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Evaluating Market Consolidation in Mobile Communications

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Abstract

We study the dual relationship between market structure and prices and between market structure and investment in mobile telecommunications. Using a uniquely constructed panel of mobile operators' prices and accounting information across 33 OECD countries between 2002 and 2014, we document that more concentrated markets lead to higher end user prices. Furthermore, they also lead to higher investment per mobile operator, though the impact on total investment is not conclusive. Our findings are not only relevant for the current consolidation wave in the telecommunications industry. More generally, they stress that competition and regulatory authorities should take seriously the potential trade-off between market power effects and efficiency gains stemming from agreements between firms.

Keywords: mobile telecommunications, market structure, prices, investments, mergers

JEL codes:K20; L10; L40; L96

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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 European Commission 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 in 2015. Another 4-to-3 merger in the UK was blocked in 2016, and yet another proposed merger in Italy has recently been approved by the European Commission (subject to a divestiture requirement). 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 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.

This debate is particularly prominent in the European Union, as the completion of the Digital Single Market (DSM) is one of the top priorities for the European Commission. In 2015, the Commission published a strategy outlining how it intends to achieve that goal, stating that the completion of the DSM "could contribute €415 billion per year to [the EU] economy and create 3.8 million jobs". A pillar of the

strategy is addressing "fragmentation" in the telecoms sector, and the resulting smaller scale of operation. While fragmentation has been identified as one of the factors behind the worse financial results of European telecoms companies compared to their US, Japanese and Korean counterparts, it has also been interpreted differently by different stakeholders. For the Commission, fragmentation relates to access availability, quality and prices that vary significantly across the continent, with telecoms markets defined by national borders. Mobile operators, instead, point to the fact that there are about 40 mobile network operators in the EU. Many operate in just one or two countries. By comparison, in the US there are four nationwide mobile operators (AT&T, Verizon, Sprint and T-Mobile). While the Commission would seem to be lenient in case there were cross-border mergers, the mobile operators appear more interested in achieving within-country consolidation.

In this paper we study the relationship between prices, investments, and market structure in the mobile telecommunications industry. 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: entry via licensing, exit via mergers and organic growth through changes in the Herfindahl-Hirschman concentration index. This provides ideal variation in the data to assess how market structure impacts on prices and investments, holding other factors constant. Our panel data approach includes fixed effects to control for systematic differences between countries and general changes over time, and instrumental variables for the remaining endogeneity related to some of the variables used to proxy market concentration. While the variation in market structure over time is not only due to mergers, but also due to new entry and organic growth, we focus our conclusions mainly on the impact of mergers because this has recently received considerable policy attention.

We find that an increase in market concentration in the mobile industry can potentially generate an important trade-off. While a merger will increase prices, investment per operator will also go up. Based on

our estimates, a hypothetical 4-to-3 symmetric merger would increase the bill of end users by 16.3% on average. At the same time investment per operator significantly increases by 19.3%, while total industry investment does not change significantly. Our evidence on the impact of concentration on total industry investment is therefore not entirely conclusive. On the one hand, it suggests that efficiencies are present, since theoretical models predict that total investment would decrease in the absence of efficiencies. But on the other hand, it is not clear whether efficiencies from coordinating total industry investment among fewer firms only stem from fixed costs savings, or whether they also involve marginal cost savings and quality improvements that benefit consumers. To shed further light on this, additional research is necessary with more complete data on the underlying investment components of all operators, or based on more in-depth individual case studies.

Our findings are not only relevant for the current consolidation wave in the telecommunications industry. More generally, they also stress that competition and regulatory authorities should take seriously the potential trade-off between market power effects and efficiency gains stemming from agreements between firms.

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 to construct the dataset. Section 4 motivates our empirical strategy to identify the causal relationship between market structure on the one hand, and prices and investments on the other hand. 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 several 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. Third, we are specifically interested in conducting an empirical study related to the mobile telecommunications industry, an important and dynamic industry and an active field of research. Finally, we contribute to work on the trade-off between market power and efficiency gains from mergers.

2.1. Literature on market structure and performance

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 (Focarelli 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". The bias in the parameters capturing market structure and competitive interactions can therefore have important policy implications.

2.2. Literature on competition and innovation/investment

There is a broad 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 two features in our data. First, changes in competition due to mergers occurred at different points in time across countries, or did not occur at all in other countries. This enables us to conduct a difference in differences analysis. Second, various regulatory interventions affected both entry and growth in the telecommunications market (see later the discussion on termination rate regulation). This allows us to construct instrumental variables that address remaining endogeneity concerns regarding our competition measure.

While the literature cited above is empirical, we note that there are also several theoretical works that study the relationship between competition and innovation (or investments). In the absence of spill-overs, Vives (2008) finds that investment per firm tends to decrease as the number of firms in a market increases, while industry investment tends to increase as the number of firms increases. Schmutzler (2013) extends Vives' model to an asymmetric setting and shows that the opposite result can hold true in the presence of a firm that is particularly efficient. Summarising the literature, Gilbert (2006) concludes that – broadly speaking – competition produces greater innovation incentives under exclusive rights to innovation, while non-exclusive rights generally lead to the opposite conclusion. We also observe that there is a surprisingly limited body of theoretical work specifically on the impact of mergers on innovation, with recent contributions by Motta and Tarantino (2016) and Marshall and Parra (2016) being notable exceptions. In particular, Motta and Tarantino (2016) find that in the absence of economies of scope, mergers reduce total industry investment.

2.3. Literature on the mobile telecommunications industry

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. (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.

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 (e.g., OECD, 2014; Frontier Economics, 2015; HSBC, 2015), 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).

2.4. Market power and efficiency gains from mergers

In an influential article, Williamson (1968) argued that mergers only need small efficiency gains to compensate for market power effects from mergers. Most competition authorities have however followed a consumer surplus standard, emphasizing that (i) efficiencies should consist of marginal cost savings in order to be passed on into consumer prices; and (ii) efficiencies should be merger-specific, i.e., could not have occurred in the absence of the merger (see the Guidelines of the European Commission (2004) and for an earlier review Röller, Stennek and Verboven (2001).

There is very little empirical work that explicitly examines the trade-off between market power and efficiency gains from increases in concentration, whether from a welfare or from a consumer surplus perspective. One notable exceptions is Focarelli and Panetta (2003). They find that mergers in the Italian banking sector benefited consumers as they raised consumer deposit rates in the long run, and they attribute this to cost savings. And, more recently, Ashenfelter et al. (2105) find that the increase in concentration in the US brewing industry due to the merger between the second and third largest firms in the industry led to an increase in pricing that was nearly exactly offset by efficiencies created by the merger.

Our study on the impact of concentration on both prices and investment can shed further light on the trade-off between market power and efficiency gains from increased concentration. We cannot do this directly, as we do not observe efficiency gains. Nevertheless, our information on investment provides indirect evidence, which we can interpret based on theoretical work by, for example, Vives (2008) and Motta and Tarantino (2016). In particular, these analyses imply that, if mergers do not reduce industry investment, then they most involve efficiencies. Such efficiencies may stem from simply saving duplicated fixed costs (in which case it benefits welfare but not consumers). But they may also come from other benefits of coordinating investment within a firm, such as marginal cost savings or quality improvements. Whether such benefits are in the interest of consumers is a question we will not be able to address with our analysis.

3. DATA DESCRIPTION AND MARKET TRENDS

Our empirical analysis focuses on the link between measures of market concentration, tariffs 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.

3.1.1. 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. Teligen 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. 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.

Several remarks on the methodology are in order. First, the prices used are not actual bills, but hypothetical bills representing the consumers' best choice for that usage profile. Empirical work with actual billing data has shown that in practice consumers do not always choose their best tariff plan, but they do not necessarily make permanent mistakes (see Miravete, 2003, and Miravete and Palacios-Huerta, 2014, who establish this after controlling for unobserved heterogeneity and endogeneity of past choices).

Second, the Teligen dataset only reports tariff data, and does not provide information on implicit discounts from subsidized handsets in the case of post-paid contract prices. Handset subsidies were especially common during the 90s, but less so after 2005. To the extent that these deals were still common across operators within a country, their effect would be captured by the country and time fixed effects. Moreover, there is no reason to expect that handset subsidies changed particularly due to mergers. We verified our results using different subsamples (after 2006 and 2010) indicating the results are robust to these perturbations. We also did a sensitivity analysis by looking at pre-paid and post-paid separately, as pre-paid

tariffs are not likely to be affected in any significant fashion by handset subsidies. This gave similar conclusions though the standard errors increase due to the reduced number of observations.

Third, 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.

The Teligen dataset has three main advantages. First, the information reported is about consumers' monthly bills, contrary to other metrics (such as average revenue per user) 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 behaviour in such a dynamic industry such as the telecommunications 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. The 2002 basket includes voice and SMS for a consumer profile that is most representative in 2002. The 2006 and 2010 baskets again includes voice and SMS, but for updated consumer profiles that are most representative in 2006 and 2010, respectively. Finally, the 2012 basket also includes data. We will focus our main analysis on the 2006-2014 period, where we allow the basket to change in 2010 and 2012 (hence the tariffs include data in the last subperiod). Nevertheless, we have considered an extensive sensitivity analysis, such as keeping the 2006 basket fixed throughout the entire period, or considering the

entire period with various basket definitions. This gave robust conclusions, as we discuss in Sections 6 and 7.

3.1.2. 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. As in other studies, the HHI is based on the installed base of subscribers, i.e., the stock of previous and recently acquired customers. Some information on operators' recently acquired customers is available. But this information is incomplete, and the HHI based on the entire stock of customers is a better proxy for the overall level of market competition.

Our market structure variables are based on the traditional mobile network operators (MNOs), i.e., those operators who obtained a licence to use the spectrum. In recent years, MNOs started to provide access to their network by so-called mobile virtual network operators (MVNOs). These operators only compete at the retail level, and their overall impact on competition has been subject to debate. We do not have information on the number of MVNOs or their market shares. If such information becomes available systematically, it would be interesting to investigate how they have influenced the impact of the recent mergers between MNOs.

Finally, 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 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.

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

3.1.3. 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.

The final dataset comprises 33 countries and more than 7,000 observations for the period 2002-2014. Table 1 provides some key summary statistics for the main variables. The top panel shows the summary statistics for the price data set, for the entire period 2002-2014 (first three columns), and for the period 2006-2014 (last three columns). The bottom panel shows the analogue summary statistics for the investment data set. Our analysis focuses on the period 2006-2014, while we also consider the entire period in the robustness section. Note that both samples contain the same set of countries and quarters, but the samples sizes differ because the unit of observation within a country/quarter differs: for prices, the unit of observation is the usage type for the largest two operators, while for investment it is simply the operator. As a result, the number of observations is larger for the price data than for the investment data.

According to the top panel of Table 1, 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 three user profiles (low = 179, medium = 498 and high = 1018 euros per year) of the two largest operators for which we have information. 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 on a 0 to 1 scale (or 3,590 on the common 0 to 10,000 scale). Finally, we report information on control variables such as GDP per capita (on average 41,182 euros per year), the mobile termination rate (on average 0.087 euros 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).

According to the bottom panel of Table 1, 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 panel of Table 1.

3.2. Market developments

Figure 1 shows the evolution of mobile tariffs (overall and by consumer profile) during 2006Q1-2014Q1, using normalized (at the beginning of the period) demeaned average prices across countries and operators. Overall prices steadily declined by almost 50% during this period, amounting to an average decline of 2.2% per quarter. Prices by consumer profile followed a similar pattern with prices for the large bundles falling faster than those for the smaller ones.

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. Investment (CAPEX) has gradually increased (with seasonal peaks in the last quarter of each year). Profits (EBITDA) increased by about 25% until 2011Q3, but then started to decline again to eventually reach the same level as in the first quarter of our data. 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 percentage EBITDA margins remained fairly stable across the period.

Table 2 shows the evolution of the number of competing operators across the countries in our data set. In most countries there are three firms, but there is considerable variation across countries and over time. Because of new firm entry, no country is left with only two operators. At the same time there has been exit through mergers that has reduced the number of countries with five operators.

These trends illustrate that there have been considerable changes in our main variables of interest: tariffs, investment and the number of competitors. 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 suggests. This provides the necessary information to study the impact of market structure on prices and investments. Nevertheless, 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

We adopt a panel data approach with fixed effects for countries and time periods, and instrumental variables for remaining endogeneity regarding the market structure variable. We first outline the specifications for prices and investment (section 4.1), and then provide a more detailed motivation where we address possible endogeneity issues (section 4.2).

4.1. Specification

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

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

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 pre-paid), 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 terminate 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: the number of operators, N_{ct}, and the Herfindahl-Hirschman Index, HHI_{ct}, in country *c* in quarter *t*.

We estimate the model in first-differences to eliminate the large set of usage-operator-country fixed effects (α_{uoc}). 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}. Estimated standard errors are clustered at the usage-operator-country level.

Note that when our market structure variable refers to discrete events (number of firms), our empirical model can be interpreted as a difference-in-differences estimator, allowing for different control groups at different points in time (similar to recent retrospective merger studies, e.g., Ashenfelter, Hosken and Weinberg (2013; 2015)). In the special case of a panel with 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. Our panel data model with multiple periods and countries can also be interpreted as a difference-in-differences estimator, with some additional structure to identify the effects (by allowing for different control groups at different points in time). In particular, the information for multiple periods enables us to account for the possibility of country-specific trends, as in Card (1992) or Besley and Burgess (2004) or as discussed in Angrist and Pischke (2009). We will consider this in an extension of our analysis.

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

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

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 which entered more recently. Third, we include the logarithm of GDP per capita. 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 also considered a dynamic specification as in Grajek and Röller (2009), but the lagged variables were insignificant. Estimated standard errors are clustered at the country-operator level.

We also present results for alternative measures of the outcome of interest in eq. (2). First, instead of investment in absolute terms we consider investment relative to the total market size ($CAPEX_{oct}$ divided by the total number of subscribers). This may better capture the fact that investment needs increase with market size (even though we already control for country fixed effects). Second, we replace investment ($CAPEX_{oct}$) in eq. (2) by alternative performance measures $EBITDA_{oct}$, $(EBITDA\ margin)_{oct}$, and $ARPU_{oct}$, respectively.

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

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

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.

4.2. Possible endogeneity concerns

Our empirical framework includes a full set of country and time fixed effects. The country fixed effects control for country-specific factors that may be responsible for systematically higher prices or higher investment in certain countries. Hence, we identify the impact of market structure on prices and investment from changes that occur within a country, and assume that the timing of new entry or merger is not correlated with the error term. As discussed above, when we use the number of operators as our market structure variable, we essentially have a difference-in-differences approach, which considers the impact of a change in market structure in the treatment countries, relative to the control countries, on performance (prices and investment). A potential concern is that there may be remaining endogeneity regarding the market structure variables, despite the inclusion of a full set of country and time fixed effects. This concern is especially relevant when we use the Herfindahl-Hirschman index, instead of the number of firms, as our market structure proxy. We discuss both in turn.

4.2.1. Number of firms

The mobile industry is not a free-entry industry. Rather, operators must be awarded spectrum licenses, and when a merger or an exit occurs, new operators still need to obtain licenses.

A big source of variation in the number of licence holders in the data comes in particular from the award of third generation (3G) licences in the early 2000s. Spectrum is typically assigned in a two-step process. First, spectrum is allocated for a certain use (e.g., broadcasting, mobile, or satellite); second, licences are

assigned to operators. The first step is most relevant for our purposes, as it determines how many licenses are granted in each country. Börgers and Dustmann (2003) consider the first allocation step in the context of the European 3G auctions. They discuss how EU countries were constrained by binding decisions made by the International Telecommunication Union and by the EU, so that each country had to allocate a fixed amount of spectrum for mobile 3G services (60 MHz of paired spectrum and 25 MHz of unpaired spectrum). The assignment also had to be conducted in a certain timeframe. The amount of spectrum implied that between 4 and 5 licences could be assigned. What is relevant for our purposes is that the status quo in the various countries was very heterogeneous, with some countries having only two 2G licence holders (Luxembourg), and other countries having already five 2G licence holders (the Netherlands). In all these countries, the country-specific timing at which these licenses were granted differed, because of idiosyncrasies in the assignment process. Similarly, when mergers started to take place in more recent years, there were differences in the timing of these events.

Börgers and Dustmann (2003) also argue that the determinants of the number of licences did not appear to be correlated with particular market characteristics, as it was affected by a wealth of political decisions as well as by idiosyncratic events that seemed largely random. For instance, the Swedish government (with three 2G incumbents) decided to award licences in a beauty contest. It first announced officially that it would issue five licences, but then reduced them down to four. By contrast, the UK (with four incumbents) chose auctions from the start, making four licences available at first, and then increasing them to five. The objectives pursued by governments were not clear, as was not also the direction in which operators would want to influence the political decisions. Government's choices over spectrum allocations are a fascinating topic that would deserve further investigation. For our purposes, we emphasise that there is no evidence of particular patterns that are related to mobile prices or investments. This is in favour of our assumption of exogeneity of the number of operators in a market, conditional on the full set of country and time fixed effects that we include in our specification.

Our specification is however still subject to criticism on two grounds. First, the variable Nct changes both because of new entry and because of mergers, and it is possible that the impact is asymmetric. In recognition of this issue, in the empirical analysis we will treat differently changes in market structure due to entry that typically reduce concentration from those due to mergers that increase concentration.

Second, N_{ct} in practice takes a limited number of values (see Table 2), which makes the effects harder to identify. For this reason, we also use a second indicator of market structure, HHI_{ct}, which shows considerably more variation, especially some very useful within-country variation. This variable will require instruments, since it can no longer be treated as exogenous conditional on the fixed effects.

4.2.2. Herfindahl-Hirschman Index

The HHI is a flexible indicator of market structure but suffers from endogeneity concerns, as market shares depend on prices and on investments. To account for this endogeneity, we follow an instrumental variable approach. As such, our framework is also closely related to a recent paper by Blake et al. (2015), who investigate the relationship between advertising and sales using time and region fixed effects and an additional instrument for advertising.

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}). MTRs are the payments that an operator has to face when it wants to terminate a call off-net, that is, on a rival's network. These charges are also known as two-way access charges in the literature that started with seminal contributions of Armstrong (1998) and Laffont et al. (1998). If left unregulated, every operator would have a unilateral incentive to monopolise the termination of calls it receives. Hence regulators world-wide have intervened repeatedly in the market for call termination. These interventions have differed widely, both within and between countries, a source of variation we can exploit in our search of a valid instrument.

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, while the level of MTRs may affect prices (and which we therefore do not use as an exclusion restriction), the difference in MTRs between the most and least regulated operator should not directly affect prices (especially not those of the large incumbent operators that are reported in the Teligen price dataset). However, one may expect that the difference in MTRs should boost the market shares of the smaller operators and hence reduce the HHI. In sum, the difference in regulated MTRs does not have a direct impact on prices (given that the level of MTRs is included as an explanatory variable), but it may have an indirect impact through the HHI. This is also confirmed by a theoretical literature than has looked directly into the asymmetric regulation of MTRs, whereby the regulation of the entrant would be more lenient than the regulation of incumbents, causing the entrant to capture a larger market share in this fashion (Peitz, 2005).

Second, following the logic of the previous sub-section: (i) we use binary indicators for the number of competitors to take advantage of the regulated nature of entry and exit in this industry, and (ii) 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.

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 the next section 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.

Column 1 uses the number of competitors as a measure of market structure. The results show that one more competitor leads to a price reduction of approximately 8.6%. However, this specification is restrictive since it assumes the same percentage effect as the number of operators' increases, irrespective of the total number of competitors. Column 2 allows the effect of the number of entrants to vary non-parametrically. This shows that prices decrease by about 15.9% in markets with four operators compared with the comparison group of two or three operators. In markets with five 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%). 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 gradually result in a new, larger firm, who may price aggressively to acquire market share. 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. 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. In addition, in column 4 we use

binary indicators for the number of competitors, whereas in column 5 we use the cumulative entry and exit variables as additional instruments. First stage coefficients, presented in the Appendix (Table A1, columns 1 and 2), all have the expected sign and the instruments are very powerful: the F-test on the excluded instruments is above 30 in column 4 and above 50 in column 5 of Table 3.

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%. 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. 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.

5.2. Investment results

Table 4 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. According to 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 4 show the results based on the HHI measure of concentration. The results from the first stage regression of the HHI on our instruments (shown in Table A1, columns 3 and 4, in the Appendix) 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). 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%.

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. This considerably reduces the size of our dataset and the aggregation also eliminates all the across mobile operators variability, leaving only the across country variation. Table 5 reports 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, but also due to the reliance on cross country variability only. Further research on more detailed investment or network quality and performance measures may give more conclusive results. Nevertheless, it is worth mentioning that theoretical work has shown that an increase in concentration would lead to a decrease in total industry investment in the absence of efficiencies (Vives, 2008; Motta and Tarantino, 2016). Hence, our finding that concentration has no effect on industry investment suggests that there may at least be fixed cost savings, and possibly benefits to consumers from coordinating investment among fewer firms.

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 materialized in 2013 and 2007 respectively, and a merger from 5 to 4 in the UK in 2010. Table 6 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 which is identical to eq. (1) and eq. (2) but includes only the European countries after 2005 (see Tables A2, column 5 and Table A7, column 3, discussed in detail in the next section).

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% points. The model predicts that this leads to a price increase by 6.6% and an increase in investment per operator by 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% 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% 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.

In principle, we could compare these predicted merger effects with the actual effects. However, simply calculating average prices in affected countries before and after the event would not provide a meaningful comparison as it would not take into consideration the underlying, unrelated to mergers, trends affecting both prices and investment. To accurately estimate the merger effect we would need to construct a case-

specific control group for each country and take an appropriate time window around the event so that it is not affected by any other changes in market structure. Instead of doing this on each merger event separately, here we use the entire panel to identify and quantify the effects. It is interesting to note that a recent study by Aguzzoni et al. (2015), which follows this methodology and looks at the merger between T-Mobile and Orange in the Netherlands in 2007, estimates a 10%-17% increase in prices. To further understand heterogeneity in market structure effects, it would be interesting to see more case studies in future research, perhaps also using alternative methods such as structural approaches. In Box 1 we describe how the entry of Free in the French market has affected competition.

BOX 1. The effect of entry on price – The case of Free in the French market

In principle, our model may be used to assess the impact of entry in specific cases. A prominent recent case has been the entry by Free as the fourth operator in the French market. In practice, our model does not seem suitable to assess this case, because the entry of Free had effects that go beyond the traditional pre-paid and post-paid prices of the largest two operators (which is what we based our econometric analysis on). As such, the impact of this fourth operator was more disruptive than the impact of the third operator, Bouygues, which was introduced many years earlier.

Free started its commercial launch in the French market in January 2012. It introduced contract-free post-paid tariff plans, much different from the traditional post-paid plans which came with at least an annual contractual commitment. Free offered these plans at low prices, and the three incumbents did not respond in the traditional way, by lowering the prices of their current brands. Instead, they introduced entirely new brands (Sosh by Orange, RED by SFR and B&You by Bouygues), which were contract free, similar to Free's offer. The incumbents in fact introduced these new brands slightly before the launch of Free, but once Free entered, they further reduced the prices of these new brands.

In ongoing work, Bourreau, Sun and Verboven (2016) investigate this case, using data on market shares and prices of all operators. Their preliminary evidence indicates that the entry of Free does not have a strong impact on the prices of the incumbents' brands (consistent with our reduced form model). However, the prices of Free and the three "fighting brands" are much lower, and consumers thus mainly gain through this channel.

END OF BOX.

6. ROBUSTNESS AND EXTENSIONS

We now discuss 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 are affected when we vary the sample. To do so we use our IV specification with the HHI as the indicator of market structure. Column 1 of Table A2 in the Appendix simply reproduces the result from column 4 in Table 3 to ease comparisons. In column 2 we consider the whole sample available (2002-2014). This shows that the HHI still has a significant impact over the entire period, but the magnitude is smaller. To further explore this, we also broke down the period 2006-2014 into two subperiods: before and after 2010 (columns 3 and 4). This confirms that the impact of competition is smaller during 2006-2009 (HHI coefficient of 0.821) than during 2010-2014 (HHI coefficient of 4.812, though with a larger standard error and only significant at the 10% significance level). The higher impact of competition on prices during the later years is consistent with our earlier discussion of the French case, where the third entrant Bouygues was much less disruptive than the fourth entrant Free (see Box 1). One interpretation is that late entrants in mature markets need to be more aggressive to compete and obtain market shares than early entrants, who can still target new consumers without a subscription. Another

interpretation for the increased impact of competition on prices may be the more common practice of quadruple play, whereby operators bundle a broadband package (internet, fixed line and TV) with a mobile subscription).

In the last two columns of Table A2, we restrict the sample to only European countries, either for the post-2005 (column 5) or for the entire period (column 6). A comparison with columns 1 and 2 shows that the estimated coefficients are slightly smaller for Europe only, but remain positive and significant.

Second, we considered the robustness of the results when we used fixed instead of varying baskets. The advantage of a fixed basket is that we use the same bundle of characteristics (combination of minutes, text, etc.) throughout the entire period, so that price comparisons over time are more transparent. 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. Results are shown in Table A3 (for the whole sample) and in Table A4 (for Europe only) in the Appendix again using the IV specification with the HHI market structure indicator. In sum, the positive impact that market concentration has on prices holds both with fixed and with varying baskets. 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.

Third, 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 IV 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.

Fourth, we extended the analysis to allow prices to follow country-specific linear trends (as opposed to the parallel trend assumption we made with the set of common time fixed effects). The results are reported in Table A5 in Appendix. This shows that the results are very close to those reported earlier in Table 3. Finally, we consider an extension of our main analysis in allowing the effects of increased concentration to differ

between different user profiles: low, medium and high. This robustness exercise is of particular policy interest as, after the recent Austrian merger, the concern was raised that the consumers most vulnerable to mergers would be low users. Table 7 presents the results. 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. Also note that the role of the control variables remains broadly similar to what we found in our main results in Table 3. In a similar spirit, we also run separate regressions for pre-paid and post-paid prices. In the first case, contract length and incentives to offer discounts through handset subsidies play no role. We find robust results for both contract types, but standard errors become considerably larger because of the reduced number of observations.

6.2. Investment results

We also considered the robustness of our investment analysis with respect to several assumptions. First, we replace absolute investment measure ($CAPEX_{oct}$) by an investment measure relative to the total market size ($CAPEX_{oct}$ divided by total number of subscribers). The results, shown in Table A6, are totally comparable to those obtained earlier (Table 4). The impact of the market structure variables is actually slightly stronger and more significant

Second, we considered how the results change for alternative samples. We conducted both the analysis of investment per operator (Table A7 in the Appendix), and the analysis of total industry investment (Table A8 in the Appendix). As before, we consider the whole sample available (column 2) and the restricted sample of only European countries either for the post-2005 (column 3) or for the entire period (column 4).

The estimated effects of the HHI on investment become less precisely estimated when we consider all years, or when we consider only European countries. The magnitude of the HHI effect is also lower when we consider the whole period. This indicates that concentration has especially raised investment in more recent years, which may reflect the strong investment needs with the roll-out of the 4G/LTE networks.

Third, we considered heterogeneity across countries, in particular the role of being a mobile operator who is also active on fixed-line telecom markets. This may create synergies and some investment expenditures may benefit both the mobile and fixed-line consumers. We found that being also a fixed telecom operator raises investment (significance at the 10%) level, but does not imply a different HHI effect (no significant interaction term).

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, even if such dynamics may be present. 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 existing data.

We note that it would be interesting in further research to perform an analysis regarding the role of network-sharing arrangements that are becoming popular in the industry. This could best be assessed through in-depth case studies. In Box 2 we describe how network sharing agreements in the UK played a role in a recent merger assessment.

BOX 2. Investment and network-sharing in the UK market

Mobile network sharing agreements play an important role in the mobile telecommunications sector. In the United Kingdom, there are two main network sharing agreements. First, MBNL is a 50/50 joint venture between Three and the recently merged British Telecom (BT)/Everything Everywhere (EE). MBNL provides a shared site portfolio which supports both shared (3G) and non-shared (2G/3G/4G) technologies used by Three and BT/EE. Second, the so called "Beacon" agreements between O2 and Vodafone comprise (i) a 50/50 joint venture between O2 and Vodafone, providing a shared site portfolio, and (ii) a contractual arrangement which provides shared 2G/3G/4G technologies used by O2 and Vodafone.

In 2016, the European Commission blocked a proposed merger between Three and O2 in the UK. The Commission was not only concerned about potential price increases due to the loss of competition, but also feared that the future development of the shared UK mobile network infrastructure would be hampered. On the latter point, the Commission found that the merged entity would have less of an interest to engage in network sharing which in turn could weaken the competitive position of Vodafone and BT/EE.

The Commission also assessed the claims by Hutchison that the integration of the networks of Three and O2 would result in a number of benefits. However, the Commission found that these claimed efficiencies were uncertain to materialise. Even if they did, they would only have started to materialise a few years after the merger and taken even longer to be realised in full. Therefore, the Commission could not conclude that the claimed efficiencies would be able to outweigh the harm to consumers, which would have materialised immediately after the merger as a result of the loss in competition in the market.

END OF BOX.

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 price 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 8 shows the results for the performance per operator. We consider the period post 2005. Results can be summarized 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.

We should note that the EBITDA margin can simply 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, which can be interpreted as an efficiency defence of mergers.

Table 9 shows the results for industry performance at the country level. Again, we consider the period post 2005. Results can be summarized 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, where 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.

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, 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, as discussed earlier, 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 keep track of MVNO information in a systematic way. We do not expect that MVNO entry is systematically correlated with the merger events, conditional on our time and country fixed effects. Hence, this would not affect our main results on the impact of mergers on prices. Furthermore, while MVNOs might be offering the best available contracts for low-usage consumers after they enter, they have relatively small market shares, and they may offer lower service quality. We therefore think that our approach, to take a fixed basket of the two largest MNOs, is justifiable. Nevertheless, in future research it would be interesting to study the separate impact of MVNOs, which may be most relevant in the low usage segment. 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.

Our analysis did not consider the role of financial constraints. Financial constraints may influence market structure, and they may also directly influence the decision to make investments. While we have financial indicators such as EBITDA in our dataset, we have treated them as endogenous. As an alternative, we considered the role of short-term interest rates. This variable does not enter significantly in our model, and does not affect our main results. Future research should consider the role of operator-specific financial constraints more thoroughly, with suitable instruments that explain the evolution of these constraints.

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, to our knowledge, 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 found an insignificant effect of market structure on total industry investments, which is possibly influenced by the smaller sample size and reduced variability (across country instead of across country and operator variation). Nevertheless, as we have already pointed out, theoretical

work has shown that an increase in concentration would lead to a decrease in total industry investment in the absence of efficiencies. Hence, our finding that concentration has no effect on industry investment suggests that efficiencies from coordinating investment among fewer firms are present. An obvious possibility is that there are fixed cost savings, because fewer firms avoid duplicating the same fixed costs. Such savings can be welfare improving, but do not benefit consumers. A second possibility is that there are economies of scope or spill-overs that generate marginal cost savings or quality improvements to the benefit of consumers.

The 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 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 to the extent that investments enhance their demand for services.

In European merger control, merging parties face tough hurdles when putting forward an efficiency defence and, as such, it remains questionable whether efficiencies will ever play an important role in decisions under the EC Merger Regulation in any but the most exceptional cases. However, this is not to say that advisers should abandon enquiries about the rationale for mergers or any anticipated efficiency gains. In practice,

though, the main pay-off from an understanding of the expected efficiencies arising from a horizontal merger is likely to be the insights this gives about the nature of competitive rivalry in an industry, which in turn will assist in gathering evidence on market dynamics and likely supply-side responses. Such evidence should not be an after-thought. It deserves a central role in a unilateral effects assessment that justifies a departure from the constraints imposed by simple theoretical static models.

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.

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9. Appendix

In this Appendix we provide the first-stage results and we discuss the results of several robustness checks of our results that we conducted.

Table A1 shows the first stage regression results of our various instrumental variables regressions for prices, operator's investment and industry investment (corresponding to specifications (3) and (4) of, respectively, Table 3, 4 and 5 in the text.

The next tables show the results of several robustness checks. First, we consider how the price results are affected when we increase the sample to the entire period available, or when we restrict the sample to only European countries, which constitute a more homogeneous group of 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 A2 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.

Second, we considered how the results change when we used fixed baskets instead of varying baskets over the period. Table A3 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).

As a further robustness analysis, we repeated this analysis for the sample of European countries only. This shows a similar picture, as summarized in Table A4: 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.

Finally, in Table A5 we re-estimate the same specifications as in Table 3, but now we also allow for country-specific linear trends. Results are qualitatively and quantitatively very similar to those reported in Table 3.

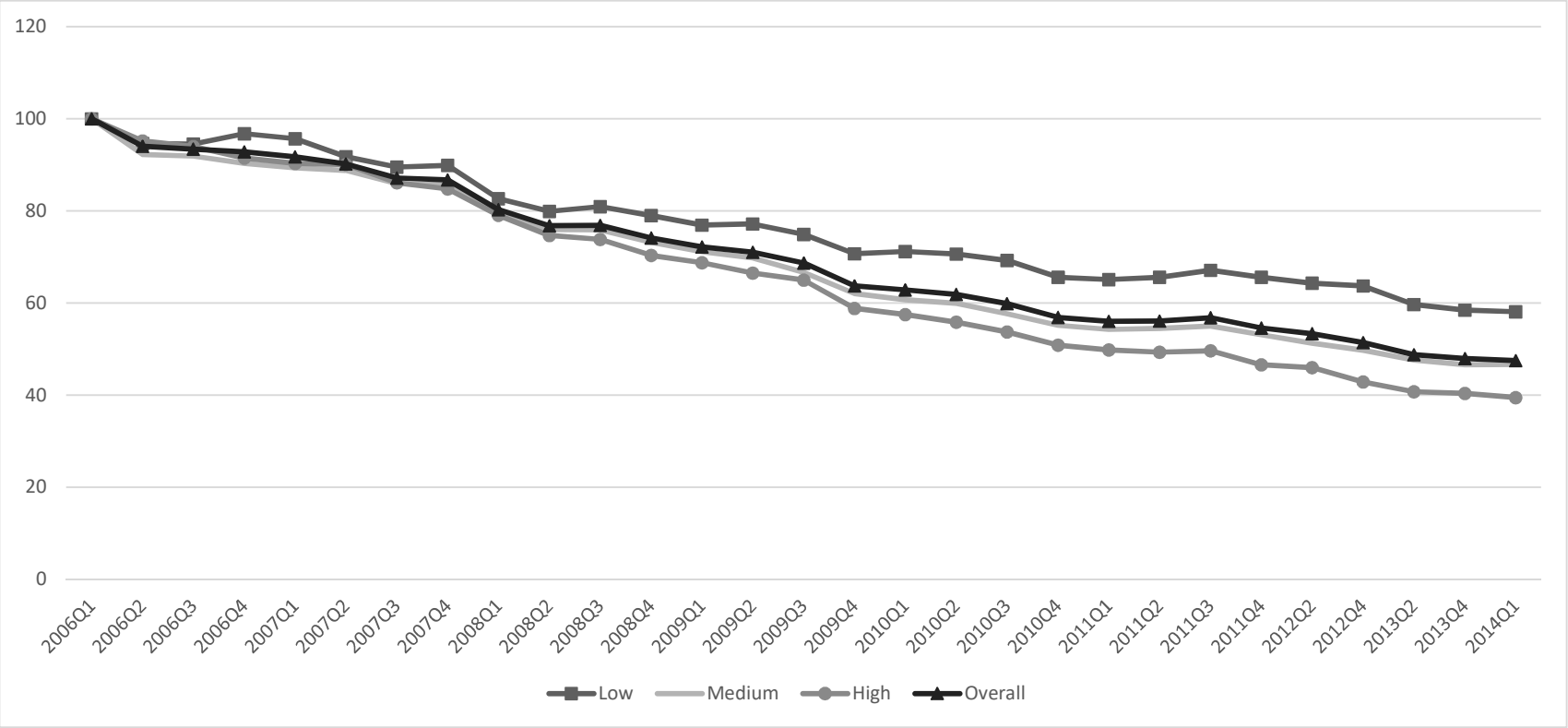
We now turn to the robustness of our investment analysis. First, we replicate the results in Table 4 by replacing the absolute investment measure (CAPEXoct) by an investment measure relative to the total market size (CAPEXoct divided by total number of subscribers). The results, shown in Table A6, are qualitatively totally comparable to those obtained earlier (Table 4), while the impact of the market structure variables is actually slightly stronger and more significant.

Second, 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 A7 shows the results for the analysis of investment per operator. In 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 A7, 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.

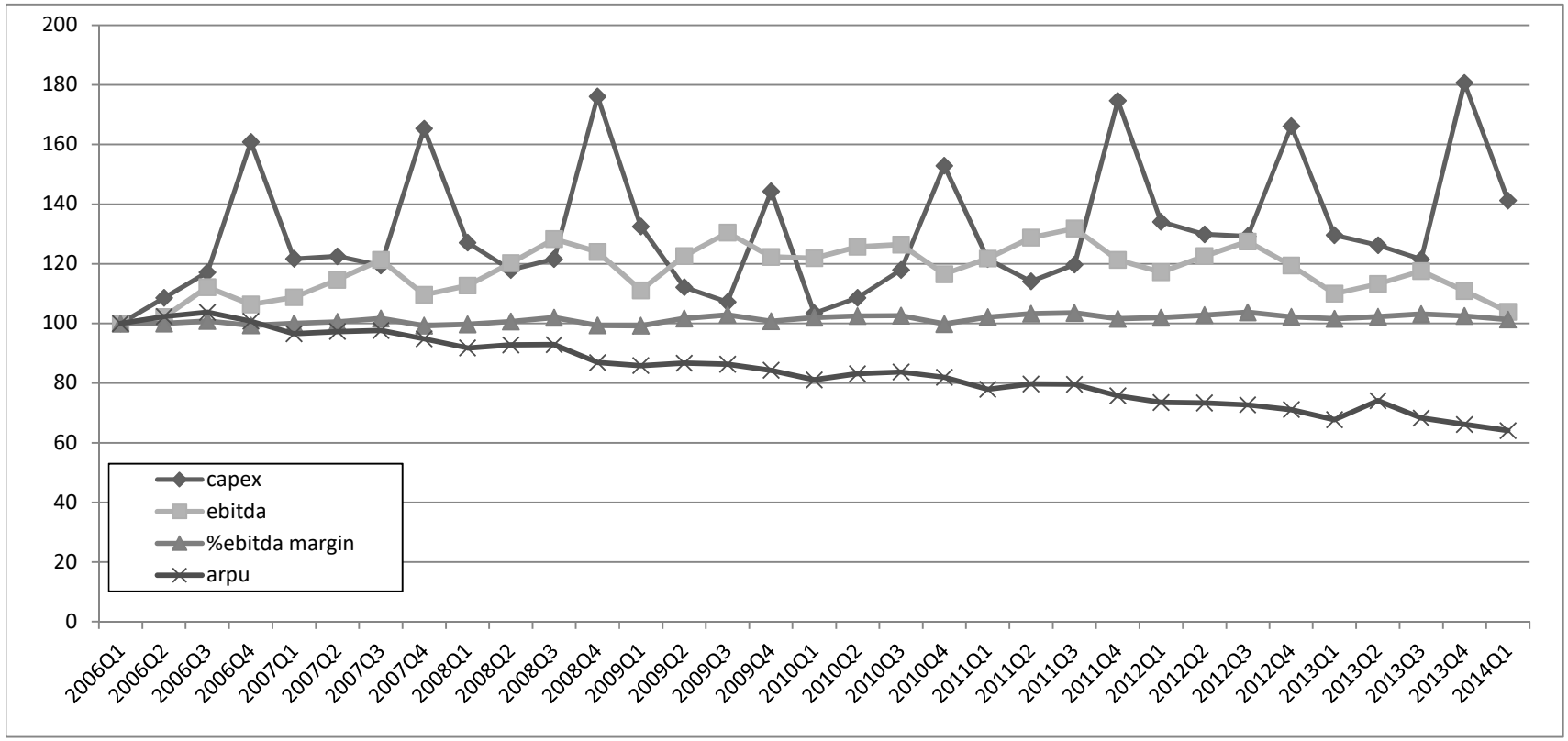
Table A8 shows the results for the analysis of total industry investment, that is, the results from estimating the investment equation (3) at the country level. The base result in column 1 (period post 2005, all countries) shows a positive but not significant impact of HHI on investments at the country 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.

FIGURE 1: PRICE EVOLUTION OF MOBILE TARIFFS, 2006Q1-2014Q1 (2006Q1=100)



Notes: The figure presents information on the normalised (at the beginning of 2006) PPP-adjusted demeaned average prices (total bill paid) across countries for all tariffs (overall) and for each consumer profile separately (low, medium, high).
Source: Authors' calculations based on the Teligen data corresponding to the best deals available at every quarter across 33 countries.

FIGURE 2: EVOLUTION OF INVESTMENT (CAPEX), PROFITS (EBITDA), PROFIT MARGINS (EBITDA MARGIN) AND REVENUES (ARPU), 2006Q1-2014Q1 (2006Q1=100)



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.
Source: Authors' calculations based on accounting information from the Global Wireless Matrix of the Bank of America Merrill Lynch (BoAML) dataset.

TABLE 1 - SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Observations	Mean	Standard Deviation
	Teligen dataset (2002-2014)			Teligen dataset (2006-2014)		
Mobile tariff price (P_{uoct})	7789	559.7	2760.7	5329	564.7	3328.2
Mobile tariff price (low user profile)	2598	186.780	78.997	1778	178.8	84.4
Mobile tariff price (medium user profile)	2596	504.701	1906.1	1776	497.6	2301.7
Mobile tariff price (high user profile)	2595	987.977	4349.1	1775	1018.4	5253.6
Number of competitors (N_{ct})	7378	3.556	0.925	5002	3.558	0.830
Four competitors dummy	7789	0.293	0.455	5329	0.343	0.475
Five+ competitors dummy	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	7789	0.349	0.477	5329	0.360	0.480
GDP per capita	7510	37803.0	20813.9	5134	41181.8	21964.2
Mobile Termination Rate	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
Number of competitors (N_{ct})	5049	3.805	1.013	2903	3.725	0.866
Four competitors dummy	5049	0.361	0.480	2903	0.429	0.495
Five+ competitors dummy	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
Mobile Termination Rate	3922	0.123	0.089	2495	0.084	0.064
MTR_Diff_{ct}	3957	0.444	2.325	2495	0.317	1.443

Notes: The above table provides summary statistics on the key variables used in Tables 3-9 based on the Teligen data corresponding to the best deals available at every quarter, the BoAML dataset and the matched MTRs. The unit of observation in the Teligen dataset is at the country-operator-usage profile level, whereasint the BoAML dataset it is at the country-operator level.
Source: Authors' calculations based on the Teligen, Cullen and BoAML matched datasets.

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

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	$\ln P_{uoct}$	$\ln P_{uoct}$	$\ln P_{uoct}$	$\ln P_{uoct}$	$\ln P_{uoct}$
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)$_{oct}$	0.192***	0.168***	0.194***	0.201***	0.201***
	(0.0693)	(0.0553)	(0.0689)	(0.0685)	(0.0689)
ln(MTR)$_{oct}$ × 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

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%.

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

TABLE 4 - THE IMPACT OF MARKET STRUCTURE ON OPERATOR'S INVESTMENT

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	IV-FE	IV-FE
Dependent variable	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$
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

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

TABLE 5 - THE IMPACT OF MARKET STRUCTURE ON INDUSTRY INVESTMENT

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	IV-FE	IV-FE
Dependent variable	$\ln CAPEX_{ct}$	$\ln CAPEX_{ct}$	$\ln CAPEX_{ct}$	$\ln CAPEX_{ct}$	$\ln CAPEX_{ct}$
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

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

TABLE 6 - 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%

Notes: Counterfactual calculations based on three recent actual mergers in Europe.
Source: Authors' calculations based on the estimated coefficients from Table A2, column 5 and from Table A7, column 3.

TABLE 7 - THE IMPACT OF MARKET STRUCTURE ON PRICES - DIFFERENT USAGE AND CONTRACT TYPES

	(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	Varying basket	Varying basket	Varying basket
Usage profile	Low	Medium	High	Pre-paid	Post-paid
Time Period	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014
HHI	1.751*	2.142*	2.246*	1.336	1.650***
	(0.904)	(1.172)	(1.182)	(1.026)	(0.636)
$Pre\text{-}paid_{jct}$	-0.00264	0.0466	0.119		
	(0.0281)	(0.0927)	(0.157)		
Log GDP per capita	0.0614	-0.0933	-0.0455	1.043**	-0.555**
	(0.230)	(0.263)	(0.456)	(0.464)	(0.220)
$ln(MTR)_{oct}$	0.0720	0.233*	0.340***	0.542***	-0.0507
	(0.105)	(0.119)	(0.112)	(0.155)	(0.126)
$ln(MTR)_{oct}$ × time trend	-0.000615	-0.00736**	-0.00785***	-0.00942***	0.000190
	(0.00297)	(0.00312)	(0.00295)	(0.00365)	(0.00290)
Constant	-0.0193	-0.113***	-0.225***	-0.103**	-0.102***
	(0.0377)	(0.0304)	(0.0515)	(0.0422)	(0.0301)
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	0.450	0.450	0.479	0.495
First stage F-test	10.35	10.96	11.01	18919	25.01
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Observations	1,520	1,516	1,514	1,542	3,008
R^2	0.916	0.791	0.741	0.749	0.810
Clusters	64	64	64	156	180

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%.

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

TABLE 8 - 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

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

TABLE 9 - 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

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

TABLE A1 - FIRST STAGE RESULTS

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	IV-FD	IV-FD	IV-FE	IV-FE	IV-FE	IV-FE
Dependent variable	lnP_{uoct}	lnP_{uoct}	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$	$lnCAPEX_{oct}$
Teligen basket	varying basket	varying basket				
Time Period	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014
Diff MTR $index_{ct}$ (x 10^3)	-0.323***	-0.463***	-1.524***	-1.649***	-1.382***	-1.405***
	(0.047)	(0.060)	(0.269)	(0.300)	(0.726)	(0.763)
Three competitors	-0.069***		-0.094***		-0.091***	
	(0.008)		(0.005)		(0.009)	
Four competitors	-0.094***		-0.133***		-0.126***	
	(0.008)		(0.006)		(0.010)	
Five competitors	-0.118***		-0.199***		-0.180***	
	(0.013)		(0.007)		(0.018)	
Six competitors	-0.116***		-0.137***		-0.130***	
	(0.013)		(0.005)		(0.008)	
Seven competitors	-0.117***					
	(0.013)					
Cumulative entry		-0.032***		-0.049***		-0.055***
		(0.005)		(0.006)		(0.013)
Cumulative exit		0.023***		0.018***		0.013
		(0.005)		(0.007)		(0.010)
First stage partial R^2 of excl. IVs	0.450	0.302	0.586	0.476	0.542	0.408
First stage F-test	33.25	51.49	252.24	65.38	70.81	11.82
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Observations	4,550	4,550	2,073	2,073	618	618

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-usage (columns 1-2) or at country-operator (columns 3-4) or country level (columns 5-6) are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

Source: Authors' calculations based on the Teligen, Cullen and BoAML matched datasets.

TABLE A2 - THE IMPACT OF MARKET STRUCTURE ON PRICES - ROBUSTNESS

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	IV-FD	IV-FD	IV-FD	IV-FD	IV-FD	IV-FD
Dependent variable	lnP_{uoct}	lnP_{uoct}	lnP_{uoct}	lnP_{uoct}	lnP_{uoct}	lnP_{uoct}
Teligen basket	Varying basket	Varying basket	Varying basket	Varying basket	Varying basket	Varying basket
Countries	All	All	All	All	Europe only	Europe only
Time Period	2006-2014	2002-2014	2006-2009	2010-2016	2006-2014	2002-2014
HHI	2.037***	1.399***	0.821**	4.812*	1.028*	0.827**
	(0.637)	(0.465)	(0.355)	(2.827)	(0.528)	(0.375)
$Pre\text{-}paid_{oct}$	0.0337	0.0287	-0.0685***	0.100	-0.0526**	-0.0446**
	(0.0543)	(0.0468)	(0.0251)	(0.0871)	(0.0212)	(0.0185)
Log GDP per capita	-0.0142	-0.0227	-0.430**	0.310	0.184	0.144
	(0.216)	(0.193)	(0.208)	(0.346)	(0.183)	(0.164)
$ln(MTR)_{oct}$	0.201***	0.177***	0.215***	0.117	0.271***	0.203***
	(0.0685)	(0.0524)	(0.0749)	(0.147)	(0.0672)	(0.0544)
$ln(MTR)_{oct}$ × time trend	-0.00484***	-0.00411***	-0.00848***	-0.00283	-0.00702***	-0.00527***
	(0.00179)	(0.00145)	(0.00190)	(0.00355)	(0.00180)	(0.00151)
Constant	-0.094***	-0.112***	-0.0794***	-0.108***	-0.133***	-0.125***
	(0.022)	(0.0238)	(0.0156)	(0.0291)	(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	*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	0.587	0.454	0.585	0.2306
First stage F-test	33.25	42.03	26.66	7190	15927.21	951.12
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Observations	4,550	6,044	2,469	2,081	3,632	4,886
R^2	0.788	0.782	0.075	0.806	0.895	0.888
Clusters	192	201	156	189	150	156

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

TABLE A3 - 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)
$Pre\text{-}paid_{oct}$	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)
$ln(MTR)_{oct}$	0.201***	0.177***	0.235***	0.197***	0.0888**
	(0.0685)	(0.0524)	(0.0503)	(0.0430)	(0.0355)
$ln(MTR)_{oct} \times$ 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

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%.

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

TABLE A4 - 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)
$Pre\text{-}paid_{jct}$	-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)
$ln(MTR)_{oct}$	0.271***	0.203***	0.244***	0.190***	0.126***
	(0.0672)	(0.0544)	(0.0522)	(0.0478)	(0.0317)
$ln(MTR)_{oct}$ × 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

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%.

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

TABLE A5 - THE IMPACT OF MARKET STRUCTURE ON PRICES - COUNTRY-SPECIFIC TRENDS

	(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	-0.0807***				
	(0.0290)				
Four competitors		-0.138***			
		(0.0399)			
Five+ competitors		-0.0557			
		(0.0607)			
Cumulative entry			-0.0960**		
			(0.0464)		
Cumulative exit			0.0261		
			(0.0268)		
HHI				2.531***	2.465**
				(0.650)	(1.133)
Instrumental Variables				*Diff MTR* $index_{ct,}$ Binary indicators for the number of competitors	*Diff MTR* $index_{ct,}$ Cumulative entry and cumulative exit
First stage F-test				26.53	33.74
				[0.000]	*[0.000]*
Observations	4,550	4,682	4,550	4,550	4,550
R^2	0.799	0.798	0.799	0.798	0.798
Clusters	192	192	192	192	192

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%.

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

TABLE A6 - THE IMPACT OF MARKET STRUCTURE ON OPERATOR'S INVESTMENT RELATIVE TO MARKET SIZE

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	IV-FE	IV-FE
Dependent variable	$\ln(CAPEX_{oct}/subs_{ct})$	$\ln(CAPEX_{oct}/subs_{ct})$	$\ln(CAPEX_{oct}/subs_{ct})$	$\ln(CAPEX_{oct}/subs_{ct})$	$\ln(CAPEX_{oct}/subs_{ct})$
Time Period	2006-2014	2006-2014	2006-2014	2006-2014	2006-2014
Number of mobile operators	-0.131***				
	(0.0413)				
Four competitors		-0.205***			
		(0.0600)			
Five+ competitors		-0.338***			
		(0.118)			
Cumulative entry			-0.131*		
			(0.0676)		
Cumulative exit			0.0832		
			(0.0519)		
HHI				2.704**	3.370***
				(1.201)	(1.207)
Time since $entry_{oct}$	0.0210	0.0217	0.0210	0.0143	0.0150
	(0.0218)	(0.0217)	(0.0220)	(0.0199)	(0.0199)
First entrant	0.663*	0.647*	0.666*	0.559*	0.546*
	(0.347)	(0.348)	(0.349)	(0.296)	(0.294)
Second entrant	0.526*	0.512*	0.529*	0.327	0.317
	(0.299)	(0.300)	(0.299)	(0.256)	(0.255)
Third entrant	0.487*	0.474*	0.491*	0.334	0.326
	(0.267)	(0.269)	(0.267)	(0.224)	(0.222)
Log GDP per capita	0.371	0.337	0.432*	0.604**	0.615**
	(0.233)	(0.236)	(0.227)	(0.245)	(0.253)
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	0.171	0.172	0.170	0.132	0.129
Clusters	78	78	78	75	75

Notes: The dependent variable is the logarithm of CAPEX of mobile operator *o* in county *c* in quarter *t* relative to the total market size (total number of subscribers). *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%.
Source: Authors' calculations based on quarterly accounting information obtained from the BoAML dataset.

TABLE A7 - THE IMPACT OF MARKET STRUCTURE ON OPERATOR'S INVESTMENT - ALTERNATIVE SAMPLES

	(1)	(2)	(3)	(4)
Estimation method	FE	FE	FE	FE
Dependent variable	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$	$\ln CAPEX_{oct}$
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

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%.

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

TABLE A8 - 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

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%.

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

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