)

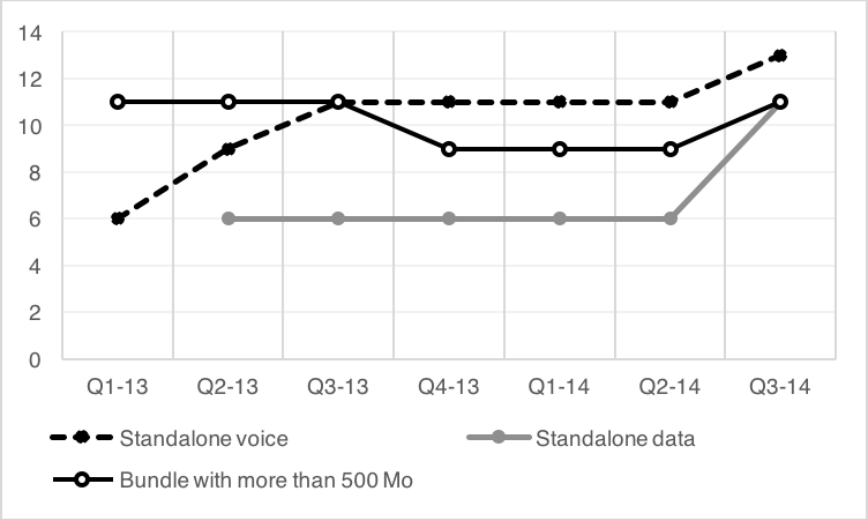

Figure 3: Evolution of the price of the least expensive plan in Austria (A1 Telekom Austria and T-Mobile)

4 Econometric identification strategy

4.1 The hedonic price model

The estimation of the hedonic price model follows from Griliches (1961). The hedonic price model is based on the intuition that any product can be viewed as a bundle of attributes such that firms and consumers trade to determine the price attached to each of them. Rosen (1974) provides a formal presentation of this model in a perfectly competitive framework and Karamti & Grzybowski (2010) applies it to study the evolution of the prices of mobile telephony services in France.

As discussed in the background section, the price of a mobile plan is typically a three-part tariff. This paper does not account for the variable part of the tariff, as this seldom applies to the mobile subscribers. Even abstracting from this component of the tariff, it is stil not clear the nature of the functional relationship between the allowance and the total tariff of a plan. For the purpose of identifying this relationship, the following figure 4 presents the scatter plot of the monthly price against the allowance of voice and data for standalone wireless plans in France in the first quarter of 2013. It turns out that the relationship is linear.

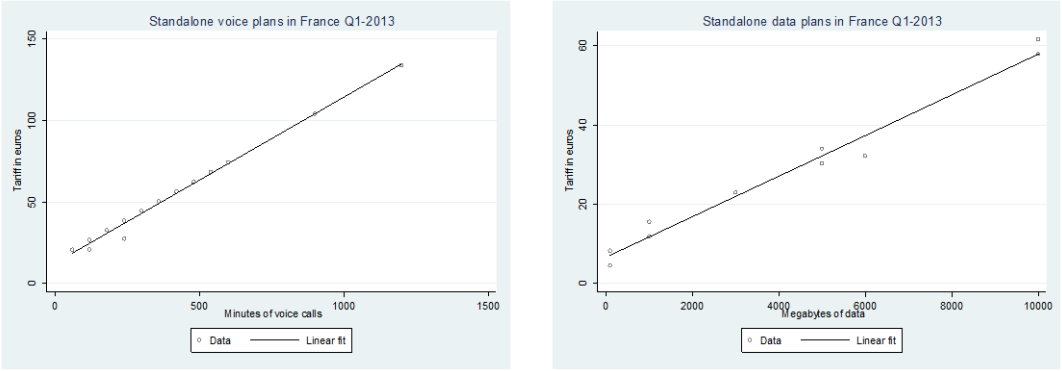

Figure 4: Allowance and monthly tariff of standalone plans

Note: Standalone wireless voice or data plan in France during the first quarter of 2013. Unlimited plans are not included in the graphical representation. The tariff of all operators are included in the graph.

Therefore, the generic tariff of a mobile plan can be expressed as:

$$T = \lambda_v + \lambda_d D + \delta B + \alpha_s SV + \alpha_b BV + \beta_s SD + \beta_b BD \tag{1}$$

This is representative of a mobile voice or data plan, either in standalone or bundle; but without any other characteristic. T is the monthly price of the mobile plan. D is the mobile data download speed. $D = 0$ for mobile voice plans so that the coefficients λ_v and λ_d measure the access price to mobile voice and data respectively. B is a dummy variable for bundles. Its coefficient δ measures the bundling discount on the access price. Its sign should be negative. SV and BV are respectively the voice allowance included in standalone and bundled plans. Their coefficients α_s and α_b measure respectively the price per hour of standalone voice and its corresponding bundling premium. Similarly, SD and BD are respectively the data allowance included in standalone and bundled plans. Their corresponding coefficients β_s and β_b measure respectively the price per Gigabyte of standalone data and its bundling premium. These seven parameters identify the tariff of a mobile plan. The hedonic price model is derived from this tariff equation.

However, in order to account for observables and unobservables characteristics of a mobile plans the following model will be estimated:

$$T_i = \lambda_v + \lambda_d D_i + \delta B_i + \alpha_s SV_i + \alpha_b BV_i + \beta_s SD_i + \beta_b BD_i + \gamma X_i + \varepsilon_i \qquad (2)$$

Where X_i includes the characteristics of the plans such as the duration of the contract in months, the market segment addressed (business or residential) and a dummy for plans without terminal subsidy (SIM-Only). ε_i includes all the unobservables characteristics such as roaming, special discount for certain phone numbers, access to wifi and tethering. These unobservables are assumed to be independent from the observables characteristics of the plans.

Given the time dimension of the dataset, the model also includes quarter dummies and their interactions terms with the characteristics of the plans. These interactions are useful to identify the evolution of each of the seven parameters of the tariff. The hedonic price model is estimated by Ordinary Least Squares (OLS). The quality of the hedonic price model is evaluated by the goodness of fit indicator, R-squared.

The following tables present the hedonic price estimates of the parameters of the tariffs at the market level in France and in Austria. These estimates correspond to the parameters of an average mobile plans without handset subsidies on the market. The underlying hedonic price model includes operator fixed effects to control for time invariant difference in the price across wireless operators. The hedonic price model fits the data, particularly in Austria where the R-squared is 87 percent. As expected,

there is a premium for mobile data in bundle due to the quantity discount applied to standalone mobile data plans. This is evidenced by the positive parameters β_d in both tables.[12] Another observation which stands out from these tables is that the price per Gigabyte of mobile data is rising in France; whereas it is falling in Austria. This observation does not tell us anything about the impact of the change in the market concentration. In the following section, I present the identification strategy that will uncover the part of this trend which is due to the change in the market concentration.

	Access price			Unit price			
	Voice	Data (Mbps)	Discount	Voice (hour)	Voice discount	Data (GB)	Data premium
	λ_v	λ_d	δ	α_s	α_b	β_s	β_d
Q1-13	10,4	0,1	-1,6	1,6	-0,4	0,2	0,5
Q2-13	11,6	0,1	-5,5	1,6	-0,3	0,0	0,6
Q3-13	12,0	0,1	-5,1	1,6	-0,1	0,0	0,4
Q4-13	13,0	0,1	-5,9	1,7	-0,7	0,0	2,8
Q1-14	0,8	0,0	9,5	2,2	-2,2	2,4	3,3
Q2-14	1,1	0,0	7,7	1,9	-2,0	2,1	4,1
Q3-14	2,2	0,0	4,8	1,9	-1,9	1,8	4,3

Table 3: Tariff parameters for an average SIM Only plan in France

	Access price			Unit price			
	Voice	Data (Mbps)	Discount	Voice (hour)	Voice premium	Data (GB)	Data premium
	λ_v	λ_d	δ	α_s	α_b	β_s	β_d
Q1-13	11,5	0,5	-2,6	-3,5	2,9	-0,2	5,5
Q2-13	10,2	0,5	10,7	0,4	-1,4	-0,3	5,5
Q3-13	10,8	0,5	-60,6	0,1	2,9	-0,4	7,7
Q4-13	12,0	0,3	-18,7	0,2	0,4	0,1	5,2
Q1-14	10,8	0,2	-34,0	-0,7	2,4	0,3	1,7
Q2-14	10,3	0,2	-48,9	-0,3	2,8	0,2	2,2
Q3-14	10,4	0,1	-55,6	0,0	2,9	0,3	1,6

Table 4: Tariff parameters for an average SIM Only plan in Austria

Note: The figures in these tables correspond to the point estimates of the hedonic price model in equation 2 for France and Austria respectively. All prices are expressed in constant Q1-2013 US dollars PPP.

4.2 Findings the matched markets and operators

A relevant matched market is the one where the prices of the mobile plans would have followed the same trend as in the treated market, should a change in the market concentration occurs. I assume that the price trend is determined by demand factors such as the level and evolution of the mobile penetration, supply factors such as the number and the age of the MNOs, as well as by the level and evolution of the market structure measured by the Herfindahl Hirschman Index (HHI). To avoid

[12]The price per Gigabyte of data in bundle is $\beta_s + \beta_d$.

the endogeneity of these factors with respect to the treatment, these variables were measured before 2012.

More precisely, the demand factors are measured by the mobile penetration rate as of the fourth quarter of 2011, just before the entry of Free in France, and by the change in the mobile penetration rate between the 2000 and 2011.[13] The supply factors have been measured by the number of MNOs in the market as of the fourth quarter of 2011, and their average and median age in years.[14] Finally, I use the HHI as of the fourth quarter of 2011 and its change between 2007 and 2011 to measure the change in the market concentration. The HHI has been constructed using data on the number of subscribers of all the firms in the market provided by the WCIS.

The following figures 5 and 6 present the Mahalanobis distance of the markets for which tariff information is available with respect to France and Austria respectively. They show that markets such as Hungary, Belgium, South Korea and Slovak Republic are closer to the French market. Likewise, Italy, Israel and Sweden are closer to the Austrian market according the Mahalanobis distance based on the set of characteristics.

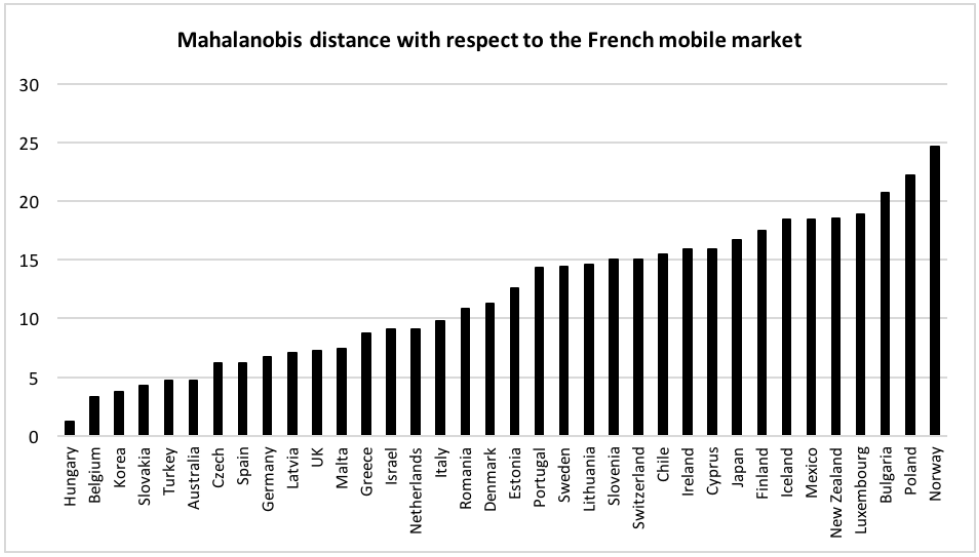

Figure 5: Mahalanobis distance with respect to the French Market

[13]The data on the mobile penetration have been retrieved from the World Cellular Information Services (WCIS) online database managed by Ovum.

[14]This information comes from the Wireless Intelligence database.

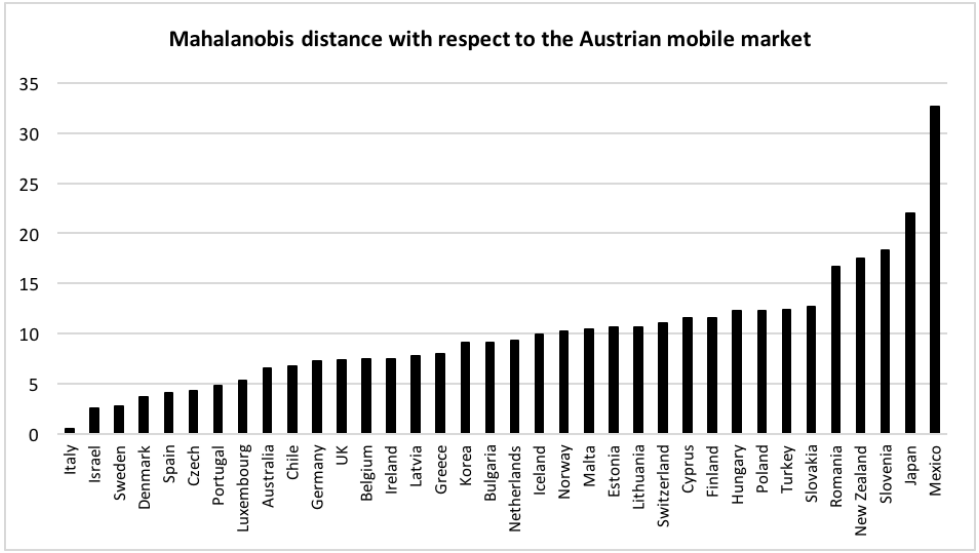

Figure 6: Mahalanobis distance with respect to the Austrian Market

Among the closest markets, I select those that had the same number of firms as the treated market before the change in the market concentration, and has not recently been subject to a change in their market structure. Within each selected match market, the first and second wireless operators in terms of their subscribers market share are respectively matched with the first and second wireless operators in the treated market. The table below presents the final outcome of the matching process. The market shares of the matched operators are very similar.

	First MNO	Second MNO
France	Orange (46.9%)	SFR (35.4%)
Hungary	T-Mobile (46.5%)	Telenor (29.7%)
Korea*	SK Telecom (49.8%)	KT Telecom (32.5%)
Slovak Republic	Orange (45.7%)	T-Mobile (36.2%)
Austria	A1 Telekom (41.4%)	T-Mobile (31.8%)
Italy	Vodafone (33.6%)	TiM (32.4%)
Spain	Telefonica (39.9%)	Vodafone (31.5%)
Germany**	Vodafone (33.4%)	Telekom (30.0%)

Table 5: Selecting the matched markets and operators

Note: Free enters into the French market in January 2012, on top of Bouygues. The merger between Orange (17.5%) and Hutchinson (9.62%) was effective starting from January 2013. Subscribers market shares of 2011 in parentheses (GSMA, Wireless Intelligence). (*) KT Telecom was not included in the analysis because of many extreme values. (**) Vodafone Germany was not used in the analysis because of the failure of the hedonic price model to describe its tariffs.

4.3 The matching estimator

■ The Basic Intuition

Before going into the details of the matching estimator, figure 7 below sketches out the constraints of the empirical identification. To the extent that full information on price is not available before the change in the market structure, the estimator will only identify the post entry/merger effect. Indeed, because of data limitation, the tariffs before the change in the market structure were not observed. For the entry in France, the observation starts one year later. For the Austrian market, the observation starts right after the merger. A synthetic control as in Abadie & Gardeazabal (2003) does not apply in this case as the tariff before the change in the market concentration is not observed. As a result, I rely on a nearest-neighbor matching based on observed characteristics of the markets prior to the change in the market structure.

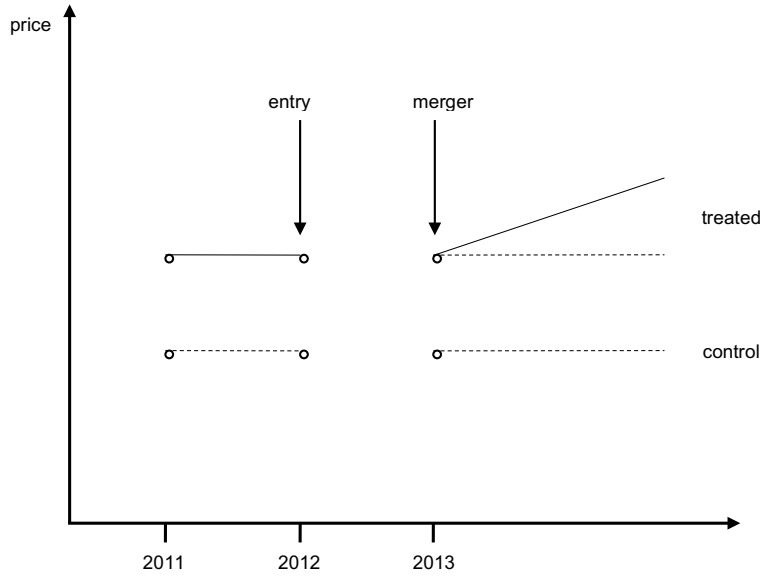

Figure 7: An illustration of the data limitation and the identification strategy

Source: Own's graphical representation.

Note: The line (bold or dotted) illustrates the available information. The entry in France occurs in 2012, one year before the observation starts. Regarding the merger in Austria, it occurs just at the beginning of the price observation. The vacuum between 2012 and 2013 may lead to an underestimation of the effect of the change in the market structure.

Following the causal identification literature, I refer to the market in which entry or merger occurs as the "treated market". Wireless operators within this market

will be referred to as "treated operators". The matching estimator is the difference in the trend between the treated market and it controls. In order to account for the heterogeneity across operators within the same market, the comparison is made at the operator level. By relying on the trend rather than the level of the hedonic prices, I control for time invariant difference across operators in different markets that may be due to difference in consumers valuation or in production cost. A formal presentation of the matching estimator is provided in Heckman *et al.* (1998). The remaining of this subsection formally presents the matching estimator.

■ Formalization of the matching estimator

This formalization is inspired by the one proposed in Abadie & Imbens (2008). Consider m markets of which one is treated and denoted by i. Each market j is made of n_j firms, all of which are either treated or untreated. A market is described by a set of characteristics Z_j independent of the treatment, typically before the change in the market concentration.

The match-markets are the ones that share similar characteristics with the treated market i. Based on the observed characteristics, they should minimize a certain measure of distance with respect to the treated market. As a result, the matches of market i belong to the set M_i defined as follows:

$$M_i = \{j \neq i : j = argmin_j D(Z_i; Z_j)\} \tag{3}$$

D is taken as the Mahalanobis distance measure to account for the correlation between the characteristics of the markets (Mahalanobis, 1936).

$$D(Z_i; Z_j) = \sqrt{(Z_i - Z_j)^t \Omega^{-1} (Z_i - Z_j)} \tag{4}$$

Where the superscript t stands for the transpose operator and Ω is the covariance matrix of the set of observations Z_i and Z_j.

Let θ_t denotes a parameter of the mobile tariff estimated from the hedonic price model in the quarter t (t= 1 to 7). The slope of the linear fit of the time series θ_t (t= 1, ..., 7) is denoted by s_θ. This slope characterizes the trend in the price of the attribute θ. The average slope of the matches writes:

$$\hat{s_{\theta i}} = \frac{1}{\#M_i} \sum_{j \in M_i} s_{\theta j} \tag{5}$$

$\#M_i$ is the number of elements in the set of the matches M_i.

The matching estimator of the effect of the treatment writes:

$$\Delta(\theta_i) = \frac{1}{n_i} \sum_{k=1}^{n_i} (s_{\theta ik} - \hat{s_{\theta ik}}) \tag{6}$$

k is an index for the firms in the treated market i. The standard error of this estimator is calculated using the formula proposed in Abadie & Imbens (2006) because the bootstrapped variance is no longer valid for a matching estimator.

5 Results

5.1 Estimation results

Figure 8 below reports the estimates of the impact of the change in the market concentration on the price of wireless communications services. The corresponding figures are presented in table 11 in appendix along with the detailed estimates in tables 12 and 13 in the appendix B.

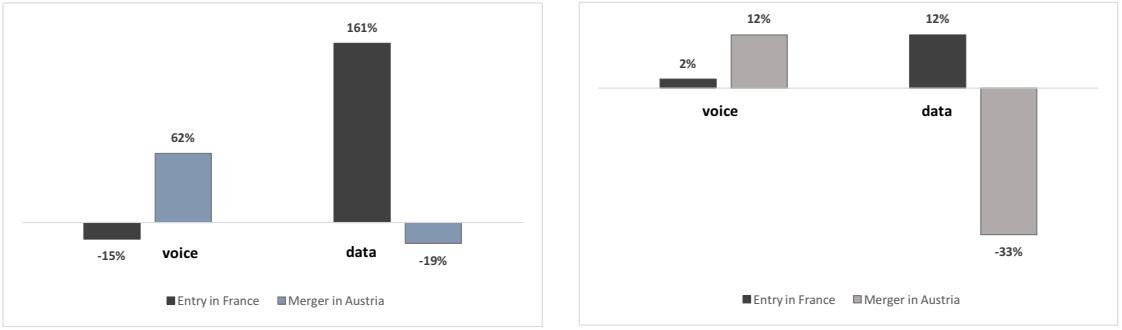

Figure 8: The impact of concentration on the price per unit (left) and the access price (right)

■ The impact of concentration on the price of the mature technology (wireless voice)

It turns out that the entry of the fourth wireless operator in the French market has lowered the price per hour of voice telephony by 7% and 15%, respectively for standalone and bundled voice. Based on the details of the results presented in table 12, the price per hour of voice has fallen in all markets, triggered by the technological progress; but this fall is greater in the French market compared to its matches. The effect is twice bigger for the bundled voice plans than for the standalone voice plans. The largest wireless operator is driving the fall in the price per hour of voice in bundle; whereas the fall in the price per hour of standalone voice is driven by the second largest wireless operator. As predicted by the theory, there is no significant effect on the access price of voice. This is consistent with the fact that no surplus can be extracted by the means of the access price, given the rise in competition with the entry of the fourth wireless operator.

On the contrary, the merger in the Austrian market has raised the price per hour of wireless voice in standalone and in bundle by respectively 84% and 62%. This rise is only observed in the Austrian market and contrasts with the fall in the price per hour of voice in the control markets (table 13). This absolute rise in the price per hour of voice is due to the gradual withdrawal of the cheapest standalone wireless voice plans and the further introduction of more expensive bundled plans (table 2). The new bundled plans contains more hours of voice telephony but less in proportion to the rise in the total price of the bundle, and compared to the controls markets. The rise in the unit of voice in the Austrian market is much more driven by the largest wireless operator as shown in the table 13. In addition, there is a rise in the access price of standalone voice which corresponds to an extraction of consumer surplus due to less competition after the merger. This is also consistent with the withdrawal of the cheapest plans from the market.

■ The impact of concentration on the price of the new technology (wireless data)

However, the picture looks different for the wireless data communications, a service based on a new technology. Actually, the impact of the change in the market concentration on the price of this service is exactly the opposite of what has been estimated for voice telephony. The entry in the French market has more than doubled the price per Gigabyte of data services, particularly in bundle; whereas the merger in Austria has lowered the price per Gigabyte of data by 19%.

The dramatic rise in the price per Gigabyte of wireless data in France is due to the withdrawal of plans with greater allowances as shown in table 1. The average data allowance in the bundled plans falls from 13 Gigabytes in the first quarter of 2013 to 3 Gigabytes in the third quarter of 2014. Although the price of the bundle has also decreased over this period, it was not sufficient to compensate for the decline in the data allowances. As a result, there is an absolute rise in the price per Gigabyte of wireless data in France after the entry of the fourth wireless operator. Therefore, the relative rise is amplified by the fall in the price per Gigabyte observed in the matched-markets. This effect is bigger for the second largest firm than for the largest wireless operator (table 12).

Interestingly, these findings accord well with the rise in the access price of standalone and bundled wireless data by respectively 17% and 12%. The access price of data represents the price per megabit per second of download speed attached to a wireless plan. Due to technological progress, this price per unit naturally falls as observed in the control markets. However, the magnitude of this fall is smaller in the French market compared to its controls. This discrepancy is wider for the second largest wireless operator, suggesting that it is lagging behind in terms of the deployment of the faster wireless data network.

In the Austrian market, the fall in the price per Gigabyte of wireless data is much more moderate. This fall is driven by the introduction of more bundled plans with more data allowance as shown in the table 2. Consistently with this evolution, there is also a fall in the access price of standalone and bundled wireless data by 12% and 33% respectively. This fall can be explained by the increase in the download speed of the wireless plans proposed by the operators, compared to their matches.

5.2 Robustness checks

This section presents the outcome of the robustness checks of the main results with respect to the parallel trend assumption and with respect to the choice of the matched-markets.

■ Testing the parallel trend assumption

The identification strategy relies on the assumption that the price trend is similar between the treated market and its controls before the change in the market concentration. This assumption could not be tested directly in the main estimation as the Teligen tariff dataset does not provide the relevant price information prior to

the change in the market concentration. The most relevant information is available from the first quarter of 2013. However, the broadband internet access cost dataset (BIAC) constructed by the European Commission can be used as an alternative data source for this test.

The BIAC dataset provides information about the tariff of **fixed broadband plans** for the first quarters of 2011 and 2012; a year before the entry of *Free* in France and two years before the acquisition of *Orange* by *Hutchison* in Austria. It was not designed for collecting tariff data about mobile plans; but still provides information about mobile voice and data services bundled with fixed broadband.

The test basically compares the evolution of the prices of mobile voice and data services between each treated market and its matches before the change in the market concentration. As mobile telecommunications services are bundled with fixed broadband, their prices have been derived from a hedonic price model using the following equation:

$$T = \alpha + \beta_1 FV + \beta_2 MV + \beta_3 MBB + \beta_4 TV + \delta M + \gamma X + \varepsilon \tag{7}$$

Where T is the monthly tariff of the fixed broadband plan, FV is a dummy variable when fixed voice service is included, MV is a dummy variable when mobile voice is included, MBB is a dummy variable when mobile broadband is included, M is a dummy variable for the matches and X is a set of characteristics of the fixed broadband plans including the download speed, the technology used and whether fixed voice is required for the purchase of the fixed broadband plan. This equation is estimated on each pair of markets (Treated and Controls) for each year. The coefficient δ captures the price difference between the treated market and its matches. A comparison of δ between 2011 and 2012 provides a test for the parallel trend assumption between the treated market and its matches.

The OLS estimation of this equation yields the tariff structure of the fixed broadband and particularly the hedonic price of mobile voice and data in each market and for each year. The results are presented in the table 6 below. I implement a test using the seemingly unrelated estimation method (Zellner, 1962). The p-values associated with these tests are shown at the bottom of the table 6. They imply that the price difference between the treated and its matches has not significantly changed between 2011 and 2012. Therefore, there is some evidence of a parallel price trend between the treated markets and their matches.

	Monthly rental price			
	France vs. Controls		Austria vs. Controls	
	Q1-2011	Q1-2012	Q1-2011	Q1-2012
Download speed (Mbps)	0.20***	0.16***	0.19***	0.33***
	(0.02)	(0.02)	(0.03)	(0.03)
Fiber	-3.81***	-4.14**	-0.35	1.27
	(1.45)	(1.78)	(2.20)	(2.55)
Satellite			42.16***	57.08***
			(5.89)	(7.92)
Fixed voice required	16.39***	10.94***	7.55***	9.24***
	(3.03)	(2.27)	(2.82)	(2.26)
Fixed voice included	16.38***	14.97***	9.78***	8.64***
	(0.95)	(1.20)	(1.60)	(1.68)
Mobile voice included	6.80	21.99***	9.66***	12.00***
	(10.34)	(4.08)	(2.26)	(3.00)
Mobile broadband included	8.37***	9.96***	8.20***	39.11***
	(1.51)	(2.08)	(1.78)	(3.08)
Television included	5.44***	6.77***	4.42***	2.61
	(0.97)	(1.21)	(1.66)	(1.63)
Difference wrt controls (D)	10.32**	16.88***	10.68**	11.77**
	(4.88)	(6.24)	(4.46)	(5.27)
Constant	6.47**	5.79	23.58***	6.60**
	(3.01)	(4.18)	(4.46)	(3.31)
Observations	503	562	269	280
R-squared	0.719	0.606	0.590	0.794
SUEST based test: D(2011) = D(2012)	Chi 2 (1) = 1.26 p-value = 0.26		Chi 2 (1) = 0.03 p-value = 0.86	

Significant at 1%(***), 5%(**) and 10%(*). Robust standard errors in parentheses.

Table 6: Testing the parallel trend assumption

Source: Broadband Internet Access Cost, 2011 and 2012.

Note: Each column is an OLS estimation of the hedonic price of the components of fixed broadband plans for each year. Testing the parallel trend assumption amounts to testing whether the differences (D) in the hedonic prices between the treated and the controls markets are statistically identical between 2011 and 2012. The Seemingly Unrelated Estimation (SUEST) was implemented in order to recover the covariance of the point estimates (D) across the two years.

■ Robustness with respect to the choice of the matched-markets

Rather than choosing the matched-markets suggested by the Mahalanobis distance, I choose intuitive matched-markets for France and Austria, typically their neighboring countries. For France, I use Germany, Italy and Spain as matched-markets; whereas Hungary, Slovakia and Switzerland serve as the matched-markets for Austria. Within each matched markets, the largest operator is matched to the largest in the treated market and likewise for the second largest. The outcome of the estimation is presented in table 14 in appendix. It turns out that the effect of the change in the market structure is qualitatively the same. More specifically, the price per

Gigabyte rises with the entry in France; but falls with the merger in Austria. The reverse holds for the price per hour of voice call. Therefore, the main finding of this paper is robust with respect to the choice of the matched-markets.

5.3 Discussion of the results

In a dynamic framework where firms invest in cost-reducing technologies, the impact of market concentration on price hinges on a balance between the static and dynamic effects of competition. This balance can be illustrated by considering an hypothetical equilibrium price $P = c+m$, where m is the market power, decreasing in the intensity of competition θ, and c is the marginal cost of production, decreasing in investment y. Let's assume a setting in which investment falls with competition. Therefore, the impact of competition on price writes:

$$\frac{\mathrm{d}P}{\mathrm{d}\theta} = \frac{\partial c}{\partial y}\frac{\partial y}{\partial \theta} + \frac{\mathrm{d}m}{\mathrm{d}\theta} = D - S$$

Under the assumptions above, D and S are positive and denote respectively the dynamic and static effects of competition. In the wireless industry, the static effects mainly stem from the reduction in the costs related to the terminal subsidies, the physical distribution of the services and the customer services. The dynamic effects, on the contrary, arise from the investment in the new technologies which allows the regular reduction of the marginal cost of production. This reduction is due to the significant rate of technological progress that characterizes the provision of wireless services. According to the findings of Amaya & Magee (2008), this rate of technological progress is much more significant for the transmission of wireless data, around 50% since 1980; meaning that the cost of purchasing the same unit of capacity halves every year. Therefore, the marginal cost of the provision of an additional Gigabyte of wireless data roughly halves every year. The progress is much less significant for wireless voice services whose provision depends upon the signal quality.

Under the hypothesis that the static effects of competition dominate the dynamic ones, a rise in competition should lower the price. The contrapositive remains true; that is if an increase in the market concentration lowers price, then it must be the case that the dynamic effects dominate the static ones. Formally,

$$\left[S > D \Rightarrow \frac{\mathrm{d}P}{\mathrm{d}\theta} < 0\right] \Leftrightarrow \left[\frac{\mathrm{d}P}{\mathrm{d}\theta} > 0 \Rightarrow S < D\right]$$

The empirical investigation shows that the price of voice services has fallen with the entry, but risen with the merger. This finding accords well with the fact that the rate of technological progress on wireless voice is no longer significant such that the static effects of competition clearly overweigh the dynamic ones. However, the fact the price of wireless data, a service subjected to strong technological progress, has risen with the entry and fallen with the merger highlights the dominance of the dynamic effects over the static ones. These conclusions emphasize the tradeoff between static and dynamic efficiencies in the wireless communications market: a rise in competition following the entry of the fourth wireless operator in France favors the mature technology at the expense of the new technology, contrary to the merger in Austria.

6 Conclusion

This paper analyzes how market concentration affects price in an industry where firms regularly invest in cost-reducing technologies. More specifically, it takes advantage of the change in the market concentration induced by the entry of a fourth wireless operator in France and the merger between the third and fourth operators in Austria to estimate the impact of market concentration on the price of wireless voice and data. It finds that the price of wireless data has been rising with the entry in France; but falling with the merger in Austria. Reversely, the price of wireless voice, a mature technology, has been falling with the entry in France; but rising with the merger in Austria.

These findings suggest that the magnitude of the dynamic efficiencies potentially outweighs the static ones for wireless data communications services. Actually, investment in new technologies is a means to increase the data allowance as well as the download speed without changing the overall tariff of the plan. As in (Jeanjean, forthcoming), this is the force driving down the price per Gigabyte of wireless data services. In addition, this paper highlights the importance of taking into account the characteristics of the plans when assessing their prices. This is because a change in the market concentration affects the quantity and bundle discounts as well as the attributes of the plans such as the terminal subsidy and the length of the contractual commitment.

The change in the price per unit is typically made by replacing the allowances of an old plan in order to introduce new plans. In addition, a new plan can be the bundle of standalone old plans. Thus, the product line is another important dimension of a firm's pricing strategies. However, this paper does not explicitly account for the attrition and the creation of new plans. To the extent that these changes are not random, they may affect the profit of the firms as well as the consumers surplus in a way that remains to be uncovered. A further research will deal with this issue.

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A Estimates of the parameters of the tariff for the treated and the controls

	Access price			Unit price			
Quarter	Voice (hour)	Data (Mbps)	Discount	Voice (hour)	Discount Voice	Data (GB)	Data premium
First MNO – France (46%)							
Q1-13	10.5	0.1	-0.5	1.5	-0.3	0.2	0.4
Q2-13	12.7	0.1	-6.2	1.4	-0.2	0.0	0.6
Q3-13	12.9	0.1	-6.4	1.5	-0.1	0.0	0.5
Q4-13	14.1	0.1	-7.3	1.5	-0.1	-0.1	-0.4
Q1-14	0.8	0.0	6.3	2.1	-1.8	2.6	2.0
Q2-14	2.4	0.0	3.6	1.8	-1.6	2.6	2.6
Q3-14	3.6	0.0	1.8	1.7	-1.4	2.6	2.5
First MNO – Hungary (53%)							
Q1-13	10.5	0.5	-83.7	0.7	2.2	1.0	0.0
Q2-13	10.5	0.5	-83.7	0.7	2.2	1.0	0.0
Q3-13	10.5	0.5	-83.7	0.7	2.2	1.0	0.0
Q4-13	15.8	0.4	-70.8	0.6	2.3	0.9	0.1
Q1-14	12.2	0.4	-63.2	1.3	1.2	1.0	0.2
Q2-14	12.2	0.4	-63.2	1.3	1.2	1.0	0.2
Q3-14	12.7	0.4	-62.2	1.3	1.2	1.0	0.3
First MNO – Korea (71%)							
Q1-13	2.8	0.1	17.0	0.8	0.0	1.5	19.6
Q2-13	5.8	0.1	13.4	0.9	0.0	1.4	20.0
Q3-13	6.3	0.1	12.5	0.9	0.0	1.3	19.4
Q4-13	2.9	0.3	8.2	0.7	0.0	1.2	21.2
Q1-14	4.7	0.1	6.9	2.0	0.0	1.4	18.0
Q2-14	1.7	-0.1	11.7	2.8	0.0	2.5	15.3
Q3-14	2.4	-0.2	11.8	3.4	0.0	2.8	13.5
First MNO - Slovak Republic (98%)							
Q1-13	5.9	-0.1	3.3	2.5	0.0	10.9	2.5
Q2-13	5.8	-0.1	6.3	3.3	0.0	11.1	-1.6
Q3-13	6.0	-0.2	3.3	1.5	0.0	10.6	0.5
Q4-13	4.1	0.0	1.4	0.9	0.0	7.7	5.4
Q1-14	2.3	0.0	2.3	1.3	0.0	7.4	4.2
Q2-14	2.3	0.0	3.3	1.0	0.0	7.4	4.8
Q3-14	3.5	-0.1	3.3	1.7	0.0	7.0	-2.1

Table 7: Estimates of the hedonic price model for the first MNO in France and its Controls

Note: Output of the OLS estimation of the hedonic price model. R-squared in parentheses.

	Access price			Unit price			
Quarter	Voice (hour)	Data (Mbps)	Discount	Voice (hour)	Discount Voice	Data (GB)	Data premium
Second MNO – France (87%)							
Q1-13	-2.7	0.0	-2.3	5.5	-4.0	3.1	-1.5
Q2-13	-3.3	0.0	2.3	5.4	-4.0	3.1	-2.2
Q3-13	0.1	0.0	3.2	4.1	-4.0	3.1	6.5
Q4-13	0.3	0.0	3.9	3.7	-4.0	3.1	7.4
Q1-14	1.7	0.0	4.8	3.9	-4.0	2.8	3.2
Q2-14	6.7	-0.1	3.1	3.9	-4.0	1.0	5.5
Q3-14	1.0	0.0	7.7	3.9	-4.0	2.1	4.3
Second MNO – Hungary (61%)							
Q1-13	1.0	0.3	-42.1	0.9	-0.1	0.1	2.7
Q2-13	1.0	0.3	-42.1	0.9	-0.1	0.1	2.7
Q3-13	1.0	0.3	-42.1	0.9	-0.1	0.1	2.7
Q4-13	9.0	0.2	-36.6	0.9	0.2	-0.1	2.7
Q1-14	-0.6	0.3	-43.7	1.3	-0.8	0.1	2.7
Q2-14	-0.6	0.3	-43.7	1.3	-0.8	0.1	2.7
Q3-14	-0.9	0.3	-43.7	1.5	-0.5	0.1	2.2
Second MNO – Korea (81%)							
Q1-13	-34.7	6.6	0.0	1.5	0.0	-12.4	24.5
Q2-13	-34.9	6.0	4.4	1.5	0.0	-11.2	23.3
Q3-13	-31.6	9.0	-20.6	1.5	0.0	-17.3	29.4
Q4-13	-45.2	0.1	57.6	1.6	0.0	1.1	11.2
Q1-14	-39.1	0.1	51.5	1.5	0.0	0.7	11.6
Q2-14	-47.4	-0.7	54.4	7.8	0.0	4.5	-0.4
Q3-14	-36.2	-0.2	45.6	4.4	0.0	1.7	6.8
Second MNO - Slovak Republic (98%)							
Q1-13	7.4	-0.2	-9.0	2.2	0.0	7.9	5.3
Q2-13	6.1	-0.6	-9.0	2.0	0.0	7.3	7.7
Q3-13	4.0	-0.4	-9.0	5.2	0.0	7.3	-22.8
Q4-13	2.4	0.5	-9.0	4.3	0.0	7.3	-16.6
Q1-14	-3.0	0.4	-9.0	1.1	0.0	7.3	6.6
Q2-14	-3.0	0.3	-9.0	1.1	0.0	7.3	6.6
Q3-14	0.4	0.2	-9.0	1.1	0.0	7.3	0.1

Table 8: Estimates of the hedonic price model for the second MNO in France and its Controls

Note: Output of the OLS estimation of the hedonic price model. R-squared in parentheses.

	Access price			Unit price			
Quarter	Voice (hour)	Data (Mbps)	Discount	Voice (hour)	Discount Voice	Data (GB)	Data premium
First MNO – Austria (94%)							
Q1-13	5.6	0.2	-37.5	0.0	2.3	0.0	2.1
Q2-13	5.4	0.2	-41.6	1.0	1.6	-0.1	-1.0
Q3-13	4.6	0.2	-40.7	1.0	1.6	-0.1	-1.0
Q4-13	5.7	0.2	-41.9	1.1	1.5	-0.1	-1.0
Q1-14	2.4	0.2	-77.9	1.5	3.6	0.3	-3.3
Q2-14	2.2	0.2	-77.6	1.6	3.5	0.4	-3.4
Q3-14	1.3	0.2	-76.8	1.6	3.5	0.4	-3.4
First MNO – Italy (85%)							
Q1-13	13.2	0.1	-2.5	0.9	0.0	0.4	3.3
Q2-13	13.5	0.0	-5.1	0.4	0.0	1.4	7.6
Q3-13	15.1	-0.3	-33.8	2.8	0.0	2.4	-1.9
Q4-13	8.5	-0.1	14.7	0.9	0.0	2.3	-2.7
Q1-14	4.1	0.1	-13.2	1.5	0.0	1.7	7.5
Q2-14	4.4	0.1	-10.0	1.5	0.0	1.7	6.3
Q3-14	6.5	0.1	-14.1	1.6	0.0	1.4	6.6
First MNO – Spain (76%)							
Q1-13	7.0	-1.2	-0.4	2.4	1.6	7.6	-7.6
Q2-13	2.4	0.1	-3.3	1.4	0.0	2.9	-1.3
Q3-13	2.0	0.0	-3.8	2.1	-0.8	3.3	-1.6
Q4-13	2.0	0.0	4.0	2.1	-1.0	3.3	-1.9
Q1-14	0.2	0.0	10.0	2.3	-1.3	3.6	-2.4
Q2-14	-3.8	0.1	8.9	2.6	-1.4	3.7	-2.2
Q3-14	-4.7	0.0	22.9	-1.3	1.6	3.9	-5.2
First MNO – Germany (49%)							
Q1-13	-35.4	-0.4	-4.8	-0.5	3.4	2.9	57.7
Q2-13	-35.4	-0.4	-0.4	-0.5	3.1	3.0	53.2
Q3-13	5.1	-1.5	-4.8	-2.0	3.4	3.0	28.7
Q4-13	0.0	-1.4	-4.8	16.3	3.4	3.0	-94.5
Q1-14	0.0	-1.5	-4.8	16.3	3.4	3.0	-94.5
Q2-14	26.1	-1.9	-4.8	-8.5	3.4	2.6	36.1
Q3-14	23.6	-1.3	-4.8	-7.1	3.4	3.5	25.9

Table 9: Estimates of the hedonic price model for the first MNO in Austria and its Controls

Note: Output of the OLS estimation of the hedonic price model. R-squared in parentheses.

	Access price			Unit price			
Quarter	Voice (hour)	Data (Mbps)	Discount	Voice (hour)	Discount Voice	Data (GB)	Data premium
Second MNO – Austria (92%)							
Q1-13	11.5	0.5	-2.6	-3.5	2.9	-0.2	5.5
Q2-13	10.2	0.5	10.7	0.4	-1.4	-0.3	5.5
Q3-13	10.8	0.5	-60.6	0.1	2.9	-0.4	7.7
Q4-13	12.0	0.3	-18.7	0.2	0.4	0.1	5.2
Q1-14	10.8	0.2	-34.0	-0.7	2.4	0.3	1.7
Q2-14	10.3	0.2	-48.9	-0.3	2.8	0.2	2.2
Q3-14	10.4	0.1	-55.6	0.0	2.9	0.3	1.6
Second MNO – Italy (76%)							
Q1-13	13.1	-0.1	4.8	-0.8	1.3	1.2	12.4
Q2-13	9.3	0.2	-1.0	-0.6	0.7	0.3	12.2
Q3-13	6.4	0.3	-1.0	-0.1	0.1	0.2	11.3
Q4-13	5.7	0.3	-31.5	0.2	1.4	0.1	8.3
Q1-14	5.0	0.4	-54.2	0.7	1.3	0.1	9.6
Q2-14	5.0	0.4	-51.7	0.6	1.3	0.1	9.2
Q3-14	10.3	-0.1	-25.0	0.6	1.3	1.0	8.3
Second MNO – Spain (65%)							
Q1-13	4.3	0.8	0.0	0.8	0.0	0.9	0.4
Q2-13	-6.9	0.8	11.1	0.8	0.0	2.7	-1.4
Q3-13	2.9	1.0	-4.5	0.5	0.0	-2.0	4.0
Q4-13	-55.2	0.5	46.2	0.3	0.0	3.8	4.7
Q1-14	-39.6	0.4	30.8	0.2	0.0	3.1	6.1
Q2-14	-39.4	0.3	31.5	0.2	0.0	3.4	5.8
Q3-14	3.7	0.1	-12.1	0.2	0.0	3.4	6.4
Second MNO – Germany (93%)							
Q1-13	8.0	0.0	1.3	1.8	0.0	1.7	1.4
Q2-13	7.7	0.0	5.5	-0.3	0.0	1.8	14.1
Q3-13	8.9	0.0	7.8	0.1	0.0	1.8	9.0
Q4-13	9.1	0.0	7.2	-0.1	0.0	1.8	10.8
Q1-14	7.5	0.0	8.8	-0.1	0.0	1.9	10.7
Q2-14	7.4	0.0	7.2	0.3	0.0	1.9	8.2
Q3-14	8.7	0.0	6.6	0.4	0.0	1.9	2.7

Table 10: Estimates of the hedonic price model for the second MNO in Austria and its Controls

Note: Output of the OLS estimation of the hedonic price model. R-squared in parentheses.

B Details of the matching estimation

B.1 Main results

	Access price			Unit price			
	Voice	Data	Bundle	Voice	Bundled voice	Data	Bundled data
Entry in France	2%	17%	12%	**-7%**	**-15%**	127%	**161%**
Merger in Austria	12%	-12%	-33%	**84%**	**62%**	30%	**-19%**

Table 11: The matching estimates

Note: This table reports the matching estimates, expressed as the percentage of the average price in the first quarter of 2013. They represent the average impact for the two largest wireless operators. They have been derived from the tables 12 and 13 above. The key estimates are in bold. The distribution of the matching estimator is unknown and cannot be approximated by bootstrapping. Therefore, it is not possible to identify the statistically significant point estimates. Nonetheless, the Abadie & Imbens standard errors estimated in the tables 12 and 13 in the appendix provide a way to rule out the non-significant coefficients. In this table, the standard errors of the underlined coefficients are so large that they cannot be deemed significant.

The tables 12 and 13 below present the estimates of the impact of the change in the market concentration on the slope of each parameter of the mobile tariff. Each coefficient represents the slope of the linear trend of the a tariff parameter. The slope is estimated from the hedonic price estimates of the components of the tariff. These estimates are presented in tables 7 to 10.

The first and second panels of the tables 12 and 13 below correspond to the point estimates for the first and second wireless operators respectively. The last panel presents the result of the matching estimation for each tariff parameter along with its standard error.

	Access price			Unit price			
	Voice	Data (Mbps)	Discount	Voice (hour)	Voice premium	Data (GB)	Data premium
	λ_v	λ_d	δ	α_s	α_b	β_s	β_d
$s_{\theta 1}$	-1.90	-0.02	1.41	0.07	-0.28	0.54	0.42
$\widehat{s_{\theta 1}}$	-0.20	-0.02	1.12	0.11	-0.08	-0.20	-0.30
$s_{\theta 1} - \widehat{s_{\theta 1}}$	-1.71	-0.01	0.28	-0.04	-0.20	0.73	0.71
$s_{\theta 2}$	1.17	-0.02	1.20	-0.29	0.00	-0.27	1.06
$\widehat{s_{\theta 2}}$	-1.01	-0.05	-0.17	-0.11	-0.06	-0.03	0.18
$s_{\theta 2} - \widehat{s_{\theta 2}}$	2.18	0.03	1.37	-0.18	0.06	-0.24	0.88
$\Delta(\theta)$	0.24	0.01	0.82	-0.11	-0.07	0.25	0.79
AI Std. error	1.89	0.00	0.15	0.00	0.01	0.12	0.00

Table 12: Estimates of the impact of the entry on the tariff parameters

Note: The parameter $s_{\theta j}$ is the slope of the linear trend of the tariff parameter θ for the firm j. Likewise, the parameter $\hat{s_{\theta j}}$ is the average slope of the linear trend of the tariff parameter θ for the matched firms. It is the arithmetic mean of the slopes of the matched firms for the treated firm j. The tariff parameter θ belongs to the following set: $(\lambda_v, \lambda_d, \delta, \alpha_s, \alpha_b, \beta_s, \beta_b)$. The firm's identifier j equals 1 for the largest MNO and 2 for the second largest MNO. The matching estimator is denoted by $\Delta(\theta)$.

For instance, -1.90 means that the trend of the access price for the first mobile network operator (MNO) is downward sloping, in other words, the access price is falling. For the Controls, the coefficient represents the average slope over all the matches. The difference is calculated between the treated MNO and its matches. For instance, $-1.71 = -1.90 - (-0.20)$. Note that in the calculation of the average slope $\hat{s_{\theta 2}}$ of λ_d, I only use the last four quarters for the second MNO in Slovak Republic.

The estimate is the matching estimation taken as the average of the differences in the slopes. The corresponding standard error is calculated following the formulae provided by Abadie & Imbens (2006).

	Access price			Unit price			
	Voice	Data (Mbps)	Discount	Voice (hour)	Voice premium	Data (GB)	Data premium
	λ_v	λ_d	δ	α_s	α_b	β_s	β_d
$s_{\theta 1}$	-0.77	0.00	-8.11	0.24	0.33	0.09	-0.84
$\widehat{s_{\theta 1}}$	-1.76	0.08	1.50	-0.10	-0.06	-0.12	0.38
$s_{\theta 1} - \widehat{s_{\theta 1}}$	0.98	-0.08	-9.61	0.34	0.39	0.20	-1.22
$s_{\theta 2}$	-0.11	-0.07	-8.99	0.30	0.28	0.12	-0.87
$\widehat{s_{\theta 2}}$	-1.52	-0.04	-2.19	0.01	0.03	0.17	0.10
$s_{\theta 2} - \widehat{s_{\theta 2}}$	1.41	-0.03	-6.79	0.29	0.25	-0.05	-0.97
$\Delta(\theta)$	1.20	-0.06	-8.20	0.31	0.32	0.08	-1.10
AI Std. error	0.02	0.00	0.99	0.00	0.00	0.01	0.01

Table 13: Estimates of the impact of the merger on the tariff parameters

Note: The parameter $s_{\theta j}$ is the slope of the linear trend of the tariff parameter θ for the firm j. Likewise, the parameter $\hat{s_{\theta j}}$ is the average slope of the linear trend of the tariff parameter θ for the matched firms. It is the arithmetic mean of the slopes of the matched firms for the treated firm j. The tariff parameter θ belongs to the following set: $(\lambda_v, \lambda_d, \delta, \alpha_s, \alpha_b, \beta_s, \beta_b)$. The firm's identifier j equals 1 for the largest MNO and 2 for the second largest MNO. The matching estimator is denoted by $\Delta(\theta)$.
For instance, -0.77 means that the trend of the access price for the first mobile network operator (MNO) is downward sloping, in other words, the access price is falling. For the Controls, the coefficient represents the average slope over all the matches. The difference is calculated between the treated MNO and its matches. For instance $0.98 = -0.77 - (-1.76)$.
The estimate is the matching estimation taken as the average of the differences in the slopes. The corresponding standard error is calculated following the formulae provided by Abadie & Imbens (2006).

B.2 Robustness checks results

	Access price			Price per hour/Go			
	Voice	Data	Bundle	Voice	Bundled voice	Data	Bundled data
Entry in France	9%	-17%	113%	-31%	-21%	148%	139%
Merger in Austria	32%	27%	-52%	*-445%*	40%	-166%	-13%

Table 14: Robustness check for the matching estimates

Note: This table reports the matching estimates, expressed as the percentage of the average price in the first quarter of 2013. They represent the average impact for the two largest wireless operators. The main difference with respect to table 11 is that the matched-markets are no longer the same. The estimates rely on intuitive matched-markets for France and Austria. The matched-markets for France are Germany, Italy and Spain. For Austria, they are Hungary, Slovakia and Switzerland. The outcome of the estimates is qualitatively similar to the results in table 11.