Centre on Regulation in Europe

Improving network industries regulation

Evaluating Market Consolidation in Mobile Communications

Dr Christos Genakos (Athens University of Economics and Business, CEP and CEPR)

Professor Tommaso Valletti (Imperial College London, University of Rome 'Tor Vergata', CERRE and CEPR)

Professor Frank Verboven (KU Leuven, Telecom ParisTech and CEPR)

15 September 2015

150915_CERRE_Mobile_Consolidation_Report_Final

Centre on Regulation in Europe (CERRE) asbl
Rue de l'Industrie 42 Box 16 - B-1040 Brussels - Belgium
Ph.: +32 (0)2 230 83 60 - Fax: +32 (0)2 23 0 83 70

Centre on Regulation in Europe

Improving network industries regulation

Contents

Centre on Regulation in Europe

Improving network industries regulation

About CERRE

Providing top quality studies and dissemination activities, the Centre on Regulation in Europe (CERRE) promotes robust and consistent regulation in Europe's network industries. CERRE's members are regulatory authorities and operators in those industries as well as universities.

CERRE's added value is based on:

- its original, multidisciplinary and cross-sector approach;
- the widely acknowledged academic credentials and policy experience of its team and associated staff members;
- its scientific independence and impartiality;
- the direct relevance and timeliness of its contributions to the policy and regulatory development process applicable to network industries and the markets for their services.

CERRE's activities include contributions to the development of norms, standards and policy recommendations related to the regulation of service providers, to the specification of market rules and to improvements in the management of infrastructure in a changing political, economic, technological and social environment. CERRE's work also aims at clarifying the respective roles of market operators, governments and regulatory authorities, as well as at strengthening the expertise of the latter, since in many Member States, regulators are part of a relatively recent profession.

This study, within the framework of which this report has been prepared, has received the financial support of a number of CERRE members. As provided for in the association's by-laws, it has, however, been prepared in complete academic independence. The contents and opinions expressed in this report reflect only the views of the authors and in no way bind CERRE, the sponsors or any other members of CERRE (www.cerre.eu). All remaining errors are those of the authors alone.

Centre on Regulation in Europe

Improving network industries regulation

About the authors

Dr Christos Genakos is Assistant Professor at the Athens University of Economics and Business, a Research Fellow at CEPR and a Research Economist at the London School of Economics' Centre for Economic Performance. He has previously lectured at Cambridge University. He holds a Master's degree in Economics from University College London and a Bachelor's in Economics from the National and Kapodistrian University of Athens, where he graduated top of his class. He received his Ph.D. in economics from London Business School.

His research focuses on industrial organisation and applied microeconomics, with an emphasis on quantitative techniques for competition analysis and regulation. He has published in many leading international peer-refereed journals, such as the Journal of Political Economy, Economic Journal, Journal of the European Economic Association, Academy of Management Perspectives and more. His research has been covered extensively by both Greek and international media.

Professor Tommaso Valletti is a Joint Academic Director of CERRE and Professor of Economics at Imperial College London and at the University of Rome. He has previously taught at the London School of Economics, Telecom ParisTech / Ecole Polytechnique, and Turin.

Tommaso is also a member of the Economic Advisory Group on Competition Policy (EAGCP) at the European Commission. He is a member of the panel of academic advisors to Ofcom and to the UK Competition Commission. He was a board director of Consip, the Italian Public Procurement Agency. He has taken numerous editorial positions, including Editor of 'Information Economics & Policy', Associate Editor of 'Journal of Industrial Economics', 'Economica', and 'Telecommunications Policy'. He is research fellow of CEPR and ENCORE. Tommaso's main research interests are in industrial economics, regulation, and telecommunications economics. He has published extensively in leading economics journals.

Professor Frank Verboven is Professor and Chairman of the Department of Economics at the University of Leuven, visiting professor at the Barcelona Graduate School of Economics (Master in Competition and Regulation) and current holder of the Innovation & Regulation in Digital Services Chair at Telecom Paris Tech He obtained his Ph.D. in Economics at the University of Toronto in 1993. He previously held appointments at Tilburg University (1993-1995), the University of Leuven (1995-1997), and the University of Antwerp (1997-2000).

Frank has been a research fellow at the Centre for Economic Policy Research (CEPR, London) and at the Center for Economic Research (Tilburg University) since 1997. He is also a member of the University of Leuven Research Council, of Ofcom's Academic Panel and of the Economic Advisory Group on Competition Policy (EAGCP) at the European Commission. He was editor of the 'Journal of Industrial Economics' between 2003 and 2008 and is currently associate editor of the 'Economic Journal' and 'De economist'.

Centre on Regulation in Europe
Improving network industries regulation

1. Introduction

Europe is experiencing a wave of merger activity in the telecommunications industry that may lead to a consolidation of the EU's telecommunications market. In mobile telecommunications, in particular, the EC has recently cleared 4-to-3 mergers in the Netherlands, Austria, Ireland and Germany but its concerns regarding the impact on prices and competition have prevented a similar merger in Denmark. Another 4-to-3 merger is, however, currently under scrutiny in the UK, and another one will soon be examined in Italy. Earlier decisions had dealt with, and approved, 5-to-4 mergers in Austria, the Netherlands, and the United Kingdom. The debate extends beyond Europe. A 4-to-3 merger in Australia was approved in 2009. In the US, the federal regulator (FCC) blocked a merger between AT&T and T-Mobile in 2009 and then indicated that it would not allow a merger between T-Mobile and Sprint in 2014. The latter deal may, however, be reignited soon due to further changes in the US telecoms competitive landscape.

These mergers have been discussed in the context of considerable debate regarding the relationship between market structure and market performance. Competition and regulatory authorities typically focus on the pricing implications of mergers, as they are concerned that increased concentration comes with higher prices for end users. However, authorities seem to have paid less attention to the impact that such mergers could have on efficiencies, and, especially, investments. Mobile operators argue that their revenues continue to decline due to increasing competition from global Internet players, such as Skype and WhatsApp, offering alternative services. At the same time, operators argue that they are investing large sums into their broadband networks to meet the demand for data traffic. Consolidation, via mergers, is for them an attempt to maintain profitability levels and keep up with investments.

In this paper we study the relationship between prices, investments, and market structure. We use an empirical approach by looking at the experience of thirty-three countries in the period 2002-2014. We collect what is, to our knowledge, the largest dataset employed to-date for works of this kind. A challenge in assembling a panel dataset like ours is to find relevant and comparable information at the operator level, between countries and over time. The dataset spans a time period long enough to capture changes in market structure (especially entry via licensing, and exit via mergers) that provide ideal variation in the data to assess how market structure impacts on prices and investments, holding other factors constant.

Our study helps the quantification of the likely horizontal effects of a merger which is only one, but nevertheless an important, element of the competitive assessment of complex mergers. We find that an increase in market concentration in the mobile industry generates a true economic trade-off. While a merger will increase prices, according to our analysis investment per operator will also go up. For example, an average hypothetical 4-to-3 symmetric merger, in our data, would suppose an increase in the bill of end users by 16.3% when compared with a situation in which no merger

would have occurred, while at the same time capital expenditure (our proxy for investment) would go up by 19.3% at the operator level.

The rest of the study is organised as follows. In Section 2 we relate our work to the existing literature, especially to price-concentration and investment-concentration studies. Section 3 describes how we matched different sources of data to construct the dataset. Section 4 illustrates the empirical strategy we follow in identifying the causal relationship between market structure, prices, and investments. Section 5 presents the main results, while in Section 6 we conduct a detailed robustness analysis and several extensions. The limitations of our approach are discussed in Section 7. Section 8 concludes.

2. Literature

This paper is related to three streams in the literature. First and foremost, we belong to a long tradition in Industrial Organisation that has studied the relationship between market structure and performance, typically proxied by profits and/or prices. Second, we are interested in the important link between market structure and investments, which is part of a much larger field that has studied innovation and market structure. Last, we are specifically interested in conducting an empirical study related to the mobile telecommunications industry, which is also an active field of research.

As for the first element of literature, a long stream of papers in economics examines the relationship between competitive features of a market and profitability. In the structure-conduct-performance paradigm of Industrial Organisation, this literature relies on cross-sectional data across industries to provide evidence on the impact of concentration on profitability. A general finding in this literature is that higher market shares and increased supplier concentration are associated with higher profitability (see for example, Schmalensee, 1989). The profit-concentration studies have been criticised on several grounds. First, these studies are afflicted by measurement problems as accounting profits are poor indicators of economic profits. Second, the cross-sectional data from different industries used in these works is challenging due to large differences in demand and supply conditions across industries. Finally, these studies are subject to the "efficiency" critique offered by Demsetz (1973), who argued that the positive correlation between profits and market concentration could be due to the superiority of a few firms.

Over the past several decades, the profit-concentration studies have been replaced by related research that examines the relationship between market structure and prices, rather than profits. An advantage of using prices as opposed to profits is that they are not subject to accounting conventions, and they may be easier to obtain, often at a more detailed level of individual products sold by the firms. Weiss (1989) provides a collection of a large number of price-concentration studies and argues that, since prices are determined in the market, they are not subject to Demsetz's critique. Furthermore, the majority of the price-concentration studies use data across local markets within an industry, rather than across industries, making comparisons easier. These studies include a wide range of industries such as groceries (Cotterill, 1986), banking (Calem and Carlino, 1991), airlines (Borenstein and Rose, 1994), driving lessons (Asplund and Sandin, 1999), movie theatres (Davis, 2005), and the beer industry (Ashenfelter et al., 2015), to name just a few examples. Several studies have used price-concentration analysis to evaluate the effect of actual mergers on prices, for example in airlines (Borenstein, 1990; Kim and Singal, 1993), banking (Facacelli and Panetta, 2003), petroleum (Hastings, 2004; Gilbert and Hastings, 2005; Hosken et al., 2011), and appliances (Ashenfelter et al., 2013).

A general finding in this price-concentration literature is that high concentration is associated with higher prices (Weiss, 1989; see also a more recent survey by Newmark, 2004). However, as pointed

out by both Bresnahan (1989) and Schmalensee (1989) in their chapters in the Handbook of Industrial Organization, the price-concentration regressions, such as those used in the literature, suffer from endogeneity issues. In particular, there might be unobserved demand and cost shocks in a market that not only influence prices but also the underlying market structure. For instance, a market with unobserved high costs is likely to have higher prices, but these markets are also likely to attract fewer entrants. Evans et al. (1993) address this issue and propose a combination of fixed effects and instrumental variable procedures that are applicable when one has access to panel data, as we do. They study the price-concentration relationship in the airline industry and find that the effect of concentration on price is severely biased using OLS procedures.

As Whinston (2008) points out, price-concentration analysis is one of the most commonly used econometric techniques employed by competition authorities when analysing horizontal mergers. Similarly, Baker and Rubinfeld (1999) note that "reduced form price equations are the workhorse empirical methods for antitrust litigation".[1] The bias in the parameters capturing market structure and competitive interactions can therefore have important policy implications.

In our work, we deal with the mobile telecommunications industry, where there is no free entry by operators, as they need to be licensed according to spectrum availability. While this may make entry costs less prominent in the empirical analysis, other endogeneity problems are likely to emerge. In particular, investments to improve the quality of the networks, their coverage, and so forth, are likely to affect, and be affected by, the underlying competitive structure in the industry. Hence, our paper also contributes to the existing empirical literature on the relationship between competition and innovation (see Nickell, 1996; Aghion et al., 2005; Blundell et al., 1999; Aghion and Griffith 2006; Acemoglu and Akcigit, 2012). The existing empirical studies on this subject face the issue that the relationship between competition and innovation is endogenous, i.e., market structure may not only affect innovation but the reverse is also possible (Jaffe, 2000; Hall and Harho, 2012). We take advantage of various regulatory interventions that affected both entry and growth in the telecommunications market (see later the discussion on termination rate regulation) that allows us to construct instrumental variables that partly address these endogeneity concerns.

Work more specific to the mobile telecommunications industry has investigated several related questions. Some papers have studied the early stages of diffusion and focused on technology 'generations' (e.g., 1G/2G/3G), industry standards, and entry regulation (see, e.g., Gruber and Verboven, 2001a,b; Liikanen et al., 2004; Koski and Kretschmer, 2005; and Grajeck and Kretschmer, 2009). Typically, these works do not explicitly address the question of the impact of market structure on diffusion. An exception is Gruber and Verboven (2001a,b) who include a duopoly dummy variable which they find to be statistically significant but quantitatively small. Liikanen et al.

[1] A main alternative empirical method in antitrust is the structural approach, which starts by estimating own- and cross-price elasticities (or diversion ratios and markups) and then uses these parameters in an oligopoly model to measure the likely competitive effects of mergers. See, e.g., Werden and Froeb (1994) and Hausman et al. (1994) for a development of so-called merger simulation models, and Peters (2006) or Björnerstedt and Verboven (2015) for evaluations of their performance.

(2004) include two market structure variables: the number of firms and a 3-firm Herfindahl index; neither is found to be statistically significant. A limitation of these papers is that they refer to data from the 90s, which were still quite early in the diffusion process. Using more recent data, but following the same spirit of looking at the process of mobile diffusion, Li and Lyons (2012) find that both the number of networks, and the history of market structure, matter for the speed of consumer uptake. This market structure effect does not work only through the level of prices. Digital technology, standardisation, privatisation and independent regulation are also important positive factors in their study.[2]

To the best of our knowledge, we are not aware of any published academic study that relates market structure to investments in the mobile telecommunications industry. While some policy reports exist,[3] the academic literature so far has investigated investment matters only in the fixed telecommunications industry, where the focus is, however, typically different. A key question in fixed telecommunications, which is however less central in mobile telecommunications, is one-way access of new entrants to the infrastructure of the incumbent fixed-line operator (see, e.g., Greenstein and Mazzeo, 2006; Economides et al. 2008; Xiao and Orazem, 2009, 2011; Grajek and Roeller, 2012; and Nardotto et al., 2015).

[2] There is also literature that has looked at a different range of issues in the mobile industry, such as optimal contracts (Miravete, 2002), consumer inertia (Miravete and Palacios-Huerta, 2014), as well as competitive dynamics and the impact of regulation (Seim and Viard, 2011; Genakos and Valletti, 2011 and 2015).
[3] See, e.g., OECD (2014), Frontier Economics (2015) and HSBC (2015).

3. Data description and market trends

Our empirical analysis focuses on the link between measures of market concentration, prices paid by end users, and investments carried out by mobile operators.

3.1 Data Description

We focus on a large panel of OECD countries over the period 2002-2014. We combine data on prices of mobile baskets and operators' market shares, with information on their investments and profitability as well as information on the interconnection prices (termination rates) operators pay to each other for termination of calls.

We matched three different data sources for our analysis that we now describe.

Prices

We used Teligen to obtain quarterly information on the total bills paid by consumers across operators and countries (2002Q3-2014Q2). Teligen collects and compares all available tariffs of the two largest mobile operators for thirty-four OECD countries. It constructs different consumer usage profiles (e.g., large, medium and low users) based on the number of calls and messages, the average call length and the time and type of call.[4] A distinction between pre-paid (pay-as-you-go) and post-paid (contract) prices is also accounted for, as this is an important industry characteristic. These consumer profiles are then held fixed when looking across countries and time.[5]

The Teligen dataset has three main advantages. First, the information reported is about consumers' monthly bills, contrary to other metrics (such as ARPU) that confound several sources of revenues for the operator paid by different parties. Second, by fixing *a priori* the calling profiles of customers, it provides us with information on the best choices of these customers across countries and time, and accounts for possible heterogeneity in the calling profiles. Third, the prices reported in this dataset include much of the relevant information for this industry, such as inclusive minutes, quantity discounts, discounts to special numbers, etc. (although it does not include handset subsidies). However, this richness of information comes at the cost of having data for only the two biggest operators of every country at each point in time. This reduces the variability and can make identification of our variables of interest harder. Moreover, examining a decade long of consumer

[4] Note that these are hypothetical profiles and not actual customer bills. The 2010 and 2012 Teligen revision of profiles includes more than three customer profiles. For consistency we selected three profiles that still correspond to large, medium and low users.

[5] While it is common to use fixed consumer profiles or consumption baskets to compare prices, it is subject to several related biases, relating to substitution, quality improvements and new product introduction. See for example Hausman (2003) for a discussion. Our approach to this issue has been to perform a sensitivity analysis with respect to alternative baskets, as discussed below.

behaviour in such a dynamic industry such as the telecommunication industry, would perhaps call into question the stability of the customer profiles throughout the whole period. Indeed, Teligen adjusted the calling profiles of its customers, first set in 2002, in 2006, and then again in 2010 and in 2012, and we will also use this information to examine the robustness of our results. Note that the 2002, 2006 and 2010 basket definitions only include voice and SMS, while the 2012 basket definition also allows for data.

Market structure and investments

The second main dataset is the quarterly information taken from the Global Wireless Matrix of the Bank of America Merrill Lynch dataset (henceforth, BoAML). BoAML reports a wealth of data, namely:

Market structure: number of mobile network operators, and total number of subscribers per operator. From the latter, we can compute market shares, as well as the Herfindahl-Hirschman Index (HHI) of concentration, which is the sum of the squares of market shares. The dataset also reports the time when the entry license was granted to each operator. We also compute indicators of cumulative entry in each market, that is, the cumulative number of entrants since 2000, and similarly for cumulative exit.

Financial indicators: BoAML compiles quarterly basic operating metrics for mobile operators in over fifty countries. For our purposes, we use, first and foremost, capital expenditure (CAPEX), that is, money invested by an operator to acquire or upgrade fixed, physical, non-consumable assets, such as cell sites or equipment. This is going to be our proxy for investments. We will also use, at times, earnings margin before interest, taxes, depreciation and amortisation (EBITDA), which is a good accounting metric for operators' profits, as well as EBITDA margins, which are informative about the profitability of an operator expressed as a percentage of revenues (hence forming an accounting proxy for the Lerner index). Finally, we also look at the quarterly reported average revenue per user (ARPU), as this is often mentioned in the policy debate. Note that, contrary to the Teligen dataset, the BoAML dataset in principle contains information for all operators in a given country.

Mobile termination rates

Mobile operators charge other network operators (fixed or mobile) for connecting calls to their subscribers – the so called mobile termination rates (MTRs). Using mainly Cullen International, but also various other industry and regulatory publications, we were in a position to identify the level of MTRs both before and after its regulation, and to identify the dates in which MTR regulation was introduced across countries and operators.

Finally, we also collected information on GDP per capita and population in each country and period.

All consumer prices, termination rates and data from financial accounts were converted to euros using the Purchasing Power Parities (PPP) currency conversions published by the OECD to ease

comparability. The final dataset comprises 33 countries and more than 7,000 observations for the period 2002-2014.[6]

Table 1 provides some key summary statistics for the main variables. The top panel shows the summary statistics for our price analysis, for the entire period 2002-2014, and for the period 2006-2014 (our main focus as this information is more complete). The average price (or bill) of a basket during 2006-2014 was 565 euro per year, with a standard deviation of 3,328 euro. This reflects variation across countries and over time, but also variation between the two largest operators for which we have information and the three user profiles. The average number of competitors during this period was 3.6, where 34.3% of the observations refer to markets with 4 competitors and 7.8% to markets with 5 or more competitors (and the remaining 57.9% referring the markets with 2, or much more frequently 3, competitors). The HHI was on average 0.359 (or 3,590 after multiplying by 10,000 as is commonly done). Finally, we report information on control variables such as GDP per capita (on average $41,182 per year), the mobile termination rate (on average $0.087 per minute) and the difference in the MTRs of the least regulated operator and the most regulated operator in each country and period (on average 0.301).

The bottom part shows similar descriptive information for our analysis of investments. Note first that the number of observations is smaller, in part because the unit of analysis is different (operator instead of the operator and user profile, even if only two operators per country has been observed in the Teligen dataset), but also in part because data are less complete for the period before 2006. Because of the latter reason, we focus our main analysis on the period 2006-2014. Investment per operator (CAPEX) had a quarterly average of $165 million post-2005, compared with average profits (EBITDA) of $386 million, with considerable variation between operators, across countries and over time. Operator EBITDA margins were on average 34.9% and monthly average revenue per user (ARPU) was $32.8. The information on the control variables is comparable to what we reported for our price analysis in the top part of Table 1.

[6] The countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, UK.

Table 1: Summary statistics

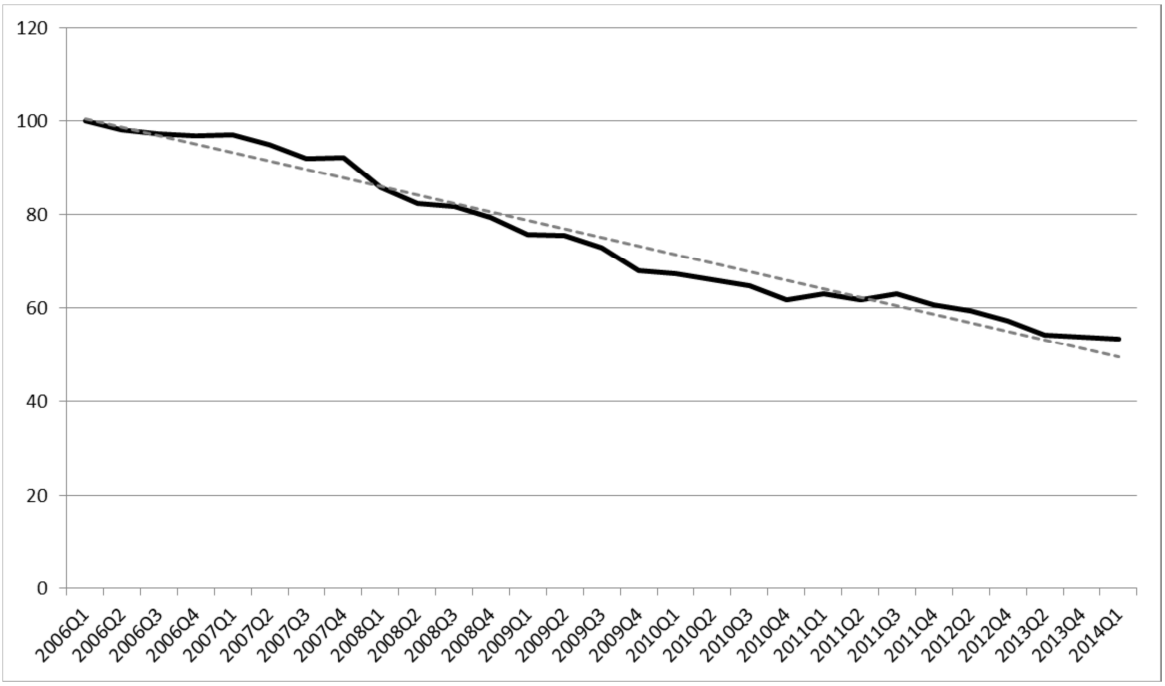
Variable	Observations	Mean	Stand. Dev.	Observations	Mean	Stand. Dev.
	Teligen dataset (2002 – 2014)			*Teligen dataset (2006-2014)*		
Mobile price (P_{uoct})	7789	559.7	2760.7	5329	564.7	3328.2
Num. of comp. (N_{ct})	7378	3.556	0.925	5002	3.558	0.830
Four competitors dummy (0/1)	7789	0.293	0.455	5329	0.343	0.475
Five+ competitors dummy (0/1)	7789	0.113	0.317	5329	0.078	0.268
Cumulative entry	7378	0.382	0.536	5002	0.419	0.548
Cumulative exit	7378	0.298	0.607	5002	0.383	0.686
HHI	7330	0.371	0.078	5002	0.359	0.065
Pre-paid dummy (0/1)	7789	0.349	0.477	5329	0.360	0.480
GDP per capita	7510	37803.0	20813.9	5134	41181.8	21964.2
MTR	6679	0.105	0.068	4930	0.087	0.058
MTR_Diff$_{ct}$	6760	0.502	2.595	4930	0.301	1.436
	Bank of America Merrill Lynch dataset (2002 – 2014)			*Bank of America Merrill Lynch dataset (2006 – 2014)*		
CAPEX$_{oct}$	2573	159.6	257.6	2345	164.9	267.0
EBITDA$_{oct}$	3004	376.5	545.1	2715	386.1	560.2
EBITDA margin$_{oct}$	4666	0.321	0.237	2704	0.349	0.221
ARPU$_{oct}$	4994	35.205	62.213	2875	32.793	81.086
Num. of comp. (N_{ct})	5049	3.805	1.013	2903	3.725	0.866
Four competitors dummy (0/1)	5049	0.361	0.480	2903	0.429	0.495
Five+ competitors dummy (0/1)	5049	0.188	0.391	2903	0.118	0.323
Cumulative entry	5049	0.317	0.481	2903	0.372	0.483
Cumulative exit	5049	0.297	0.597	2903	0.454	0.711
HHI	5049	0.361	0.077	2903	0.349	0.069
GDP per capita	4793	33782.4	16886.1	2761	39335.5	17791.8
MTR	3922	0.123	0.089	2495	0.084	0.064
MTR_Diff$_{ct}$	3957	0.444	2.325	2495	0.317	1.443

Source: Authors' calculations based on the Teligen, Cullen and BoAML matched datasets.
Notes: The above table provides summary statistics on the key variables used in Tables 3-14 based on the Teligen data corresponding to the best deals available at every quarter, the BoAML dataset and the matched MTRs.

3.2 Market trends

Figure 1 shows the evolution of mobile tariffs during 2006Q1-2014Q1, using normalised at the beginning of the period demeaned average prices across countries from the Teligen data. Prices steadily declined by almost 50% during this period, amounting to an average decline of 2.2% per quarter.

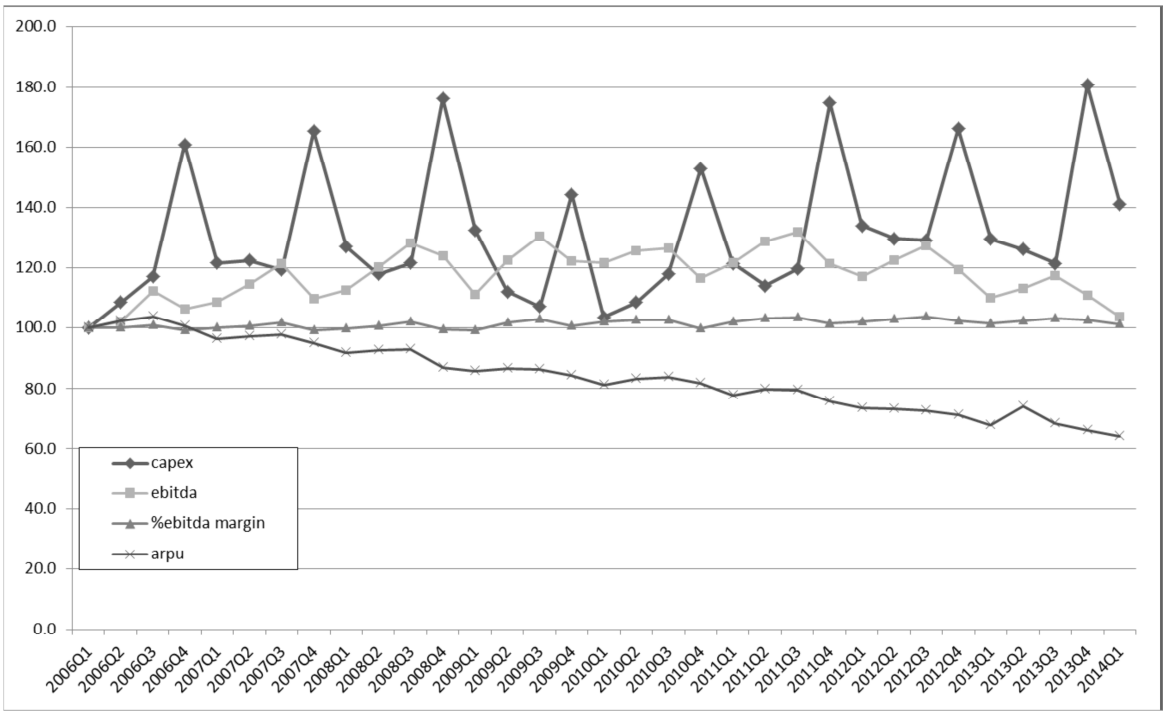
Figure 1: Price evolution of mobile tariffs, 2006Q1-2014Q1 (2006Q1=100)



Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.
Notes: The figure presents information on the normalised (at the beginning of the period) PPP-adjusted demeaned average prices (total bill paid) across countries.

Figure 2 shows the evolution of the demeaned average investment (CAPEX), profits (EBITDA and EBITDA margin) and average revenue per user (ARPU) across countries and operators from the BoAML data. Investment (CAPEX) has gradually increased (with seasonal peaks in the last quarter of each year). Profits (EBITDA) increased by about 25% from 2006Q1 until 2011Q3, but then started to decline again to reach the same level per operator in the last quarter as in the first. This may be due to a gradual decline in average revenue per user across the period, insufficiently compensated by a growth in the number of subscribers as markets matured. Finally, notice that average EBITDA margins remained fairly stable across the period.

Figure 2: Evolution of investment (CAPEX), profits (EBITDA) and revenues (ARPU), 2006Q1-2014Q1



Source: Authors' calculations based on accounting information from the Global Wireless Matrix of the Bank of America Merrill Lynch (BoAML) dataset.
Notes: The figure presents information on the normalised (at the beginning of the period) PPP-adjusted demeaned average CAPEX, EBITDA, EBITDA margin and ARPU across countries.

Table 2 shows the evolution of the number of competing operators across the countries in our data set. In most countries there were 3 firms, but there is considerable variation across countries and over time. Several new firms entered, so there are no more countries left with only 2 operators, and in an increasing number of countries there are now 4 instead of 3 operators. At the same time, there has also been exit through merger, since there are only a few countries remaining with at least 5 competitors.

Table 2: Countries and competitors

Period	2002Q2	2006Q1	2010Q1	2014Q1
	Number of countries	***Number of countries***	***Number of countries***	***Number of countries***
2 competitors	3	3		
3 competitors	14	14	16	18
4 competitors	7	7	10	13
5 competitors	3	3	1	1
6 competitors	1	1	1	1
TOTAL	**28**	**28**	**28**	**33**

Source: Authors' compilation based on BoAML dataset

These trends illustrate that there has been considerable changes in our main variables of interest: prices, investment and the number of mobile network operators. This variation is not just limited to the time dimension; it is also present at the country and operator level, as our summary statistics in Table 1 suggested. This provides us with the necessary information to study the impact of market structure on prices and investments. Nevertheless, this discussion also tells us that we should be cautious in accounting for general trends (or fluctuations), as we are interested in identifying the impact of market structure over and above any historical trends. We discuss how we do this in the next section, where we introduce our empirical framework.

4. Empirical framework

For our empirical analysis on prices, we estimate the following equation:

(1) $$\ln P_{uoct} = \alpha_{uoc} + \alpha_t + \beta_1 Mkt\_Str_{ct} + \beta_2 Char_{uoct} + \varepsilon_{uoct}.$$

The dependent variable in eq. (1) is the logarithm of (euros PPP adjusted) retail prices ($\ln P_{uoct}$) paid by a customer with the usage profile u = {low, medium, high} and subscribing to mobile operator o in country c in quarter t. Time fixed effects (α_t) and usage-operator-country fixed effects (α_{uoc}) control for global trends and for time-invariant usage-operator-country characteristics, respectively. The vector $Char_{uoct}$ includes several control variables that may influence prices and vary across tariffs, operators or countries. Specifically, we include a dummy variable for whether the tariff is post-paid (instead of prepaid), the logarithm of GDP per capita, the logarithm of the mobile termination rate to account for a possible "waterbed effect" of regulation, and the logarithm of the mobile termination rate interacted with a time trend to account for a possible declining effect as fixed-to-mobile calls have decreased in importance over time (Genakos and Valletti, 2011, 2015). The main variable of interest, Mkt_Str_{ct}, is an indicator of the market structure in country c in quarter t. In particular, we use two alternative indicators of market structure in country c in quarter t, respectively N_{ct}, that is, the number of operators, and HHI_{ct}, that is, the Herfindahl-Hirschman Index.

We estimate the model in first-differences to eliminate the large set of usage-operator-country fixed effects (α_{ujc}). While a within-transformation would achieve the same purpose, the first-difference approach is more appropriate here because of the presence of serial correlation in the error terms ε_{uoct}. We use clustered standard errors at the usage-operator-country level.

Note that in the special case of where our panel consists of only two countries and two time periods, our model simplifies to a standard difference-in-differences estimator, where one estimates the effect of a change in market structure in one country relative to a control country where no change occurred. Hence, our panel data model with multiple periods and countries can be interpreted as one that puts some additional structure to identify the effects (by allowing for different control groups at different points in time).

When we turn to the analysis on operator investment, we estimate the following equation:

(2) $$\ln CAPEX_{oct} = \alpha_c + \alpha_t + \beta_1 Mkt\_Str_{ct} + \beta_2 Op\_Char_{oct} + \varepsilon_{oct},$$

where the dependent variable is now the logarithm of Capex of mobile operator o in country c in quarter t. We include time fixed effects (α_t) to account for general trends and especially seasonal effects, and country fixed effects (α_c) to account for systematic differences between countries. The vector Op_Char_{oct} includes several variables that may affect investment and that may vary across operators and/or time. First, we include dummy variables for the order of entry (first, second and third entrant relative to the remaining operators). Second, we include a variable to indicate the time since the operator first entered. These variables capture the fact that first-movers who are in

the market for a long time may have different incentives to invest than late movers who entered more recently. Third, we include the logarithm of GDP per capita.[7] We estimate the model using fixed effects (and not first-differences) because Capex is most often lumpy and not serially correlated (although it does show seasonal variation, for which we control). We cluster the standard errors by country and operator.

We also present results for alternative measures of the outcome of interest, where $CAPEX_{oct}$ in eq. (2) is replaced by $EBITDA_{oct}$, $(EBITDA\ margin)_{oct}$, and $ARPU_{oct}$, respectively.

Finally, we also consider an analysis of total industry investment at the country level, based on the following specification:

$$(3) \qquad lnTOTCAPEX_{ct} = \alpha_c + \alpha_t + \beta_1 Mkt\_Str_{ct} + \beta_2 Mkt\_Char_{ct} + \varepsilon_{ct},$$

The dependent variable is now the logarithm of total industry Capex across all mobile operators in country *c* in quarter *t*. Since Capex is not observed for some operators, we adjusted total industry Capex by dividing by the total market share of the operators for which we have Capex information. We again include time fixed effects (α_t) and country fixed effects (α_c). The vector Mkt_Char_{ct} includes the logarithm of GDP per capita and the logarithm of population (as measures of potential market size). As for the operator investment equation, we estimate the model using a within transformation (fixed effects). Finally, we cluster the standard errors at the country level.

We also considered alternative measures of industry performance outcomes at the country level, where we replace $TOTCAPEX_{ct}$ in (3) by $TOTEBITDA_{ct}$ (again adjusted by the market share) and total mobile subscription penetration.

Our empirical analysis faces one key empirical challenge, as potential endogeneity plagues the identification of the effects of market structure on prices and investments. When we use the number of operators as a proxy for market structure, recall that the mobile industry is not a free-entry industry. Rather, operators must be awarded spectrum licenses. It is possible to argue that the main driver of the entry process is therefore related to license conditions, spectrum availability, and ultimately to the institutional endowments of various countries that can be assumed to be exogenous to the level of prices or investments in a specific industry, such as mobile communications. Hence, we will treat N_{ct} as exogenous. This is however subject to criticism on two grounds.

First, the variable N_{ct} also changes because of mergers, which can be endogenous to the level of prices and investments, meaning that mergers may depend on price levels and prospects for investments. Since we are aware of this problem, in the empirical analysis we will treat differently changes in market structure due to entry that typically reduce concentration (likely to be

[7] We also considered a richer specification with operator and country fixed effects α_{oc}, but these additional interaction effects are not jointly significant. Similarly, we considered including the mobile termination rate (and trend interaction), and these effects were not significant. Since we had no clear *a priori* expectations on the role of these additional variables, we therefore focus on a more parsimonious specification without these variables.

exogenous) from those due to mergers that increase concentration and may suffer from endogeneity problems. In this way, the interpretation of the empirical findings should be more transparent by distinguishing between increases in number of operators (possibly more exogenous) from decreases (possibly more endogenous).

Second, N_{ct} in practice takes a limited number of values (typically, 2 to 5, with most countries at 3 or 4), and so it does not show a lot of variation in the data, making the effects tougher to identify. For this reason, we experiment with a second indicator of market structure, HHI_{ct}, which shows considerably more variation, especially some very useful within-country variation. The HHI however cannot be taken as exogenous, as market shares depend on prices and on investments. For this reason, we follow an instrumental variable approach to account for the endogeneity of this HHI. This means that we first explain the HHI based on a number of instrumental variables, where at least some of these variables do not have a direct impact on the dependent variable (prices or investment). More specifically, we use the following instruments to predict the HHI and hence deal with the endogeneity issue. First, we use the *difference* in the MTRs of the least regulated operator and the most regulated operator in country *c* in period *t* (MTR_Diff_{ct}).[8] We take advantage not only of the different timing of the introduction of regulation across countries, but also of the widespread variation on the rates imposed across operators within countries. This variation in regulated MTRs was particularly evident in countries where there was a large asymmetry between the "large" incumbents and the "small" entrants. In practice, regulators have been more reluctant in cutting the MTRs of the new entrants. They did this, most likely, with the idea of helping them secure a stronger position in the market. Thus, the *difference* in MTRs should not directly affect prices, especially of the large incumbent operators that are reported in the Teligen price dataset, but rather should boost the market shares of the smaller operators, thus impacting on HHI and on prices only indirectly via this channel.[9] Second, we use binary indicators for the number of competitors to take advantage of the regulated nature of entry and exit in this industry. Third, we use two separate variables to measure separately cumulative entry and exit of operators in each country to proxy the differential impact of entry and exit in market concentration.

[8] Note that while the *level* of MTRs might have a direct impact on prices, especially via off-net calls, thus violating the exclusion restriction, this is not true for the *difference* in the MTRs that we focus on. Statistical tests on the validity of the instruments are performed in the analysis below.

[9] Regulatory intervention over MTRs does not occur randomly either, but is the outcome of a long regulatory and political process. However, as reported by Genakos and Valletti (2011 and 2015), this process regarding MTRs has been driven in practice by legal and institutional aspects. The UK has been at the forefront and already started regulating MTRs back in 1997. Other countries followed suit. Importantly, the European Commission introduced a New Regulatory Framework for electronic communications in 2002. The Commission defined mobile termination as a relevant market. Procedurally, every Member State is obliged to conduct a market analysis of that market and, to the extent that market failures were found, remedies would have to be introduced. Indeed, all the countries that completed the analysis did find problems without exception, and imposed (differential) cuts to MTRs (typically, substantial cuts to incumbents and either no cut or only mild cuts to entrants). Hence, the timing of the introduction of regulated MTRs, but also the severity with which they were imposed across mobile operators, has been driven by this regulatory process and varied widely across countries with no systematic pattern.

5. Main results

In this section we discuss the main results on the effects on prices (subsection 5.1) and investment (subsection 5.2). In section 6 we report the results of a detailed robustness analysis, including alternative performance measures.

5.1 Price results

Table 3 shows the results from estimating the price equation (1), for alternative measures of market structure. These results are based on the sample of prices for all countries in our dataset post-2005, where we allow for varying baskets to account for changes in user profiles (such as an increased use of data in recent years): the 2006 basket for the period 2006-2009, the 2010 basket for the period 2010-2011 and the 2012 basket for the period 2012-2014.

First consider the effects of market structure on prices using our alternative measures of market structure. Based on column 1 of Table 3, one more competitor leads to a price reduction of approximately 8.6%. This specification is restrictive since it assumes the percentage effect is the same whether one moves from 2 to 3 or from 6 to 7 operators. Column 2 allows for different effects depending on the number of entrants. This shows that prices decrease more, by about 15.9%, in markets with 4 operators compared with the comparison group of 2 or 3 operators. In markets with 5 or more operators, prices are reduced by 7.9% with a new entry, but the effect is estimated rather imprecisely (standard error of 6.3%).[10] Column 3 allows for asymmetric effects of entry and exit, using variables that measure the cumulative net entry or cumulative net exit since 2000. Cumulative entry is typically related to new licenses being awarded, while exit is typically associated with mergers. Results in column 3 show that a net entry reduces prices by about -9.3%, whereas a net exit increases prices by only 4.3% (with significance at the 10% level). One possible interpretation of this finding is that exit due to a merger mainly occurs between smaller firms, whereas entry may result in a new, larger firm. An additional possible explanation of this asymmetric effect is that mergers are scrutinised and approved by authorities, who may impose pro-competitive remedies to clear the mergers.

The previous results are informative, but they do not account well for the impact of entry and mergers of different sizes. Accounting for different sizes is particularly interesting to evaluate the effects of specific mergers. For this reason, the last two columns show the effects of increases in concentration based on the HHI index, defined earlier. As discussed, we account for the endogeneity of the HHI using the difference between the highest and lowest mobile termination rate (MTR_Diff_{ct}) as an instrument. A first stage regression shows that the coefficient on MTR_Diff_{ct}

[10] We considered a more general specification, where we distinguish between 3, 4, 5, 6 or 7 operators relative to the base of 2 operators. Results from this specification are often imprecisely estimated, because there are only a few markets/countries with 2, or with 6 or more operators as shown earlier in Table 2.

has a highly significant negative impact on concentration. This is as expected when the regulator intends to help small firms through higher MTRs. The first-stage regressions also show that our instruments are very powerful: the F-test on the excluded instruments is above 30 in column 4 and above 50 in column 5. Column 4 also uses dummies for the number of competitors as instruments, whereas column 5 uses the cumulative entry and exit variables as additional instruments. Both specifications show that an increase in the HHI has a positive and significant impact on prices: 2.037 in column 4, and 2.529 in column 5. To illustrate, according to the first case in column 4, an increase in the HHI by 10 percentage points (for example from 0.3 to 0.4) would increase prices by 20.37%.[11] Similarly, a 4-to-3 merger in a symmetric industry (raising the HHI by 8 percentage points from 0.25 to 0.33, would increase prices by 16.3%. This is an average effect based on the sample of all countries post-2005. While this effect is statistically significant, it has a relatively wide 90% confidence interval, between 7.9% and 24.7%. This may reflect the fact that the merger effects depend on specific circumstances in a country at a certain point in time. How important is this effect against the background of the general price drop of 47% over the same period of eight years? Given that the price trend is -2.2% per quarter, a hypothetical merger that increases the HHI by 10 percentage points is roughly equivalent to going back to the price level of about 8 or 9 quarters ago.

The rest of the control variables in Table 3 are in line with expectations. First, the pre-paid dummy is not significant, indicating that the impact of market structure on post-paid and pre-paid prices is on average equivalent. This is not surprising since Teligen selects the best possible prices across pre and post-paid contracts within each user profile. Second, changes in GDP per capita over time and across countries do not have a significant impact on prices over and above possible effects from systematic cross-country variation. Again this is to be expected given the extensive set of country-operator-usage and time control variables. Third, the mobile termination rates have a significant effect on prices, though this effect declines over time.[12] These findings are consistent with recent findings of Genakos and Valletti (2015): they also find a significant but declining waterbed effect, which they attribute to a fundamental change in the telecoms market. While in the early years, most calls to mobile phones would be made from fixed lines, more recently mobile voice traffic has overtaken fixed line call volumes, changing the economic forces that give rise to the waterbed effect.

[11] In a common convention where the HHI is multiplied by 10,000, an increase in the HHI by 10 percentage points from 0.3 to 0.4 corresponds to an increase from 3,000 to 4,000.

[12] For example, in the fourth regression (column 4) the mobile termination rate coefficient is 0.201, saying that a 1% increase in the mobile termination rate in the first quarter of 2006 led to a price increase of 0.201%. Because of the declining trend effect (-0.00451), the effect declined to an insignificant 0.0612 in the last quarter of 2013 (0.201-31*0.00451).

Table 3: The impact of market structure on prices

	(1)	(2)	(3)	(4)	(5)
Estimation method	**FD**	**FD**	**FD**	**IV-FD**	**IV-FD**
Dependent variable	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**
Teligen basket	**varying basket**	**varying basket**	**varying basket**	**varying basket**	**varying basket**
Time Period	**2006-2014**	**2006-2014**	**2006-2014**	**2006-2014**	**2006-2014**
Number of mobile operators	-0.0855***				
	(0.0290)				
Four competitors		-0.159***			
		(0.0425)			
Five+ competitors		-0.0785			
		(0.0629)			
Cumulative entry			-0.0934*		
			(0.0488)		
Cumulative exit			0.0432*		
			(0.0248)		
HHI				2.037***	2.529**
				(0.637)	(1.148)
Pre-paid$_{jct}$	0.0338	0.0360	0.0344	0.0337	0.0337
	(0.0543)	(0.0537)	(0.0544)	(0.0543)	(0.0543)
Log GDP per capita	-0.0153	-0.0845	-0.0199	-0.0142	-0.0110
	(0.213)	(0.180)	(0.213)	(0.216)	(0.216)
ln(MTR)$_{jct}$	0.192***	0.168***	0.194***	0.201***	0.201***
	(0.0693)	(0.0553)	(0.0689)	(0.0685)	(0.0689)
ln(MTR)$_{jct}$ × time trend	-0.00449**	-0.00403***	-0.00451**	-0.00484***	-0.00486***
	(0.00182)	(0.00139)	(0.00181)	(0.00179)	(0.00179)
Constant	-0.066	-0.052	-0.056**	-0.094***	-0.094***
	(0.050)	(0.077)	(0.026)	(0.022)	(0.022)
Instrumental Variables				*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Cumulative entry and cumulative exit
First stage partial R^2 of excl. IVs				0.450	0.302
First stage F-test				33.25	51.49
				[0.000]	[0.000]
Observations	4,550	4,682	4,550	4,550	4,550
R^2	0.788	0.787	0.788	0.788	0.787
Clusters	192	192	192	192	192

Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.
*Notes: The dependent variable is the logarithm of the euros PPP adjusted total bill paid by consumers with different usage at every quarter. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

Next, we consider how the results are affected when we increase the sample to the entire period available, and/or restrict the sample to only European countries (which constitute a more homogeneous group of treatment and control countries). For simplicity, we focus only on the results based on the HHI measure of concentration, using the first instrument set that, based on the previous results, is somewhat more conservative.

Table 4 presents the results. Compared with the sample of all countries post-2005 (column 1) the estimated effect of the HHI drops to 1.399 (column 2), when we consider the full sample (since 2002). Furthermore, the estimated effect of the HHI is also lower for the sample of European countries (it decreases to 1.028 in column 3 in the sample post-2005 and to 0.827 in the full sample in column 4). The estimated effect remains significant at the 10% level or higher.

Table 4: The impact of market structure on prices - robustness

	(1)	(2)	(3)	(4)
Estimation method	**IV-FD**	**IV-FD**	**IV-FD**	**IV-FD**
Dependent variable	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**
Teligen basket	**Varying basket**	**Varying basket**	**Varying basket**	**Varying basket**
Countries	**All**	**All**	**Europe only**	**Europe only**
Time Period	**2006-2014**	**2002-2014**	**2006-2014**	**2002-2014**
HHI	2.037***	1.399***	1.028*	0.827**
	(0.637)	(0.465)	(0.528)	(0.375)
Pre-paid$_{jct}$	0.0337	0.0287	-0.0526**	-0.0446**
	(0.0543)	(0.0468)	(0.0212)	(0.0185)
Log GDP per capita	-0.0142	-0.0227	0.184	0.144
	(0.216)	(0.193)	(0.183)	(0.164)
ln(MTR)$_{jct}$	0.201***	0.177***	0.271***	0.203***
	(0.0685)	(0.0524)	(0.0672)	(0.0544)
ln(MTR)$_{jct}$ × time trend	-0.00484***	-0.00411***	-0.00702***	-0.00527***
	(0.00179)	(0.00145)	(0.00180)	(0.00151)
Constant	-0.094***	-0.112***	-0.133***	-0.125***
	(0.022)	(0.0238)	(0.0274)	(0.0271)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.450	0.194	0.585	0.2306
First stage F-test	33.25	42.03	15927.21	951.12
	[0.000]	[0.000]	[0.000]	[0.000]
Observations	4,550	6,044	3,632	4,886
R^2	0.788	0.782	0.895	0.888
Clusters	192	201	150	156

Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.

*Notes: The dependent variable is the logarithm of the euros PPP adjusted total bill paid by consumers with different usage at every quarter. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

5.2 Investment results

Table 5 presents the results from estimating the investment equation (2) at the operator level, for alternative measures of market structure. As for our price analysis, these results are based on the sample of all countries in our dataset post-2005. We find that the number of firms does have an impact on investment. Markets with more operators have lower investment per operator than those with fewer operators.

The impact of our various measures of market structure can be summarised as follows. In column 1, each additional competitor reduces investment per operator by about 10.7%. The impact of entry may depend on the number of entrants. As column 2 shows, in markets with four operators, investment per operator is 18.3% lower than in the comparison group of markets with two or three operators. Furthermore, in markets with five or more operators, investment per operator is 25.3%, or an additional 7%, lower. Column 3 shows that a new entrant has a stronger negative effect on investment than the positive effect on investment associated with exit, though the effects are estimated imprecisely.

The last two columns of Table 5 show the results based on the HHI measure of concentration. The results from the first stage regression of the HHI on our instruments are comparable to what we found before (though not identical since the two samples differ somewhat). An increase in the HHI by 10 percentage points raises investment per operator by 24.1% using the first instrument set (column 4) and by 27.9% using the second instrument set (column 5). In both cases, the effect is statistically significant at the 5% level. Perhaps more concretely, a 4-to-3 merger in a symmetric industry (raising the HHI by 8 percentage points) would raise investment per operator by about 19.3% (under the first instrument set).[13] This suggests that increases in concentration involve a trade-off: on the one hand operators in more concentrated markets raise prices, but on the other hand, they also increase investments.

The control variables show that the order of entry matters to some extent, as the first, second and third entrants invest more than the comparison group (fourth and fifth entrants). The effects are, however, only significant at the 10% level, and there do not appear to be significant differences between the first three entrants. Similarly, the time since first entry does not seem to affect investment levels. GDP per capita has a significant and strong, nearly proportional effect on investment. For example, based on the results in column 4, an increase in GDP per capita by 1% raises the investment of an operator by 0.89%.

[13] The 90% confidence interval is larger than in our price analysis, between 4.0% and 34.6%, which reflects the more volatile nature of the investment data.

Table 5: The impact of market structure on operator's investment

Estimation method	(1) FE	(2) FE	(3) FE	(4) IV-FE	(5) IV-FE
Dependent variable	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$
Time Period	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014
Number of mobile operators	-0.107**				
	(0.0416)				
Four competitors		-0.183***			
		(0.0612)			
Five+ competitors		-0.253**			
		(0.120)			
Cumulative entry			-0.110		
			(0.0695)		
Cumulative exit			0.0560		
			(0.0541)		
HHI				2.410**	2.786**
				(1.164)	(1.204)
Time since entry$_{oct}$	0.0199	0.0204	0.0197	0.0120	0.0124
	(0.0220)	(0.0219)	(0.0223)	(0.0203)	(0.0203)
First entrant	0.676*	0.661*	0.681*	0.584*	0.577*
	(0.349)	(0.350)	(0.351)	(0.301)	(0.300)
Second entrant	0.535*	0.521*	0.539*	0.344	0.339
	(0.300)	(0.301)	(0.301)	(0.259)	(0.259)
Third entrant	0.496*	0.484*	0.501*	0.353	0.348
	(0.268)	(0.270)	(0.268)	(0.226)	(0.225)
Log GDP per capita	0.673**	0.631**	0.728***	0.888***	0.894***
	(0.264)	(0.270)	(0.261)	(0.275)	(0.279)
Instrumental Variables				*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Cumulative entry and cumulative exit
First stage partial R^2 of excl. IVs				0.586	0.476
First stage F-test				252.24	65.38
				[0.000]	[0.000]
Observations	2,202	2,202	2,202	2,073	2,073
R^2	0.173	0.174	0.173	0.139	0.137
Clusters	78	78	78	75	75

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable is the logarithm of CAPEX of mobile operator o in county c in quarter t. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

However, from a policy perspective it is also interesting to evaluate the investment at the country level. To do so we aggregate investment at the country level, weighting it by each operator market share to account for the fact that we do not have data on several, mainly small operators. Table 6 shows the results. GDP per capita is estimated to increase total industry investment, consistent with our earlier finding on investment per operator. Market size has a negative effect, suggesting some economies of scale, but its effect is not significant, most likely due to limited variation of population over time.

Regarding the main variables of interest, the first three measures of competition suggest that there is a negative effect of entry on total investment, but the effect is not statistically significant. According to our last measure, the HHI index, there is a positive relation between concentration and industry investment, but again the effect is estimated imprecisely (columns 4 and 5). The imprecise estimates may be due to the fact that investment is a noisier variable than prices, and further research on more detailed investment measures may give more conclusive results. Nevertheless, it is worth mentioning that our estimated effects on industry investment are presumably a lower bound for the effects on productive industry investment. Indeed, when there are fewer firms it is likely that there will be less duplication of fixed costs, so that the same level of industry investment may be better spent.

Table 6: The impact of market structure on industry investment

	(1)	(2)	(3)	(4)	(5)
Estimation method	**FE**	**FE**	**FE**	**IV-FE**	**IV-FE**
Dependent variable	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**
Time Period	**2006-2014**	**2006-2014**	**2006-2014**	**2006-2014**	**2006-2014**
Number of mobile operators	-0.0358				
	(0.0439)				
Four competitors		-0.0594			
		(0.0672)			
Five+ competitors		-0.0877			
		(0.0872)			
Cumulative entry			-0.0558		
			(0.0950)		
Cumulative exit			0.0179		
			(0.0525)		
HHI				1.196	1.457
				(1.592)	(1.240)
Log GDP per capita	0.559*	0.546	0.573*	0.625*	0.630*
	(0.335)	(0.335)	(0.321)	(0.377)	(0.381)
Log Population	-0.103	-0.107	-0.104	-0.124	-0.128*
	(0.0755)	(0.0792)	(0.0762)	(0.0772)	(0.0768)
Instrumental Variables				*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Cumulative entry and cumulative exit
First stage partial R^2 of excl. IVs				0.542	0.408
First stage F-test				70.81	11.82
				[0.000]	[0.000]
Observations	720	720	720	618	618
R^2	0.030	0.030	0.031	0.022	0.018
Clusters	27	27	27	24	24

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable is the logarithm of the market share adjusted CAPEX in county c in quarter t. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

5.3 Merger effects in specific cases

To better understand the economic significance of our previous findings, we consider what the model predicts for three actual mergers that took place in Europe during our sample. In particular, we consider two mergers from 4-to-3 in Austria and the Netherlands that materialised in 2013 and 2007 respectively, and a merger from 5-to-4 in the UK in 2010. Table 7 provides various market details about the three mergers, as well as our calculations for the predicted price and investment effects in these cases. Since the three considered mergers are all European and took place after 2005, we base the calculations on the estimates of a specification that includes only the European countries after 2005.

In Austria, the mobile operator Orange (with a market share of 19%) sold its business to 3-Hutchinson (with a market share of 11%). This resulted in an increase in the HHI by 6.4 percentage points. The model predicts that this leads to a price increase of 6.6% and an increase in investment per operator of 13.3%, though in both cases the 90% confidence intervals support the possibility of only a small increase, or fairly large increases up to 12.2% and 25.5%, respectively. In the UK, the 5-to-4 merger between T-Mobile and Orange had a comparable impact on the HHI (+6.9 percentage points), so that the predicted price and investment increases are comparable to those in Austria, +6.9% and 13.9% respectively. Finally, in the Netherlands the merger between the same firms had a lower impact on the HHI (+3.6 percentage points), so that the predicted impact is about half as large as in the other two countries, + 3.7% on prices and +7.5% on investment.[14] In principle, we could compare these predicted merger effects from the model with all EU countries, with the actual effects in the specific countries considered. But in practice, it proved difficult to provide accurate estimates on price and investment effects for individual countries, which motivated us to use the entire panel to identify the effects.

[14] Note that, when operator-level market shares remain constant after the merger, the HHI would increase by 2 times the product of the market shares of both merging firms (so by 4.2% in Austria, +3.6% in the Netherlands and +8.4% in the UK, based on the market shares in Table 7). In practice, market shares can, however, decrease or increase after a merger (depending on market power and efficiencies), so it is better to look at the actual change in the HHI. It is worth noting that, compared with the constant market share HHI increase, the actual change in the HHI was larger in Austria, about equal in the Netherlands, and smaller in the UK.

Table 7: Predicted merger effects for selected countries

Country	Austria	Netherlands	UK
Time of merger	2013Q1	2007Q4	2010Q2
Type of merger	4 to 3	4 to 3	5 to 4
Buyer	3 (Hutchison)	T-Mobile	T-Mobile
Market share buyer	11%	15%	21%
Seller	Orange	Orange	Orange
Market share seller	19%	12%	20%
HHI before	0.291	0.347	0.221
HHI after	0.355	0.383	0.288
Change in HHI	0.064	0.036	0.067
Predicted change in price	6.6%	3.7%	6.9%
90% confidence interval	1.0% 12.2%	0.6% 6.8%	1.1% 12.7%
Predicted change in investment	13.3%	7.5%	13.9%
90% confidence interval	1.2% 25.5%	0.7% 14.3%	1.2% 26.5%

Source: Authors' calculations based on the estimated coefficients from Table 4, column 3 and from Table 11, column 3.

Notes: Counterfactual calculations based on three recent actual mergers in Europe.

6. Robustness and extensions

We now report the results from several robustness checks and extensions.

6.1 Price results

We considered the robustness of our price analysis with respect to several assumptions. First, we considered how the results change for alternative samples (longer period, restriction only to European countries). This robustness analysis was already discussed in section 5.1 and the results from the European sample were applied to specific European countries in section 5.3.

Second, we considered how the results change when we used fixed baskets instead of varying baskets over the period. Table 8 shows the results of this exercise. The first two columns repeat our previous results where we allow for varying baskets (for the HHI measure of competition with the first instrument set), both for the sample post-2005 and for the full sample. The next two columns show the results when we use the 2002 basket throughout the entire period, again both for the sample post-2005 and for the full sample. The advantage of a fixed basket is that we use the same price proxy throughout the entire period. The disadvantage is, however, that the basket may become less representative, especially in recent years when consumers may have shifted their behaviour towards more data consumption. The estimated impact of the HHI becomes lower in this model. For the sample post-2005, an increase in the HHI by 10% is now estimated to increase prices by a statistically significant 12.93% (column 3), compared to the 20.37% estimate we obtained before using the varying baskets price measure. A similar finding holds when we use the whole sample since 2002, where the estimated effect of the 10% increase in the HHI is now 10.48% (column 4) compared to 13.99% under the varying basket measure (column 2). Finally, the last column reports the results when we use the 2006 basket (for the period post-2005). This again shows a lower estimate of the HHI: a 10% increase in the HHI raises prices by 16.28% (column 5) compared with 20.37% under the varying basket measure (column 1). In sum, accounting for varying baskets tends to result in somewhat larger price effects of increased concentration. This suggests that the price effects mainly manifest themselves in increased prices for data services rather than voice services.

Table 8: The impact of market structure on prices – varying vs. fixed baskets

	(1)	(2)	(3)	(4)	(5)
Estimation method	**IV-FD**	**IV-FD**	**IV-FD**	**IV-FD**	**IV-FD**
Dependent variable	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**
Teligen basket	**Varying basket**	**Varying basket**	**2002 basket**	**2002 basket**	**2006 basket**
Time Period	**2006-2014**	**2002-2014**	**2006-2014**	**2002-2014**	**2006-2014**
HHI	2.037***	1.399***	1.293***	1.048***	1.628***
	(0.637)	(0.465)	(0.375)	(0.351)	(0.450)
$Pre\text{-}paid_{jct}$	0.0337	0.0287	-0.0234	-0.0196	-0.00595
	(0.0543)	(0.0468)	(0.0176)	(0.0150)	(0.0189)
Log GDP per capita	-0.0142	-0.0227	-0.309***	-0.281***	-0.241**
	(0.216)	(0.193)	(0.101)	(0.0920)	(0.115)
$ln(MTR)_{jct}$	0.201***	0.177***	0.235***	0.197***	0.0888**
	(0.0685)	(0.0524)	(0.0503)	(0.0430)	(0.0355)
$ln(MTR)_{jct}$ × time trend	-0.00484***	-0.00411***	-0.00565***	-0.00459***	-0.00329**
	(0.00179)	(0.00145)	(0.00124)	(0.00112)	(0.00133)
Constant	-0.094***	-0.112***	-0.0357**	-0.0315**	-0.0257**
	(0.022)	(0.0238)	(0.0164)	(0.0154)	(0.0124)
Instrumental Variables	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.450	0.194	0.453	0.194	0.455
First stage F-test	33.25	42.03	33.44	41.94	58.58
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	4,550	6,044	4,533	6,027	4,590
R^2	0.788	0.782	0.094	0.088	0.021
Clusters	192	201	192	201	192

Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.

*Notes: The dependent variable is the logarithm of the euros PPP adjusted total bill paid by consumers with different usage at every quarter. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

As a further robustness analysis, we repeated this analysis for the sample of European countries only. This shows a similar picture, as summarised in Table 9: the estimated price effects from increased concentration tend to become smaller if we used fixed baskets for 2002 and 2006, but they remain statistically significant.

Table 9: The impact of market structure on prices – varying vs. fixed baskets, Europe only

	(1)	(2)	(3)	(4)	(5)
Estimation method	**IV-FD**	**IV-FD**	**IV-FD**	**IV-FD**	**IV-FD**
Dependent variable	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**
Teligen basket	**Varying basket**	**Varying basket**	**2002 basket**	**2002 basket**	**2006 basket**
Time Period	**2006-2014**	**2002-2014**	**2006-2014**	**2002-2014**	**2006-2014**
HHI	1.028*	0.827**	0.654**	0.500*	1.009***
	(0.528)	(0.375)	(0.281)	(0.299)	(0.318)
Pre-paid$_{jct}$	-0.0526**	-0.0446**	-0.0317*	-0.0264*	-0.00647
	(0.0212)	(0.0185)	(0.0165)	(0.0137)	(0.0200)
Log GDP per capita	0.184	0.144	0.0373	0.0133	0.0557
	(0.183)	(0.164)	(0.101)	(0.0931)	(0.105)
ln(MTR)$_{jct}$	0.271***	0.203***	0.244***	0.190***	0.126***
	(0.0672)	(0.0544)	(0.0522)	(0.0478)	(0.0317)
ln(MTR)$_{jct}$ × time trend	-0.00702***	-0.00527***	-0.00600***	-0.00458***	-0.00420***
	(0.00180)	(0.00151)	(0.00134)	(0.00127)	(0.00125)
Constant	-0.133***	-0.125***	-0.0217	-0.0150	-0.0145
	(0.0274)	(0.0271)	(0.0179)	(0.0170)	(0.0111)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.585	0.231	0.587	0.231	0.594
First stage F-test	15927.21	951.12	15436.07	1018.71	25310.55
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	3,632	4,886	3,591	4,845	3,654
R^2	0.895	0.888	0.093	0.086	0.025
Clusters	150	156	150	156	150

Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.

*Notes: The dependent variable is the logarithm of the euros PPP adjusted total bill paid by consumers with different usage at every quarter. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

Finally, to account for simple dynamics we also considered a specification with one-period lags for the market structure variables (with suitable lagged instruments in the specification with the HHI). We find that the coefficient of the lagged variable is statistically insignificant and also reduces the precision of the main estimate somewhat, so we prefer a simple specification with price adjustment within the same quarter.

We also considered one extension of our main analysis: we allow the effects of increased concentration to differ between different user profiles: low, medium and high. Table 10 presents the results. First, we remark that the role of the control variables remains broadly similar to what we found in our main results in Table 3. As for our main variables of interest, Table 10 shows that the impact of the HHI is the smallest for consumers with a low usage, and it is largest for consumers with a high usage. This seems to indicate that mergers or entry especially affects the high users. However, when taking into account the rather large standard deviations due to the reduced sample sizes, these differences are not statistically significant, so that one can conclude that different user profiles are not affected differentially by changes in market concentration.

Table 10: The impact of market structure on prices – different usage types

	(1)	(2)	(3)
Estimation method	**IV-FD**	**IV-FD**	**IV-FD**
Dependent variable	**lnP_{uoct}**	**lnP_{uoct}**	**lnP_{uoct}**
Teligen basket	**Varying basket**	**Varying basket**	**Varying basket**
Usage profile	**Low**	**Medium**	**High**
Time Period	**2006-2014**	**2006-2014**	**2006-2014**
HHI	1.751*	2.142*	2.246*
	(0.904)	(1.172)	(1.182)
Pre-paid$_{jct}$	-0.00264	0.0466	0.119
	(0.0281)	(0.0927)	(0.157)
Log GDP per capita	0.0614	-0.0933	-0.0455
	(0.230)	(0.263)	(0.456)
ln(MTR)$_{jct}$	0.0720	0.233*	0.340***
	(0.105)	(0.119)	(0.112)
ln(MTR)$_{jct}$ × time trend	-0.000615	-0.00736**	-0.00785***
	(0.00297)	(0.00312)	(0.00295)
Constant	-0.0193	-0.113***	-0.225***
	(0.0377)	(0.0304)	(0.0515)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.450	0.450	0.450
First stage F-test	10.35	10.96	11.01
	[0.000]	[0.000]	[0.000]
Observations	1,520	1,516	1,514
R^2	0.916	0.791	0.741
Clusters	64	64	64

Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter.

*Notes: The dependent variable is the logarithm of the euros PPP adjusted total bill paid by consumers with different usage at every quarter. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

6.2 Investment results

We also considered the robustness of our investment analysis with respect to several assumptions. First, we considered how the results change for alternative samples: longer period, restriction to European countries. As before, we only present the robustness analysis for the results of our specification with the HHI measure of competition (first instrument set). Table 11 shows the results for the analysis of investment per operator, while Table 12 shows the results for the analysis of total industry investment.

In Table 11, column 1, for ease of comparison we report the earlier obtained results for the main sample (period post-2005, all countries, shown in Table 5, column 4). According to Table 11, the estimated effect of the HHI on investment per operator becomes lower when we consider all years, or when we consider only European countries. However, using the entire sample is less appropriate since the investment information was available for fewer countries in the earlier periods.

In Table 12 we show the results from estimating the investment equation (3) at the country level. The base result in column 1 (period post-2005, all countries) shows a positive but not significant impact of HHI on investments at the country level. The estimated effect of the HHI on total industry investment also becomes lower when we consider all years or only European countries, but as before the effect is imprecisely estimated and insignificant.[15]

[15] We also did not find any statistically significant impact of our alternative market structure variables on total investment at the country level.

Table 11: The impact of market structure on operator's investment – alternative samples

	(1)	(2)	(3)	(4)
Estimation method	**FE**	**FE**	**FE**	**FE**
Dependent variable	**lnCAPEX$_{oct}$**	**lnCAPEX$_{oct}$**	**lnCAPEX$_{oct}$**	**lnCAPEX$_{oct}$**
Countries	**All**	**All**	**Europe only**	**Europe only**
Time Period	**2006-2014**	**2002-2014**	**2006-2014**	**2002-2014**
HHI	2.410**	1.400*	2.075*	1.119
	(1.164)	(0.796)	(1.149)	(0.786)
Time since entry$_{oct}$	0.0120	0.0123	-0.00232	0.00813
	(0.0203)	(0.0202)	(0.0365)	(0.0362)
First entrant	0.584*	0.568*	0.725	0.600
	(0.301)	(0.290)	(0.501)	(0.476)
Second entrant	0.344	0.307	0.554	0.405
	(0.259)	(0.252)	(0.429)	(0.414)
Third entrant	0.353	0.303	0.416	0.300
	(0.226)	(0.218)	(0.363)	(0.343)
Log GDP per capita	0.888***	0.941***	1.830***	1.688***
	(0.275)	(0.260)	(0.356)	(0.348)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.586	0.640	0.614	0.672
First stage F-test	252.24	168.70	534.62	500.43
	[0.000]	[0.000]	[0.000]	[0.000]
Observations	2,073	2,269	1,612	1,789
R^2	0.139	0.143	0.161	0.162
Clusters	75	75	59	59

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable is the logarithm of CAPEX of mobile operator o in county c in quarter t. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

Table 12: The impact of market structure on industry investment – alternative samples

	(1)	(2)	(3)	(4)
Estimation method	**FE**	**FE**	**FE**	**FE**
Dependent variable	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**	**lnCAPEX$_{ct}$**
Countries	**All**	**All**	**Europe only**	**Europe only**
Time Period	**2006-2014**	**2002-2014**	**2006-2014**	**2002-2014**
HHI	1.196	0.354	-1.362	-1.029*
	(1.592)	(0.956)	(1.425)	(0.554)
Log GDP per capita	0.625*	0.726**	1.341***	1.277***
	(0.377)	(0.321)	(0.289)	(0.321)
Log Population	-0.124	-0.121*	-0.123	-0.126
	(0.0772)	(0.0715)	(0.0926)	(0.0911)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.542	0.621	0.523	0.652
First stage F-test	70.81	38.38	330.54	125.00
	[0.000]	[0.000]	[0.000]	[0.000]
Observations	618	671	467	514
R^2	0.022	0.032	0.140	0.130
Clusters	24	24	18	18

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable is the logarithm of the market share adjusted CAPEX in county c in quarter t. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

Finally, as with the price analysis, we also considered a dynamic specification with one-period lags for the market structure variable. This is potentially more relevant for investment than for prices, as investment is more sluggish to adjust. However, we find that the effect of the lagged variable is insignificant and also implies an imprecise estimate for the effect of the market structure variable in the current period. This suggests that the data make it hard to identify the dynamics over time. As a further robustness check, we omitted the current market structure variable and only included the one-period lagged variable. In this specification, the lagged effects are very close to the effects found in the model without lags. We conclude that the impact of increased concentration on investment may not be immediate, but the precise response length is difficult to identify from the data.

6.3 Impact of market structure on other performance measures

As an addition to the price and investment analysis, we also considered other performance measures available from the same data source at the level of the operators. For the analysis of performance per operator, we considered the following performance measures: the impact on profits (EBITDA), on percentage profit margins (EBITDA margin) and on average revenue per user (ARPU). For the analysis of industry performance we considered total industry profits and total market penetration (subscribers as a percentage of total population). We also checked how the results for industry investment and industry profits change when we do not adjust the measure by total market size.

Table 13 shows the results for the performance per operator. We consider the period post-2005. Results can be summarised as follows:

- Profits (EBITDA) per operator (column 2): Both the order of entry and the time since entry have a significant and positive impact on profits. Furthermore, an increase in the HHI by 10 percentage points significantly raises profits per operator by 48.1% (column 2), whereas investment per operator increases by 24.1% (column 1), and vice versa for a decrease in the HHI by 10 percentage points.
- EBITDA profit margin (column 3): The order of entry matters, with the first entrant obtaining the highest profit margin, followed by the second and third entrant. An increase in concentration by 10 percentage points raises the profit margin by 5.37 percentage points. This increase in profit margin is consistent with our findings in the price analysis, but it can also be in part due to efficiencies from increased investment.
- Average revenue per user (ARPU; column 4): No operator-specific variables have a significant impact on this performance measure. Furthermore, the HHI does not have a significant impact either.[16]

[16] Note that EBITDA margin can be rewritten as (Average revenues – Average costs)/Average revenues = 1 – ACPU/ARPU, where ACPU denotes the average cost per user. Since we find that ARPU does not change with concentration, while EBITDA increases, this suggests that concentration should decrease the average cost per user.

Table 13: The impact of market structure on operator's performance – alternative measures

	(1)	(2)	(3)	(4)
Estimation method	**FE**	**FE**	**FE**	**FE**
Dependent variable	**lnCAPEX$_{oct}$**	**lnEBITDA$_{oct}$**	**EBITDA Margin$_{oct}$**	**lnARPU$_{oct}$**
Countries	**All**	**All**	**All**	**All**
Time Period	**2006-2014**	**2006-2014**	**2006-2014**	**2006-2014**
HHI	2.410**	4.809***	0.537**	0.115
	(1.164)	(1.531)	(0.267)	(0.627)
Time since entry$_{oct}$	0.0120	0.0481*	0.00285	0.0124
	(0.0203)	(0.0286)	(0.00372)	(0.00896)
First entrant	0.584*	2.017***	0.224***	-0.107
	(0.301)	(0.437)	(0.0471)	(0.0875)
Second entrant	0.344	1.753***	0.198***	0.0203
	(0.259)	(0.385)	(0.0398)	(0.0711)
Third entrant	0.353	1.524***	0.162***	-0.0805
	(0.226)	(0.334)	(0.0348)	(0.0546)
Log GDP per capita	0.888***	0.789**	0.0423	0.293***
	(0.275)	(0.361)	(0.0513)	(0.100)
Instrumental Variables	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors	*Diff MTR* index$_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.586	0.613	0.614	0.612
First stage F-test	252.24	309.02	307.69	311.34
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
Observations	2,073	2,231	2,221	2,338
R^2	0.139	0.596	0.371	0.051
Clusters	75	80	79	81

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable varies by column as indicated in row 3. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

Table 14 shows the results for industry performance at the country level. Again, we consider the period post-2005. Results can be summarised as follows:

- Industry investment (columns 1 and 2): When we adjust the missing observations on investment by the market share, the estimated impact of a 10% increase in the HHI on industry investment is estimated to be 11.96% but insignificant, compared to 30.88% (significant at the 10% level) when we do not adjust.
- Industry profits (columns 3 and 4): Similarly, an increase in the HHI does not have a significant impact on the adjusted measure of industry profits, whereas it has a significant positive impact on the unadjusted measure.
- Market penetration (column 5): An increase in the HHI does not have a significant effect on the number of mobile users, possibly reflecting the finding that the mobile industry is quite mature with inelastic demand at the industry level.

Table 14: The impact of market structure on industry performance – alternative measures

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	FE	FE
Dependent variable	$lnCAPEX_{ct}$ - adjusted	$lnCAPEX_{ct}$ - unadjusted	$lnEBITDA_{ct}$ - adjusted	$lnEBITDA_{ct}$ - unadjusted	$lnSubscribers_{ct}$
Countries	All	All	All	All	All
Time Period	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014
HHI	1.196	3.088*	0.537	2.519***	0.441
	(1.592)	(1.859)	(0.787)	(0.680)	(0.485)
Log GDP per capita	0.625*	0.852**	0.267	0.494*	0.280
	(0.377)	(0.408)	(0.307)	(0.282)	(0.197)
Log Population	-0.124	-0.0904	-0.0715*	-0.0395	-0.0207
	(0.0772)	(0.0878)	(0.0418)	(0.0360)	(0.0220)
Instrumental Variables	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors	*Diff MTR* $index_{ct}$, Binary indicators for the number of competitors
First stage partial R^2 of excl. IVs	0.542	0.542	0.542	0.559	0.559
First stage F-test	70.81	70.81	70.81	72.14	72.14
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	618	618	618	624	624
R^2	0.022	0.023	0.010	0.042	0.065
Clusters	24	24	24	24	24

Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

*Notes: The dependent variable varies by column as indicated in row 3. P-values for diagnostic tests are in brackets and italics. Standard errors clustered at the country level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.*

7. Discussion and caveats

This study is driven by data availability and has some limitations that we wish to discuss in this section.

We start with our metrics for prices. We used the Teligen basket methodology, which identifies the cheapest tariff for different usage profiles. An advantage of this approach is that it provides a clear and undisputed measure for what a certain customer would pay. That is, Teligen obtains a measure for the customer bill, with many details that are practically relevant and accounted for (e.g., distribution of calls, SMS, data downloads, and so forth). This raises the question, however, of how representative the hypothetical bill identified by Teligen is compared to the actual bill paid by customers. Customers in different countries may have different mobile usage attitudes: to the extent that these are time invariant, or that they change proportionally over time in the various countries, our (country-operator-usage, as well as time) fixed effects would capture such differences, and therefore we included them in our analysis. If instead there are variations that are time *and* country specific, then our results could be biased – though the direction of bias is not clear *a priori*. We also note that we used both fixed baskets, as well as time-varying baskets, and we did not find qualitative differences, which should be reassuring for the robustness of our findings.

An alternative to the basket approach would be to look at aggregated revenues, such as ARPU. But we would argue that these measures, which are sometimes used in other studies (including the EC's analysis of recent mergers), are not very meaningful. This is for two reasons. First, by definition, ARPU relates to total *revenues* per subscriber. These revenues also include revenues for incoming calls, which are not paid by a given subscriber but by calling subscribers from other networks. Hence this is not related to the customer bill, but it is closer to a measure of profitability. Second, total revenues per subscriber depend also on the usage made by the subscriber for a given price, so ARPU may be large also because the allowance of a given price is large. In other words, changes in ARPU may reflect changes in the composition of consumption rather than real price changes. It is of no surprise that, when analysing ARPU directly, we found that it has no clear relationship with market structure. We therefore conclude that ARPU, which may be monitored perhaps to provide a view on profitability, is not an interesting variable to study when looking at the impact on subscriber prices. In itself, this is also an interesting finding of our analysis.

One could make a step further by constructing "average" prices, that is, ARPU (excluding termination revenues) adjusted for some measure of quantity and quality. Some imperfect measures of usage exist, but they are always related to voice services, while almost nothing is available over time and across countries for data. Hence it is very difficult to revert to average pricing measures in an exercise, like ours, involving a large panel with many operators and several years of observations, where data comparability is a strong driver of the empirical strategy. The basket approach ultimately is the only one that allows consistent comparisons. An alternative, of course, is to renounce a panel approach and to concentrate on country-specific studies with all the details that could be gathered at the country level, but not internationally.

Another limitation of the basket approach is that, given the data intensive exercise to find the cheapest price in every quarter among the universe of available offers, Teligen supplies information only for the two largest operators in every country/period. The implication of this, given that it is rare that the largest operators are involved in a merger, is that we may *underestimate* the impact of a merger. The largest operators, to the extent that they are outsiders to a merger, will have an indirect (strategic) effect to increase prices when competing in strategic complements. This effect is typically smaller than the (direct) effect of merging operators who internalise their pricing choices. Keeping this remark in mind, we also point to our analysis on EBITDA margins, which comes from a different dataset (BoAML): while this analysis is only indirectly related to prices, it does however look at *all* operators, and produces findings that are in line with the price results.

Both our price and our investment analysis produce *average* results across time and countries. It would be interesting to try to distinguish in more accurate ways between the impact that entry or exit might have when related to smaller or to larger firms, or to "pure" mobile operators as opposed to those integrated with fixed line operations. Similarly, one could collect more data on operator characteristics, such as public ownership or multi-market presence. Also, our analysis lacks data on mobile virtual network operators (MVNOs) because these are not available in any consistent way over time and across countries. We used the available data as collected in the BoAML dataset, but this does not seem to be done in a systematic way. Again, the best advice for an analysis of MVNOs is probably to conduct a narrower but deeper analysis at the country level. We also note that MVNOs are also proposed as possible remedies to recent mergers, and that mergers are themselves endogenous and not randomly allocated. A similar remark applies also to other remedies, such as network sharing. The best we could do in our data was to distinguish between net entry (likely to be related to licensing) and net exit (likely to be related to mergers). We pointed above to the asymmetric effects on prices and investments due to entry/exit, which is a transparent and parsimonious way to describe the differences in the mechanisms and outcomes.

8. Conclusions

In this paper we have analysed the impact of market structure on prices and investments in the mobile telecommunications industry. We have conducted an empirical study using a panel of 33 OECD countries over the period 2002-2014. We have collected detailed information at the level of individual mobile network operators, assembling what is the largest dataset employed to-date for works of this kind.

We find that, during the analysed period, when mobile markets became more concentrated, prices increased to end users with respect to the case in which no concentration happened (absolute prices actually decreased in all cases during the analysed period). At the same time, capital expenditures increased. These results are robust to various perturbations and remain significant even when we control for unobserved heterogeneity using panel data techniques and when we address market structure endogeneity using different instrumental variables. At the country level, we did not find a significant effect of market structure on total industry investments, although the sample size is much smaller and results are noisier.

These effects refer to average effects on past changes in market structure, which are significant but also with margin of error, and the past results do not necessarily apply to future mergers. Keeping this caveat in mind, our results are significant not only statistically but also economically. A hypothetical average 4-to-3 symmetric merger in our data would have increased the bill of end users by 16.3%, while at the same time capital expenditure would have gone up by 19.3% at the operator level, always in comparison with what would happen in the case of no merger. More realistic asymmetric 4-to-3 mergers (between smaller firms in European countries) are predicted to have increased the bill by about 4-7%, while increasing capital expenditure per operator by between 7.5-14%.

To our knowledge, it is the first time that the dual impact of market structure on prices and investments has been assessed and found to be very relevant in mobile communications, both from an economic and from a statistical point of view. Our findings are therefore of utmost importance for competition authorities, who face a real trade-off when confronted with an average merger similar to one captured in our sample. *Ceteris paribus*, a merger will have static price effects to the detriment of consumers, but also dynamic benefits for consumers as investments can enhance their demand for services. An open question that our study raises, but cannot answer due to data limitations, is an assessment of the impact of investments on consumer surplus. Capital expenditures, our measure for investments, refer to all the money spent to acquire or upgrade physical assets. This could be related to cell sites, which improve coverage and/or speed, both of which would be enjoyed by consumers. Understanding where the extra investment money goes when a market gets more concentrated is an inescapable question to properly assess the consequences of mergers in mobile telecommunications markets. The missing link, which we hope

will be further researched by operators, competition authorities and scholars alike, is the understanding of the consumer benefits that arise as a consequence of operators' investments.

9. References

Acemoglu, D. and U. Akcigit (2012), "Intellectual Property Rights: Policy, Competition and Innovation," Journal of the European Economic Association, 10, 1-42.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005), "Competition and Innovation: an Inverted-U Relationship," Quarterly Journal of Economics, 120, 701-728.

Aghion, P. and R. Griffith (2006), Competition and Growth: Reconciling Theory and Evidence, The MIT Press, Cambridge (MA).

Ashenfelter, O., D. Hosken and M. Weinberg (2015), "Efficiencies brewed: pricing and consolidation in the US beer industry," RAND Journal of Economics, 46(2), 328-361.

Ashenfelter, A., D. Hosken, and M. Weinberg (2013), "The Price Effects of a Large Merger of Manufacturers: a Case Study of Maytag-Whirlpool," American Economic Journal: Economic Policy, 5(1): 239-261.

Asplund, M. and R. Sandin (1999), "Competition in interrelated markets: An empirical study," International Journal of Industrial Organization, 17, 353–369.

Baker, J and Daniel L. Rubinfeld (1999), "Empirical Methods in Antitrust Litigation: Review and Critique," American Law and Economics Review, 1 (1/2).

Björnerstedt, J. and F. Verboven (2015), "Does Merger Simulation Work: Evidence from the Swedish Analgesics Market," working paper.

Blundell, R., R. Griffith and J. V. Reenen (1999), "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms," Review of Economic Studies, 66, 529-554.

Borenstein, S. (1990), "Airline Mergers, Airport Dominance, and Market Power," American Economic Review, 80, 400-404.

Borenstein, S. and N. Rose (1994), "Competition and Price Dispersion in the U.S. Airline Industry," Journal of Political Economy, 102(4), 653-683.

Bresnahan, T. F. (1989), "Empirical Studies in Industries with Market Power," in Handbook of Industrial Organization, Volume II, edited by R. Schmalensee and R. D. Willig. Amsterdam: Elsevier Science Publishing B. V.

Calem, P. S. and G. A. Carlino (1991), "The Concentration/Conduct Relationship in Bank Deposit Markets," Review of Economics and Statistics, 73(2), 268-276.

Cotterill, R. (1986), "Market Power in the Retail Food Industry: Evidence from Vermont," Review of Economics and Statistics, 68(3), 379-386.

Davis, P. (2005), "The Effect of Local Competition on Retail Prices in the US Motion Picture Exhibition Market", Journal of Law and Economics, 48 (2), 677–707.

Demsetz, H. (1973), "Industry Structure, Market Rivalry, and Public Policy," Journal of Law and Economics," 16, 1-9.

Facarelli, D. and F. Panetta (2003), "Are Mergers Beneficial to Consumers? Evidence from the Market for Bank Deposits," American Economic Review, 93, 1152-1172.

Economides, N., K. Seim, and V. B. Viard (2008), "Quantifying the Benefits of Entry Into Local Phone Service," RAND Journal of Economics 39(3), 699–730.

Evans, W., L. Froeb and G. Werden (1993), "Endogeneity in the Concentration-Price Relationship: Causes, Consequences, and Cures," Journal of Industrial Economics, 61(4), 431-438.

Frontier Economics (2015), "Assessing the case for in-country mobile consolidation," Report prepared for the GSMA, February.

Genakos, C. and T. Valletti (2011), "Testing the 'Waterbed' Effect in Mobile Telephony," Journal of the European Economic Association, 9(6), 1114–42.

Genakos, C. and T. Valletti (2015), "Evaluating a decade of mobile termination rate regulation," Economic Journal, 125(586).

Gilbert, R. and J. Hastings (2005), "Market Power, Vertical Integration and the Wholesale Price of Gasoline," Journal of Industrial Economics, 53 (4), 469-492.

Grajeck, M. and T. Kretschmer (2009), "Usage and Diffusion of Cellular Telephony, 1998–2004," International Journal of Industrial Organization, 27, 238–249.

Grajek, M. and L.-H. Roeller (2012), "Regulation and Investment in Network Industries: Evidence from European Telecoms," Journal of Law and Economics, 55, 189–216.

Greenstein, S. and M. Mazzeo (2006), "The Role of Differentiation Strategy in Local Telecommunication Entry and Market Evolution: 1999–2002," Journal of Industrial Economics, 54, 323–350.

Gruber, H. and F. Verboven (2001a), "The Diffusion of Mobile Telecommunications Services in the European Union," European Economic Review, 45, 577–588.

Gruber, H. and F. Verboven (2001b), "The evolution of markets under entry and standards regulation – the case of global mobile telecommunications," International Journal of Industrial Organization, 19, 1189–1212.

Hall, B. H. and D. Harho (2012), "Recent Research on the Economics of Patents," Annual Review of Economics, 4, 541-565.

Hausman, J. (2003), "Sources of Bias and Solutions to Bias in the Consumer Price Index", Journal of Economic Perspectives, 17(1), 23-44.

HSBC (2015). "Supercollider. European telecom mergers will boost capex, driving prices lower and speeds higher," HSBC Global Research, Telecoms, Media and Technology, April.

Hastings, J. (2004), "Vertical Relationships and Competition in Retail Gasoline Markets: Empirical Evidence from Contract Changes in Southern California," American Economic Review, 94(1), 317-328.

Hosken, D., L. Silvia, and C. Taylor (2011), "Does Concentration Matter? Measurement of Petroleum Merger Price Effects," American Economic Review: Papers & Proceedings, 101(3), 45-50.

Jaffe, A. B. (2000), "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process," Research Policy, 29, 531-557.

Kim, E. and V. Singal (1993), "Mergers and Market Power: Evidence from the Airline Industry," American Economic Review, 83, 549-569.

Koski, H. and T. Kretschmer (2005), "Entry Standards and Competition: Firm Strategies and the Diffusion of Mobile Telephony," Review of Industrial Organization, 26, 89–113.

Li, Y. and B. Lyons (2012), "Market structure, regulation and the speed of mobile network penetration," International Journal of Industrial Organization, 30, 697-707.

Liikanen, J., O. Toivanen and P. Stoneman (2004), "Intergenerational Effects in the Diffusion of New Technology," International Journal of Industrial Organization, 22, 1137–1154.

Miravete, E. J. (2002), "Estimating Demand for Local Telephone Service with Asymmetric Information and Optional Calling Plans," Review of Economic Studies 69(4), 943–71.

Miravete, E. J. and I. Palacios-Huerta, (2014), "Consumer Inertia, Choice Dependence and Learning From Experience in a Repeated Decision Problem," Review of Economics and Statistics 96(3), 524–537.

Nardotto, M., T. Valletti and F. Verboven (2015), "Unbundling the incumbent: Evidence from UK broadband", Journal of the European Economic Association, 13(2), 330-362.

Newmark, C. (2004), "Price Concentration Studies: There You Go Again," Manuscript Prepared for the DOJ/FTC Merger Workshop, "Concentration and Market Shares" panel.

Nickell, S. J. (1996), "Competition and Corporate Performance," Journal of Political Economy, 104, 724-746.

OECD (2014), "Wireless Market Structures and Network Sharing", OECD Digital Economy Papers, No. 243, OECD Publishing.

Peters, C. (2006), "Evaluating the Performance of Merger Simulations: Evidence from the U.S. Airline Industry," Journal of Law and Economics, 49, 627-649.

Schmalensee, R. (1989), "Inter-Industry Studies of Structure and Performance" in Handbook of Industrial Organization, Volume 1, edited by R. Schmalensee and R. D. Willig. Amsterdam: North-Holland, 1989.

Seim, K., and V. B. Viard (2011), "The Effect of Market Structure on Cellular Technology Adoption and Pricing," American Economic Journal: Microeconomics 3(2), 221–51.

Weiss, L. (1989), Concentration and Price, The MIT Press, Cambridge (MA).

Whinston, M. D. (2008), Lectures on Antitrust Economics, Chapter 3: Horizontal Mergers, The MIT Press, Cambridge (MA).

Xiao, M. and P. F. Orazem (2009), "Is Your Neighbor Your Enemy? Strategic Entry into the US Broadband Market," Working paper, University of Arizona.

Xiao, M. and P. F. Orazem (2011), "Does the Fourth Entrant Make any Difference?: Entry and Competition in the Early US Broadband Market," International Journal of Industrial Organization, 29, 547–561.