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Does the number or the composition of players matter on the mobile broadband markets? - Lessons from a benchmarking study of the largescreen mobile broadband prices in the European Union

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Does the number or the composition of players matter on the mobile broadband markets? - Lessons from a benchmarking study of the large-screen mobile broadband prices in the European Union

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This paper presents preliminary findings of an ongoing research project

Results may change

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Abstract

Cross-country price comparison is a useful, but often deceptive exercise. The paper addresses the underlying methodological challenges, offering a practicable solution, which is both sound enough and meaningful for the comparison of mobile broadband prices on different markets. Both the simple comparisons and the econometric analysis give valuable insights into how the structural characteristics and also other factors are associated with the price-differences between national mobile markets of the European Union. The result suggests that the presence of a challenger player on the market is important to have lower prices and wider choice of options on the market. This factor seems more important than the mere number of the players.

Need for empirical information about the functioning of the mobile broadband markets

A good telecom regulation and competition policy must be built on the understanding of and solid evidence on the functioning of the market. Analyzing the effect of market structure, especially the number of competitors shaped by entries and mergers, the market shares and concentration, and also the different characteristic strategies and behaviors of the players are important ingredients for gaining empirical knowledge. The need for such evidence is manifest especially in the case of mobile markets where the current industry opinion on the desired market structure and the view of the European Commission (and in many cases also that of the local competition authorities) differ, due to the highly divergent assessments of the overall effects of a merger or an entry on the consumers.

For better industrial and competition policy decisions in the current development phase of the mobile markets, it is important to gain empirical evidence on the role of structural parameters on the functioning of the market. This is a challenging exercise because the market is changing fast and mobile usage now is more and more data driven. This affects the industry cost structure and the revenue stream and alters the viable business models. Recent market changes are also complicating the assessment of whether the competition is effective on the market.

The relatively few recent studies[1] on the effect of entries and mergers, or the number of market players on mobile penetration and price development are valuable from a competition policy point of view, but their shortcoming is that they are only capable of providing empirical insight into a former stage of the mobile market development when voice was evidently the dominant feature of the mobile communication service. The ongoing changes in technology, cost structure and consumption patterns require that evidence on the effects of the current functioning of the markets on prices and mobile broadband development must be collected, analyzed and the results are used in making policy and competition decisions concerning these markets.

In addition to any controlled experiment being almost impossible to perform, preparing event studies is also aggravated by the rare occurrence of the relevant events, the difficulties of collecting information for the evaluation, and the shortness of the time horizon for the evaluation of the effects. In such circumstances, benchmark studies capable of providing comparative information on the mobile markets with different relevant characteristics can be a valuable source of information on the functioning of these markets. Though these comparisons are usually not sufficient to reveal causal relationships, they can provide at least well enough comparative results that can be considered in policy decisions.

This paper is about the comparison of large screen mobile broadband prices in the EU countries between 2013 and 2016, addressing the underlying methodological challenges and offering a practicable solution, which is both sound enough and meaningful for the comparison of prices on different markets. The comparison in turn gives valuable insights into the structural and also some competitive incentive factors associated with the price-differences between national mobile markets. The results of cross-country comparison, appropriately interpreted can be used as a valuable input for competition policy and regulation.

[1] Csorba G., Pápai Z. (2013): "Does one more or one less mobile operator affect prices? A comprehensive ex-post evaluation of entries and mergers in European mobile telecommunication markets", ITS Conference paper, 24th European Regional Conference of the International Telecommunication Society, Florence, Italy, 20-23 October 2013, available at http://econstor.eu/bitstream/10419/88503/1/773139184.pdf ; Affeldt P., Nitsche R., (2014) A price concentration study on European mobile telecom markets, ESMT Working Paper, ISSN 1866-3494, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2526821; Aguzzoni L., Buehler, Di Martile L., Ecker G., Kemp R., Schwarz A., Stil R., (2015): Ex-post analysis of two mobile telecom mergers: T-Mobile/tele.ring in Austria and T-Mobile/Orange in the Netherlands, European Commission; Genakos C., Valletti T., Verboven F. (2015): "Evaluating Market Consolidation in Mobile Communications", CERRE Report, available at: http://cerre.eu/sites/cerre/files/150915_CERRE_Mobile_Consolidation_Report_Final.pdf

Methodological challenges in the comparison of prices

Though it is a well-established practice by international organizations to collect and provide comparative data on different national markets, it is not without challenges. Comparability requires the straightforward collection and processing of raw data inputs, a methodologically sound and transparent calculation of the figures for comparison, and the clear interpretation of the results. There are public sources like the OECD, and the European Commission that regularly publish data, which is useful for comparison of different national telecom markets. These publications present processed data that was supplied by some private provider[2] or contractor[3] for special projects. There are also commercial products providing comparative price information, however these are not available to the public and can only be accessed by the clients and allowed for use only in their internal organization processes or decision making.

Transparent and sound methodology is a must-have requirement for the proper understanding and interpretation of the results, i.e. taking any result of the comparison seriously at all. Even if the data collection is sound and trusted, some calculations are required to obtain comparable prices. In general two methods can be used, the average price per unit (GB, in case of data), and the basket price method.

The first method requires historic revenue data and the consumed quantities, preferably by product category. The revenue and the consumption is real, but the calculated price is a mass average and does not say much about how the product was offered and what price structure the consumers met on the market.

The basket method is working without quantities and uses only the observed list prices. Then, the price of some fixed baskets which correspond to some "typical" consumption quantity patterns, i.e. as consumer baskets are calculated. The basket method uses the price information as it was presented to the customers. The consumption patterns are artificial, nevertheless intended to be represent some fairly homogeneous large groups of different users.

Both methodologies are incomplete and have their pros and cons[4]. However, in most cases only the basket method is feasible for public studies due to the lack of sensitive company data.

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[2] Like Strategy Analytics (former Teligen).

[3] Like the Van Dijk (2015) study on Mobile Broadband Prices, prepared for the European Commission.

[4] Some discussion of the problems with price measures can be found in Growitsch, Marcus and Wernick 2010. Growitsch C., Marcus,J. S.,Wernick, C. (2010):The Effects of Lower Mobile Termination Rates (MTRs) on Retail Price and Demand, Communications & Strategies, 80,Q4. p. 119-140, and also in Genakos, Valletti, Verboven (2015).

Mobile service is a complex bundle of different service elements, so it is not the ideal case of a single price for a simple product, and unfortunately in practice we can hardly find a single price tag attached to any of its comprising elements. In order to make mobile bundles comparable, usually some kind of basket comparison methodology is used. The basket method does not come without its merits and risks as well. Its merit is that it creates comparable bundles that comprise the same quantity of service elements, i.e. consumer "baskets" for a calculated single basket price. Although it is transparent and sound, there is a risk that the basket created for comparison is artificial and arbitrary, without many real consumers using anything close to them. In this case the basket and any comparison based on it is irrelevant. The other potential weakness of the basket method is that if it uses a consumption pattern relevant in a group of countries and less fitted to, or totally irrelevant in others, it shows a distorted picture, favoring one group of the compared countries to another. Therefore the proper construction of the baskets is key.

Having these drawbacks as they are, basket comparison seems to be more useful and trusted than other potentially interesting, but dubious methods, of which a good example of the Digital Fuel Monitor prepared by Rewheel[5]. The Digital Fuel Monitor compares highly extreme usage patterns using a preset price, thereby keeping minimum quantity thresholds of the arbitrarily considered different bundle elements and focusing only on how much GB of data this price covers. Baskets must be defined with relevant, realistic usage patterns, which covers significant portion of the real market demand

For mobile broadband price comparison we intentionally chose a well-defined special segment, the large-screen mobile broadband with data only SIM cards that are used with mobile sticks, dongles or any mobile data modems. It is a clear advantage with large-screen offers that in this segment there is no need to define voice and sms consumption patterns, thereby the price of the data is not distorted by the different allocation between the classic mobile and the data services.

Large-screen mobile broadband price data

Large-screen mobile broadband is a distinct segment of the mobile broadband market. Both usage goals and circumstances, and also the pricing are different from small-screen packages. On one hand there is no voice service included in the large-screen plans, on the other they offer higher data traffic than small-screen plans. While these plans are not applicable to smartphones, they may also be appropriate for tablets.

Most operators set up different packages for different user groups (low, medium and high-intensity users) with considerable differentiation in the prices and features of the plan. The key element of this differentiation is the monthly data allowance included in the package. There are packages advertised as "unlimited", however, after a certain data limit, the speed of the connection is significantly reduced (typically to a GPRS speed of 64 or 128Kbps). We

[5] See www.dfmonitor.eu

do not consider these plans "unlimited", as the reduced speed is not broadband at all. In some countries, plans with de facto unlimited data traffic are available, but in this case usually the maximum connection speed differs between packages offered by a given operator. In our categorization we use the GB data allowances that are included in the monthly price of the plan as the primary identification characteristic. We also use an explicit benchmark for the achievable download speed in the baskets' definitions because some operator differentiate among consumers not (or not only) in data allowance but also in the allowed speed.

In each March from 2013 to 2016, Infrapont collected data from the websites of all mobile network operators' in each member state about the actually advertised large-screen mobile broadband offers. Only some of the nearly hundred operators did not have offers that could be categorized as LSMBB (large-screen mobile broadband). The table below shows the number of member states, operators and plans in the database for each year.

Table 1. | Database of large-screen mobile plans

	2013	2014	2015	2016
number of countries	27	28	28	28
number of operators	90	92	91	90
number of plans	322	343	338	319

Methodology

This chapter presents the methodology we used for the LSMBB price comparison. Despite the relative simplicity of the LSMBB offers (compared to the small-screen tariff structures) several methodological challenges emerge that can seriously influence the results of the benchmarking and the conclusions that can be drawn from it.

The first issue concerns the design of the consumer baskets. Although plenty of different offers exist on the European market, the prices can be compared only by predefined consumer baskets that represent the supply structure. If we define too few basket, there is a risk that the results of the comparison will be distorted or misleading since the baskets fit to the real consumer pattern of only a small part of the markets/countries. We can improve the coverage of real usage patterns by increasing the number of baskets, however the comparison can be untreatable after a certain point. The challenge is to find the right balance between the number of baskets and the relevance of the comparison.

The second task is the calculation of the average monthly prices of the plans in such a way that the different tariff structures used by the operators become comparable. This includes the uniform treatment of the monthly and one-off service price elements, the equipment costs, bundling prices and the different discounts or free of charge extra services.

The third task is to select or calculate a price at the operator-level that we can use for benchmarking in cross-country comparisons. Here we have several options such as the cheapest price on the market, cheapest offer of the two major players or some kind of average price.

Finally, there is the recurring issue in using benchmark studies of how well the results represent the overall market situation. Any basket can represent only a segment of a national market at best. In this study we want to address this fourth task too, offering a workable solution for comparison of the overall price levels.

In this chapter we deal with the first three issues, while the fourth will be discussed after the presentation of the results of the basket price comparisons.

Consumer baskets for price comparison

Large-screen mobile broadband plans are highly diverse across countries, which makes it hard to directly compare them. For this reason, we define user baskets which represent certain user profiles, and compare the prices of these user baskets instead of the exact offers. With this method a comprehensive picture will emerge of the overall relative positions of member states on the market.

When the baskets were designed we considered three principles:

- different baskets must describe relevant, realistic usage patterns,
- baskets must be empirically relevant: they must be based on the frequency distribution of the real packages (the modes of the distribution of the plans are the starting points for defining the baskets), and
- it is preferable to use baskets similar to OECD-defined large-screen mobile broadband baskets if there is no particular reason not to.

With the first two criteria in mind, we decided to define the user baskets based on the plans' monthly data allowances. We believe that the first and foremost identifier of how the consumer wishes to use mobile broadband is how big a data allowance she chooses. Different usage patterns describe a low, a medium, or a high-intensity user, which most likely materialises in the data limit chosen.

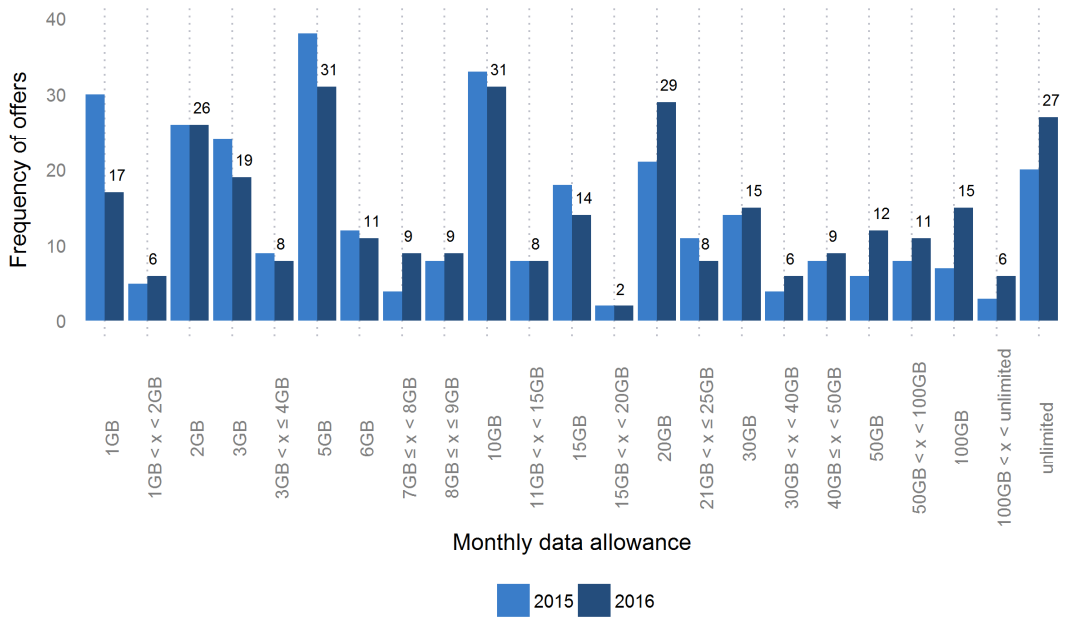
Our consumer baskets are the following:

- three low user baskets: 1, 2 and 3 GB;
- two medium user baskets: 5 and 10 GB;
- three high user baskets: 15, 20 and 30 GB data allowance.

Taking a look at the frequency of offers by monthly data allowance (Figure …) it is clear that the above defined user baskets are relevant, as these are offered in the highest number of plans. Plans corresponding to these 8 baskets cover 64% and 55% of all offers in

2015 and 2016 respectively, which confirms the relevance of the defined set of baskets. However, we cannot overlook the significant increase in the number of offers over 30GB, particularly of 50GB, 100GB and unlimited offers. However, unlimited offers are available still only in nine countries, and out of the 27 such plans 11 is offered in Finland.

Figure 1. | Frequency of offers by monthly data allowance (GB; number of plans)



Source: Infrapont, based on operators' websites

Note: Labels are for 2016 frequencies.

Regarding the OECD-defined large-screen mobile broadband baskets, 4 out of the 5 is the same as in our examination. The only exception is the OECD basket with 500 MB which is apparently too small compared to the observed usage patterns and has no or marginal relevance. The OECD baskets (500 MB, 1, 2, 5, 10 GB data allowance) seem to be a bit outdated, since they do not cover the higher user consumer segments at all, despite the fact that half of the operators' offers in 2016 are of higher allowance than 10GB.

Even though the major differentiator used by the operators is the data allowance, there are some markets where allowed maximum download speed also play a role in the design and segmentation of the plans. Especially in countries where plans with very high or unlimited data allowance are prevalent, operators use different download speed limits to address the different consumer segment.

Therefore in calculations relating to consumer baskets we also used an explicit benchmark for the achievable download speed in the baskets' definitions so that we can handle plans differentiating among consumers not (or not only) in data allowance, but also in the speed limit, which is apparently a steadily growing trend.

Table 2. | Baskets and the maximum download speed considered appropriate for such a basket

User basket	Monthly data allowance (GB)	Maximum allowed download speed (Mbps)
low user I.	1	≥1
low user II.	2	≥2
low user III.	3	≥3
medium user I.	5	≥4
medium user II.	10	≥4
high user I.	15	≥6
high user II.	20	≥6
high user III.	30	≥6

We only consider a plan as corresponding to a given user basket if the maximum allowed speed equals or exceeds the level defined in the table above. For example, even if a plan grants unlimited data, but the maximum download speed is below 6 Mbps, we do not consider it appropriate for the high user basket.

Calculation of the prices of individual plans

To calculate the prices of the baskets, first the prices of the individual plans offered by mobile operators need to be accounted for. The following elements were considered when we calculated the average monthly price of the plans:

- monthly list price of the plan,
- one-time fees related to the package: activation fees, administrative fees, service fees, etc.,
- price of the stick/modem,
- unambiguously quantifiable discounts.

The average monthly price of plans was calculated according to the following formula:

$$\text{average monthly price} = \text{monthly list price} + \frac{\text{one-time fees}}{\text{contract length}} + \frac{\text{price of the stick/modem}}{24} - \frac{\text{discounts}}{\text{contract length}}$$

which was constructed using the considerations listed below.

- The *monthly list price* of the plan in many cases depends on the length of the accepted loyalty contract. Available contract lengths can vary, however, 12 and 24 months' loyalties are the most frequent. Usually, the longer the loyalty period, the lower the monthly list price. We use the most favourable monthly list price for the price comparison, which is usually the price with the longest loyalty contract.

- O*ne-time fees* are taken into account by dividing the sum of the fees by the duration of the chosen loyalty contract (expressed in the number of months).
- The *price of the stick/modem* varies significantly among operators. Some provide plans with the price of the stick included in the monthly list price, while in other cases customers need to select a stick/modem from a predefined choice set. In the latter case, the cheapest stick allowing the functional use of the plan is taken into account for the calculation of the price (i.e. we preferred using the cheaper 3G modems until they can allow a bandwidth that satisfies the requirements of a given basket). The price of the stick/modem is divided by 24 in these cases, because we assume that sticks and modems can be written down over two years[6].
- Mobile operators offer a wide variety of discounts on their plans. These discounts play a significant role in attracting customers and they are also important tools of differentiation and discrimination. Some of the discounts are well quantifiable and can be expressed in monetary terms, like lower monthly list prices for the first few months, abandonment of a one-time activation fee, or price reductions in the case of online purchase. We take these discounts into account when calculating average prices, and divide them by the length of the contract, to reflect how the discount affects the price of the plan over the entire duration of the contract. Other discounts, like a reduction in the price if the customer has a voice plan with the operator, or services available free or with discounts (e.g. music, hotspot usage, virus protection etc.) are not taken into account.

Matching plans and consumer baskets

We select each operator's most affordable plan to each user basket defined above whenever possible. Usually, this plan is the one with the exact data allowance that the basket's definition calls for. When an operator does not have an offer corresponding exactly to the size of the predefined basket, we apply the cheaper one of the following two options:

- the price of the plan with the closest, but higher data allowance,
- the price of the package with the closest, but smaller data allowance, plus the charge of the extra data volume the consumer would incur to achieve the data volume specified for the basket.[7]

[6] In some cases, there is a monthly fee for the stick/modem. When the price is a monthly fee, it is added in the following way: we multiply the monthly price of the stick/modem by the length of the contract and divide it by 24. This way, we get a stick/modem price comparable to those offers where a one-time fee is paid for the stick/modem.

[7] In fact, extra data volumes in almost all cases result in significantly higher costs according to our calculations; therefore principally the first option is preferred and used.

If there is no exactly matching offer for the smaller user baskets, i.e. the operator's smallest offer contains a higher data allowance than the basket in question, we choose the plan with the smallest data allowance.

For countries where plans with high data allowances are not available, prices for the large user baskets could theoretically be determined by adding the cost of the extra data charge to the monthly list price of the closest available offer. However, in most of the cases this would lead to such high prices that the purchase could not have been considered rational under normal circumstances. These high prices are not presented in our figures, and in the rankings these countries are listed behind the country with the most expensive "real" offer. These markets are considered as having no plans available that corresponds to the high user basket for a rational consumer[8].

Defining prices for cross-country comparison

From the operators' basket prices we have to select or calculate that price which we can use for the cross-country comparison. We use two methods: first, we make the comparison of the *minimum* prices on national markets corresponding to a given user basket, and second, we compare the *average* prices on the national markets.

Both approaches have advantages and disadvantages. The average price better reflects the overall market price level[9] but it can make some countries appear more expensive than they actually are to a rational consumer who is able to find the cheapest offer. For example, in the case of high user baskets, if four operators supply the market with a corresponding plan and three of them advertise the service with a high price and one at a lower price, the average price will be higher than it would be if only one operator offered the plan at a relatively modest price.

Conversely, in the case of low user baskets it can occur that only one operator has a low-priced offer that corresponds exactly to the data allowance specified for the given basket, while the other operators' monthly data allowances are larger and their prices are higher too. Thus the average price would be higher than in the situation where every operator supplied the same "appropriately sized" package.

Comparing the minimum prices avoids these problems, but leads to another: minimum prices are more volatile or contingent on some special issues than average prices, as

[8] Our study also ignores the possibility that a user with high data demand can fulfil his or her needs by purchasing two or more plans with smaller data allowances from one or even several operators. In some cases, this arbitrage scenario would in fact be rational as the calculated monthly average cost of two or three combined plans could be lower than the cost of one single plan.

[9] The correct measure for the average market price would be the operators' average price weighted by their market share. Due to the missing market share data we use simple (unweighted) average.

they often reflect discounts available for a limited time period only (e.g. if a consumer orders the plan online by March 31, 2016 she gets a discount from the monthly list price for some months). The other possible drawback of the minimum price comparison is that in some cases these prices are based on plans offered by the smallest and newest operators with the poorest coverage, so they are not really comparable with full-fledged plans. For these reasons, we use both the results of the minimum price and the average price in the cross-country comparison.

Prices are compared in euros. Prices in national currencies are converted to euros at the average Eurostat exchange rates as of March 2013, 2014, 2015 and 2016. Price comparisons often use exchange rates based on purchasing power parities (PPP) instead of nominal exchange rate values. These comparisons reflect the relative expensiveness of the service for the consumers by filtering out the overall price level differences among the countries.[10] Therefore, price comparisons based on PPP can be suitable for evaluating the market from the residential consumer's point of view. Using the available purchasing power parity indices[11] we calculated all the prices in euro PPP.

Features of advertised large-screen mobile broadband plans in the EU

The main intention of building the database was to make it suitable for an international comparison of the large-screen mobile broadband prices in the EU. However our database enables us to paint a picture on the availability of offers with various data allowances and other features of the large-screen mobile broadband offers.

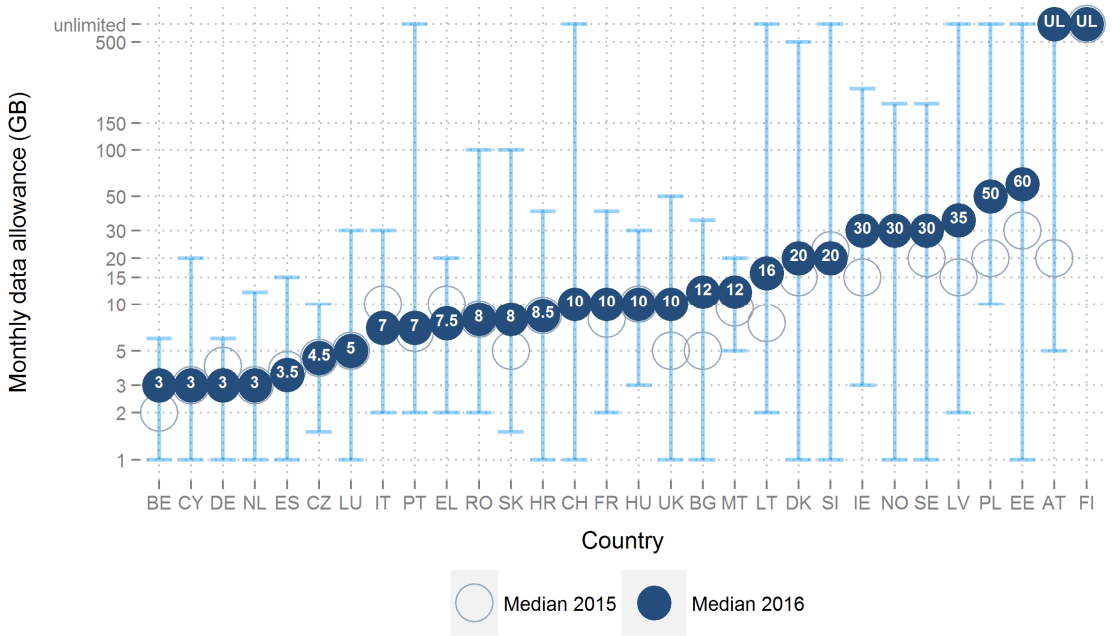
Mobile operators typically offer plans targeted at different users: low, medium and high-intensity, and sometimes extra-heavy users. Therefore, an operator usually offers three or four plans. Operators within a given country tend to provide plans similar to their competitors', but the offers vary significantly between countries.

In Belgium, or Germany for example, the plan targeted at "high users" offers only a 6 GB data limit, while 6GB data allowance in some other countries are at the lower end of the spectrum. Figure 2 gives an overview of the minimum and maximum data allowances provided by mobile operators in the 28 observed countries in March 2016.

[10] "PPPs serve both as convertors and as spatial price deflators. They convert different currencies to a common currency and, in the process of conversion, equalize their purchasing power by eliminating the differences in price levels between countries. (…) In their simplest form, PPPs are nothing more than price relatives that show the ratio of the prices in national currencies of the same good or service in different countries." Eurostat-OECD Methodological Manual on Purchasing Power Parities, European Union / OECD, 2012, p.13.

[11] Purchasing power parities (PPPs), price level indices and real expenditures for ESA2010 aggregates (prc_ppp_ind). Last update: 15-06-2016
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_ppp_ind&lang=en

Figure 2.| The minimum, maximum and median offers by country



Source: Infrapont, based on operators' websites

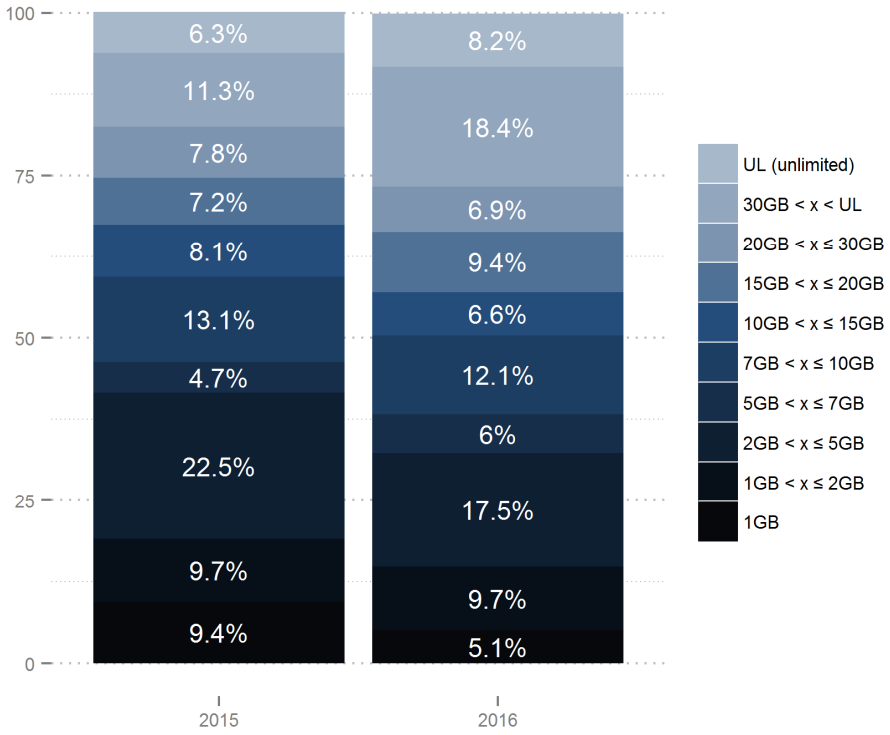
The range of data allowances across countries is quite large and the differences seem to have increased in the last year. 23 countries have plans both with low (1, 2, or 3GB) and high (more than 15GB) data allowances, while the lowest offer is 10GB in Poland and 5GB in Austria and Malta. Operators in Finland still provide only unlimited offers. In eleven countries the maximum data allowance increased from the last year (after the decreasing tendency from 2014 to 2015), and decreased only in Germany. This is the second consecutive year we identified a decrease of the maximum data allowance in Germany which was 30GB in 2014. In a similar fashion, the minimum data allowance increased in 6 and decreased only in 2 countries.

Belgium and newly Germany offer the lowest maximum data allowance at only 6GB; in every other country, there are plans available offering at least 10GB. Maximum data allowance increased only moderately in the Netherlands and in Belgium but more substantially in the other nine countries. Most notably, in Ireland from 60GB to 250GB and in Sweden from 100GB to 200GB, while in Lithuania from 50GB to unlimited and in Poland from 70GB to unlimited. As of March 2016, out of the 28 EU countries 20 have plans with a 30GB or higher data allowance compared to 2015's 19 and the two new countries also belong to this group. This year Lithuania and Poland introduced unlimited offers joining Austria, Estonia, Finland, Latvia, Portugal and Slovenia from last year, while also Switzerland have such packages.

Comparisons based on the maximum data allowances, however, may not provide the best representation of the relative positions of countries. To provide a better description of the supply structure, Figure 2.1. also depicts the median offers in the observed countries. The

median data allowance is again 10GB just as last year both with and without Norway and Switzerland, although it almost turns into 12GB. The trends across the countries underpin the expected increase in the median in the future. In Ireland, Sweden, Estonia, Latvia and Poland the median values increased with more than 10GB, whereas in Austria it jumped from 20GB to unlimited (joining Finland). These countries along with Denmark, Slovenia and Norway serve now the highest median data allowances (over 20GB). The trend across the 28 countries from the last year is just moderately affected by some countries with decreasing median allowances: median allowance shrank in Germany, Italy, Greece, Slovenia and Spain.

Figure 3. | Distribution of offers by data allowance (GB), March 2015, March 2016



Source: Infrapont, based on operators' homepages

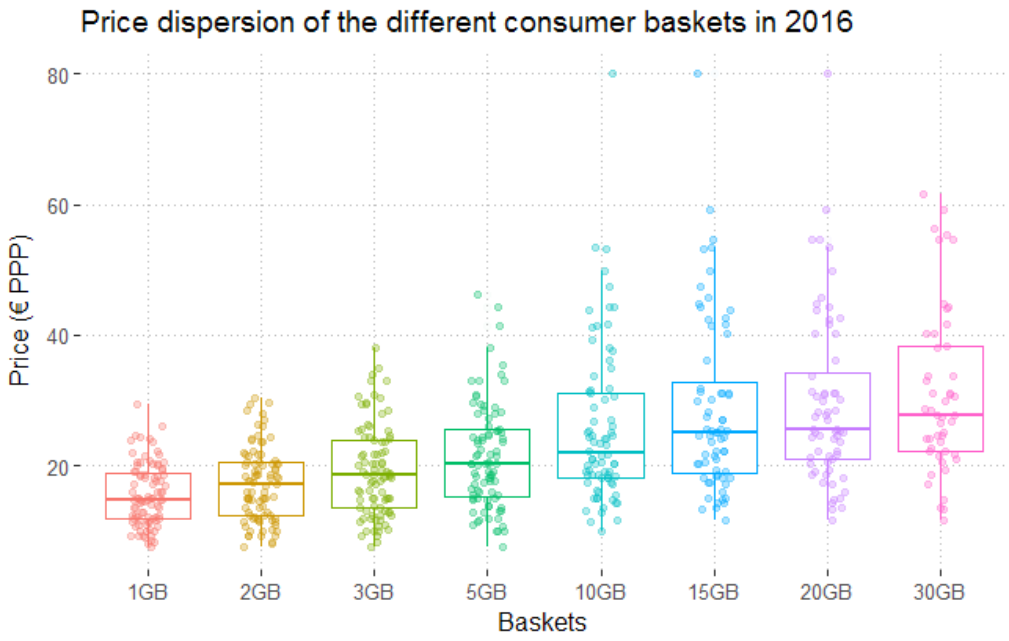
The distribution of plans by data allowance shows two substantial changes from the last year. First, while last year most offers situated in the 2-5GB range (22.5%), this category now provides only 17.5% of the offers. Instead, the relatively most plans (18.4%) in 2016 are larger than 30GB but not unlimited yet, showing 7.1 percentage point increase for these packages from last year. This shift in these two categories has been ongoing since 2014, nevertheless producing the greatest change this year. Second, after the modest increase in the share of plans higher than 10GB throughout the previous years, from 40.7% in 2015 it surged to 49.5% in 2016 which is driven mainly, but not only, by the upper mentioned category. Moreover, it seems that from the two trends that were visible between 2013-2015, the lowering importance of 1GB offers continues with a more considerable change this year than ever before, however, breaking the trend, the percentage of unlimited offers raised after 2015 (from 6.3% to 8.2%).

Price differences in the EU

There are large differences between countries and operators in the prices of the respective baskets. The ratio of the most expensive offer to the cheapest one in 2016 in the EU28 was the highest in case of the minimum prices of 10 GB plan, it was 12,7. The cheapest price for 10 GB is €5.60 compared to the maximum of €70.88. Differences measured with this ratio are smaller at the lower end of the basket range. A possible reason is that significant price differences of 10GB plans reflect the different service positioning of the operators: in some countries 10GB plan is positioned as a high user basket while on other market it is only a low user offer.

Nominal prices on average only slightly decreased from 2013 to 2016, but the differences in general have remained still high. However the number of relevant baskets in each category increased, so the whole basket range becomes more and more available in the different national markets. There are only some countries where the supply still does not cover the whole basket range, i.e. there is no at least one operator with a corresponding offer.

Figure 4. | Prices and price differences by baskets in 2016



In order to give a flavor of the results of the basket comparison we present the price rankings of the European Union member states in case of the largest low user 3GB basket here. First with the nominal average price and second with the PPP adjusted average price.

Figure 5. | Country rankings by the nominal price of the 3GB basket of 2016

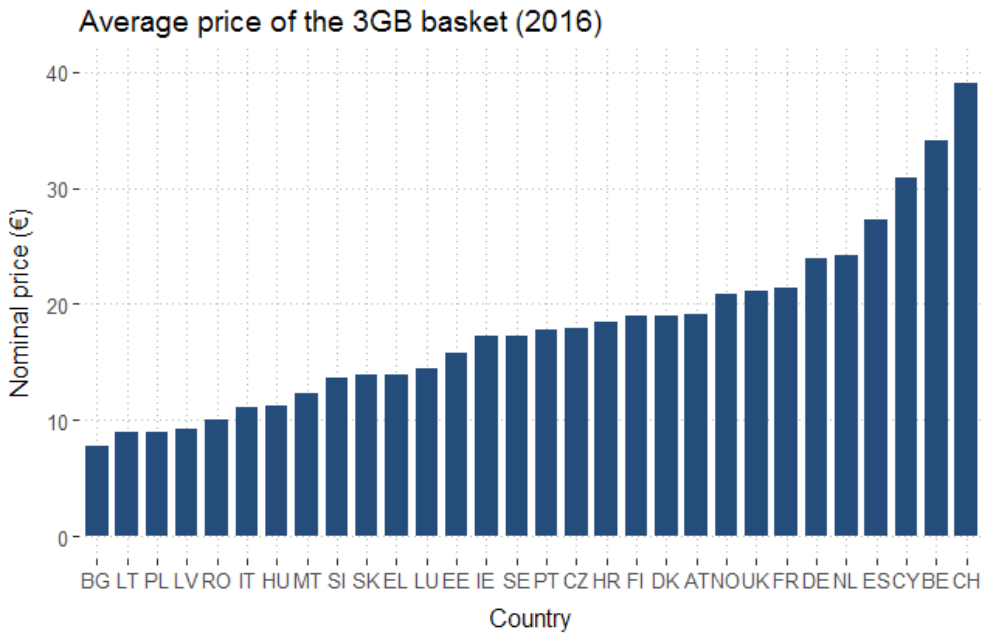
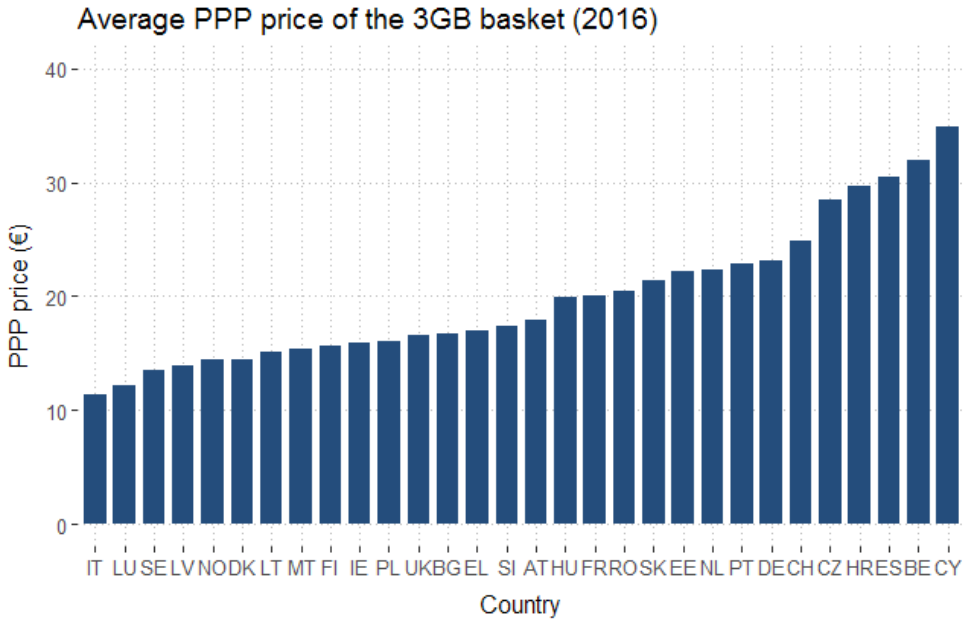


Figure 6. | Country rankings by the PPP adjusted price of the 3GB basket of 2016



Similar differences can be shown by using the country minimum price.

Our data shows that price differences within countries are smaller than between them. For example in 2016 in case of the 3GB basket the smallest ratio between the most expensive and the cheapest offer was 1.06 in case of Hungary. The highest ratio was 3.14 in Bulgaria. This ratio was below 2 in 22 of the 28 EU member states.

Differences between countries are higher if the minimum price is considered. The ratio of the most expensive and the cheapest 3 GB offer on PPP adjusted price was 4.64 in 2016. In case of the average price this ratio was only 3.07. This difference was still among the highest between countries.

The tendency is the same for every basket, though the measured differences can be higher or slightly smaller. Based on the comparison of the quantity and price of the large-screen mobile broadband, it seems clear that these markets are national. There are large differences between even neighbor countries. The 4-year time span is not enough to judge whether there is a tendency of convergence between countries. However the differences between the country average prices decreased significantly from 2013 to 2016.[12]

The Large-Screen Mobile Broadband Price Index

It is useful to study and compare the prices of the different baskets, however, it is too complex and difficult to comprehend the whole picture and hard to discover the different patterns of pricing. It is reasonable to look for some simple tool for comparison, a single index value for each country, which is an aggregate overall price level for large-screen mobile broadband. Using such an index we can present a comprehensive picture of large-screen mobile broadband price levels prevailing on each national market.

Basket price comparisons provide information about the relative positions of the national markets in relation to different consumer segments. These rankings reveal partial comparative positions, but the overall picture is also of interest, as are the relative price levels of the member states over all consumer segments. The task at hand is to create a measure which enables this comparison, hiding accidental differences, but highlighting important, structural or country-specific ones.

A solution for comparing the overall price level would be to calculate some type of average price per GB for each member state. In the case of mobile voice services, for instance, ARPM (average revenue per minute) provides the standard measure of the overall price level on the market. Similarly, average revenue per GB could serve as a measure for the large screen mobile broadband market. Unfortunately, revenue data or traffic information even for the total mobile internet usage is not available. Based on the basket prices, however, we can create a measure, as a workable proxy solution.

One approach applied in some studies would be to calculate an average or sum of the baskets' prices. However, this method may lead to deceptive results, since the sum or the average would be dominated by the high user baskets (whose prices are three or four times higher than those of the low user baskets). Without any information on the quantity of consumption corresponding to the predefined baskets, it is without any justification to grant larger weight to any of the packages in the aggregate price level indicator. For example, if the prices of low and medium user baskets are fairly low in a country, and the prices of the high user baskets are high, an indicator based on summing or averaging prices will show this country as an expensive one. These price averaging of the baskets

[12] In case of the average price, the most expensive/cheapest ratio of the PPP adjusted prices decreased from 2013 to 2016 for every baskets, however with the minimum price the picture is more controversial. In case of the 3 GB basket the ratio diminished from 3.57 in 2013 to 3.07 in 2016.

methods, therefore, cannot give a balanced picture of the general relative price level because they are biased toward exactly those (higher) baskets which currently represent only a very limited portion of the whole customer base. The differences in the relative positions of medium and low users, who represent the majority of the customers, could completely disappear in the sum or in the average.

In order to avoid this evident bias, we first calculate indices as a comparative measure of price differences between countries by baskets then calculate the simple arithmetic average of these indices. This method gives a more balanced result in comparisons by taking into account the relative price differences in each particular basket with equal weight. Unlike the simple average indicators, our price index is still keeping the information on the relative position, and the ratio of one ofe to the others for the same basket, but not influenced by the magnitude of the prices of the various baskets[13].

The Large Screen Mobile Broadband (Comparative) Price Index is calculated as follows:

- A score of 100 is assigned to the entity (operator or country) with the highest price in a given basket. Other entities' scores with respect to a particular basket are then calculated as a percentage of the highest basket price. The overall Price Level Index for a particular entity is calculated as the simple average of the individual basket scores. For each entity (operator or country) the index is thus between 0 and 100 and gives an indication of how expensive is an entity's offer compared to the most expensive EU level. 100 is a theoretical maximum which could be the result if a country were the most expensive in case of each and every basket. It can be interpreted as a benchmark for the highest European price level. An index score shows that entity's achievement compared to this benchmark. The lower the score, the lower the price level.

- For intertemporal comparison we use 2013 as a base year, so the 100 point of the index is calculated only for 2013, and the data from consecutive years are benchmarked toward this base level[14].

- Since on country level we have a minimum and an average price for each basket, the index can be calculated for both cases.

[13] Take the following example of two hypothetical countries, A and B. If A's prices exceed B's by 20% in the low user baskets, and the converse is true in the high user baskets, and their prices are equal in the medium user baskets, then their index will be identical, irrespective of the baskets' absolute price levels. While it is still possible that certain segments will be over- or underweighted compared to their real consumption weights on the market, we believe these results will still be more balanced and more reasonable than the averaging of basket prices alternative.

[14] Compared prices are nominal. It might happen that the value of the index for the most expensive operators or countries rises above 100 in case the basket price was higher than the highest corresponding 2013 value.

- There can be two approaches in the calculation of the price index of an entity without supplying the full range of baskets (e.g. no available offer for heavy users):

  a) averaging only the indices of those baskets of which plans with the appropriate data allowance are available for the particular entity. This calculation might show those countries in a slightly more favorable position where not all of the baskets are available on the market.

  b) averaging all basket indices, but imputing an index value of 100 for the missing baskets. This calculation takes into account the structural differences in the supply, penalizing those entities where there are missing elements on the higher end of the basket portfolio[15].

Both methods have their pros and cons and produce somewhat different outcomes in the rankings. A correlation check of the indices and the rankings based on the indices shows that the correlation between the two index versions is above 0.95, both in case of the operators and the countries. In the presentation of the results we mostly use option *a)*, where all baskets considered relevant, but for the missing ones, we use an imputed 100 point index value.

As a result of the calculation we get an interval scale, with 0 index value at the zero price. If an index value is double of another, we can conclude that the price level of the first entity is twice the others'.

We calculated the price indices for each predefined basket for each entity (operator or country). Then we calculated the aggregate index for entities (both for operators and for countries) with the averaging methods *a)* and *b)*. This one dimensional scale based on the level of prices serves us well in making the comparisons of entities, being operators or countries.

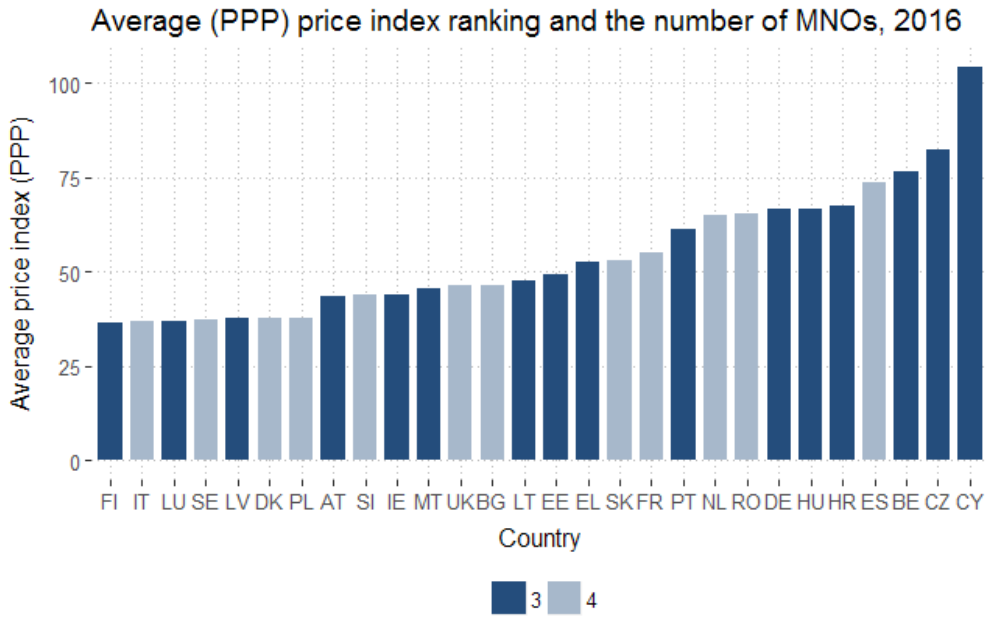
Main results of index based country comparison

The first thing of interest is the overall ranking of countries with respect to the large-screen mobile broadband prices. For the presentation of the country ranking we use the price index based on the average price, i.e. calculated as the average of the available baskets' prices on each national market. For the comparison we use the PPP adjusted price. We use the index type *a)* which punishes a little the lack of a full basket portfolio. Now, in order to make the figure more informative, the number of mobile network operators on the market is signaled with different colors.

[15] This penalty is not applicable for baskets containing smaller data amount than the corresponding entity's closest offered plan, since customers preferring lower amount of data are able to use this plan to satisfy their needs. To put it simply, a 3GB plan can serve 2GB demand, if there is no closer option.

The picture is different from what we have seen on the figure about the country price rankings of the 3 GB basket. There are countries where large-screen mobile broadband is fairly cheap, like Finland, Italy, Sweden, Denmark, Luxembourg, Latvia and Poland. There are other markets where this service is rather expensive and moreover some larger baskets are not available at all. At the right and we find Cyprus, the Czech Republic, Belgium, and Spain.

Figure 7. | Country ranking by the Large-screen Mobile Broadband Price Index based on the PPP adjusted average price, and the number of MNOs on the national market 2016



From a policy point of view the causes of the differences between countries, or at least factors that are associated with the differences are interesting as much as the ranking itself. However this presentation with the help of the coloring does not seem to reveal information about the association between the price level and the number of players. Though some 3 player markets are at the high end of the order, we also see other 3 player markets among the best[16].

There are other factors which are measurable and their association with the results is worth to study in order to gain more insights into the background of the differences.

A short list of other potentially influential factors is the following:

- economic environment: GDP per capita, population density
- market characteristics: number of MNOs on the market, position of an operator, presence of a challenger, an operator is a subsidiary of the fixed incumbent, an operator competing with a challenger

[16] The minimum price index figures are a little less controversial, because most of the 3 player markets are found right to the median.

- availability of the new technology: presence of LTE, LTE coverage,
- penetration of different communication technologies: fixed broadband penetration, mobile penetration, mobile broadband penetration
- country usage environment: internet usage characteristics, internet capabilities of the population

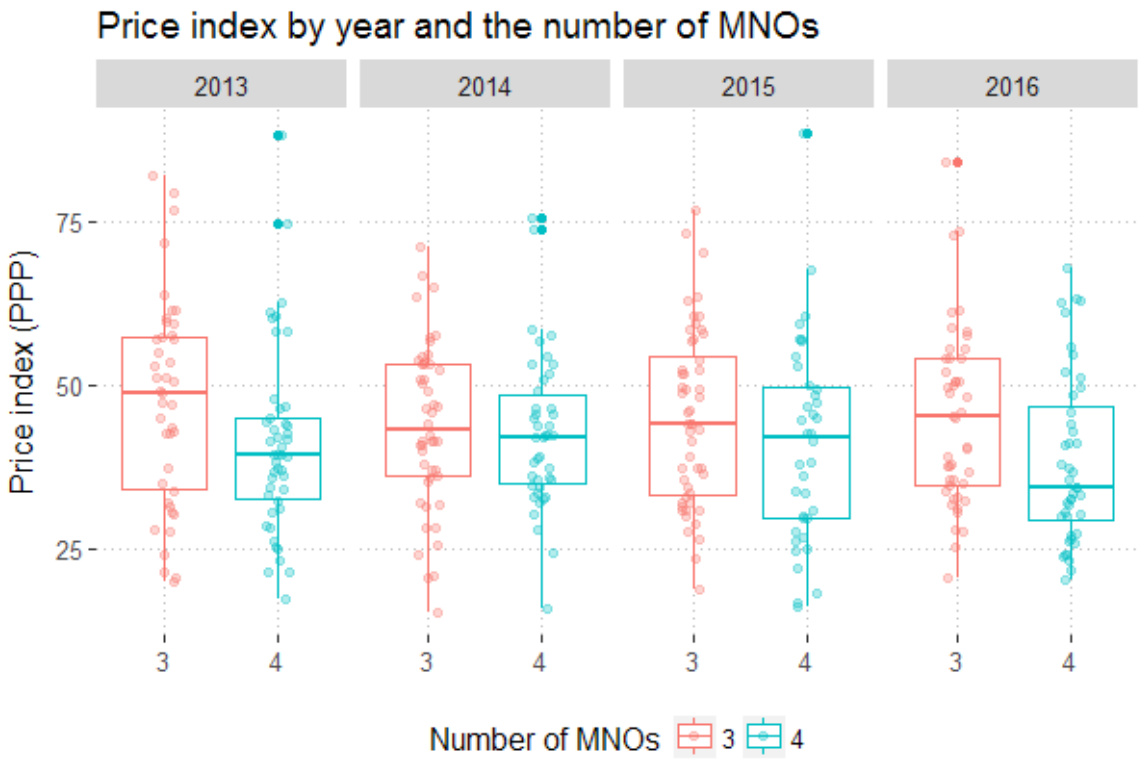
As we have input data for most of these factors at least country level we can study their effects on, or at least their associations with the level of the index.

Comparisons of price levels by different market characteristics based on operator price indices

First we present – in a visually comprehensive form with boxplots – the relationships between one or more of these factors and the large screen mobile broadband price level. The change in time may also be of interest, so we present the distributions for each year separately.

On the next figure the average individual operator price level distribution is shown between 2013 and 2016, measured by the index and grouped by the number of MNOs present on the market. As Cyprus is the only country with less than 3 operators until 2015, and because from a policy point of view we are interested in comparing the 3 and 4 player markets, Cyprus is intentionally left out from further comparisons.

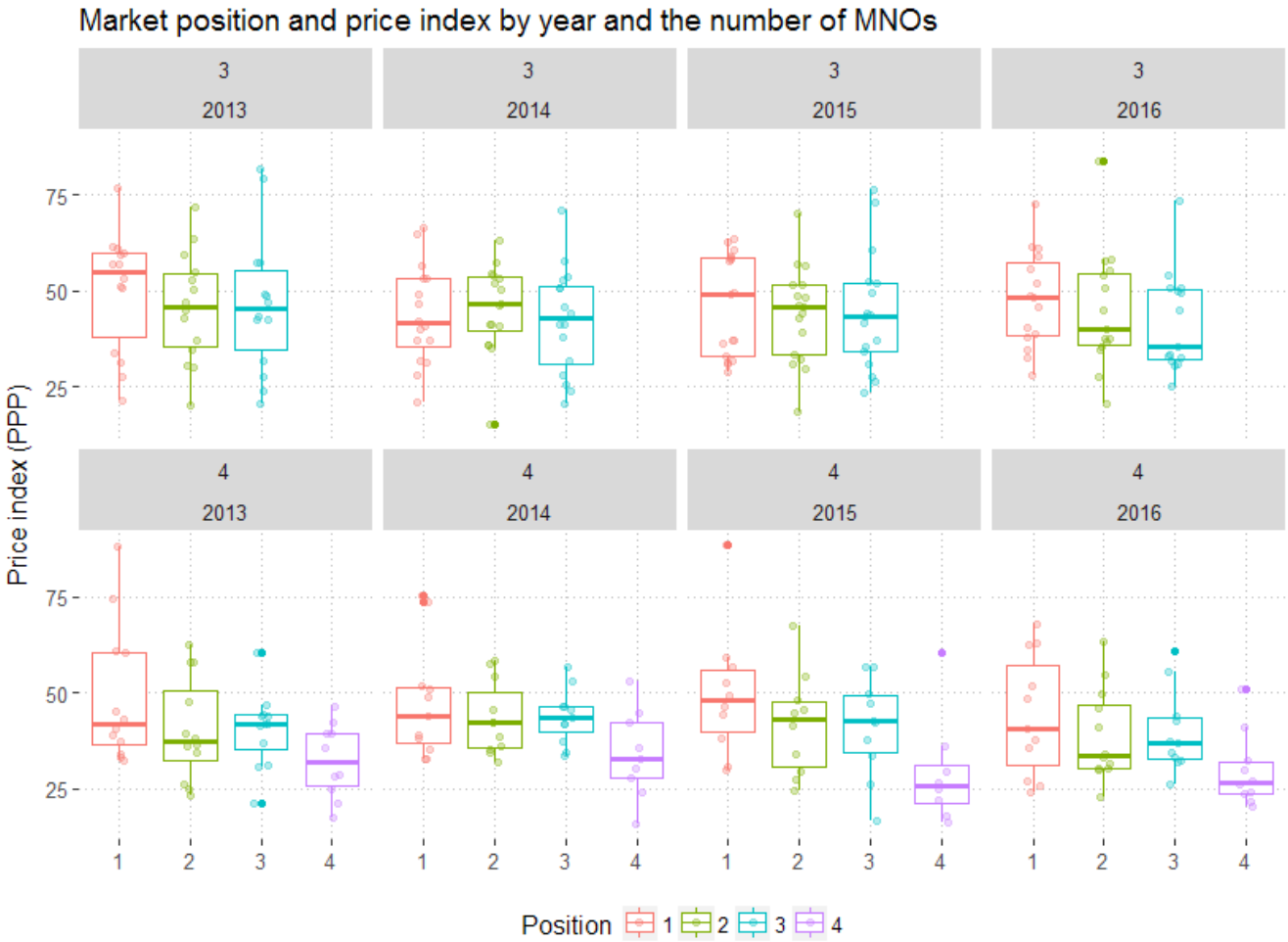
Figure 8. | The Large-screen Mobile Broadband Price Index by the number of MNOs, 2013-2016



There is some but not significant difference between the operator price index at the 3 and 4 player markets[17].

It is a relevant question whether the players in different positions on the market are pricing differently. Unfortunately, we do not have full and trusted market share data neither in subscriber number, nor in revenue. We have information only about the position of the operators in ranking order by subscribers. The next figure shows the distribution of price level values by the position of the operators.

Figure 9. | The Large-screen Mobile Broadband Price Index by the ranking position of the of the MNOs and by the number of MNOs operating on the market, 2013-2016

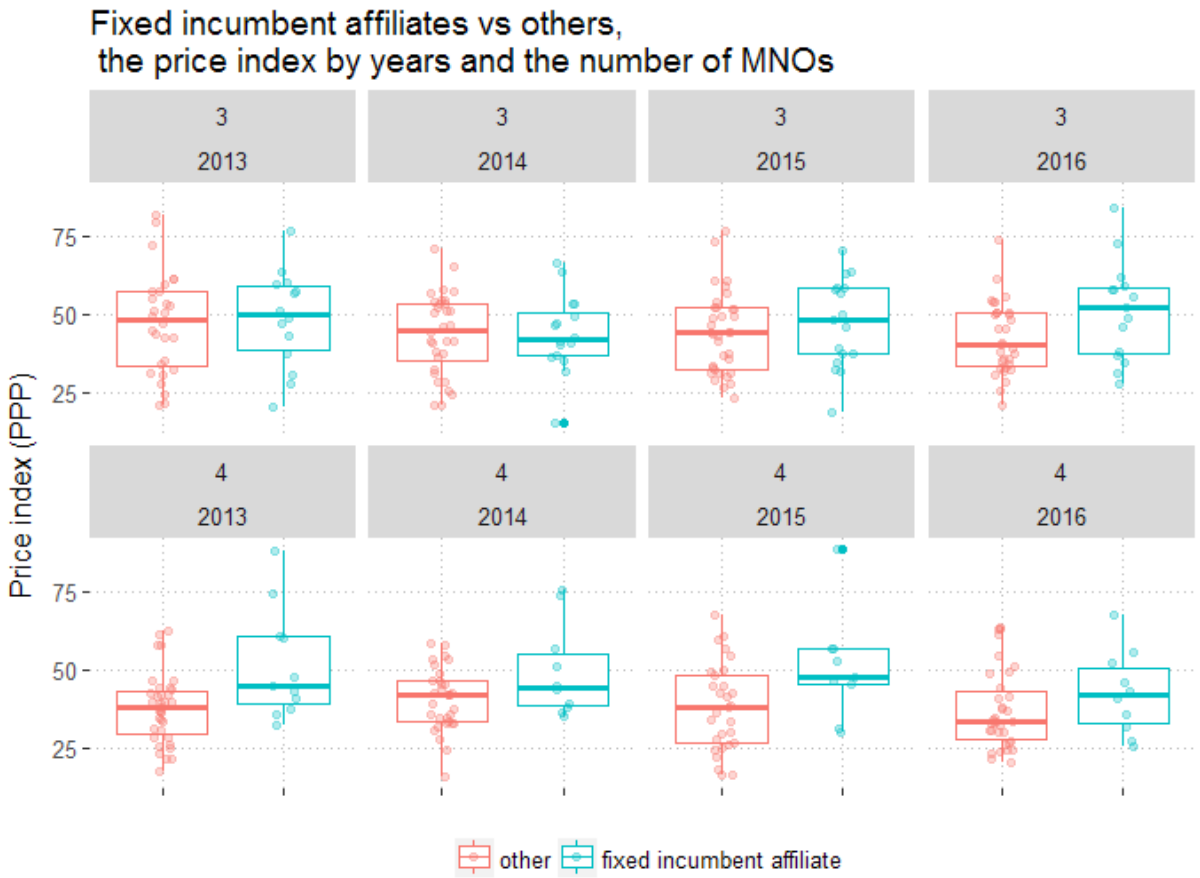


Neither market position nor the change in time makes much difference in the relative pricing behavior of the first 3 players on the 3 and 4 players markets. In this comparison the first 3 players' pricing seems rather close to each other. In contrast, the fourth players' price seems to be somewhat lower than the prices charged by the first three in the 4 player markets.

[17] As 4-to-3 mergers occurred in Austria, Ireland and Germany, and as a consequence the composition of the 3 and 4 player groups changed, it does not make significant bias in the picture. Entry into some 3 players markets, like the Netherlands, Bulgaria and Slovakia also affected the composition between years

The next figure shows the distribution of the price level index values by the affiliation of the MNOs to the fixed incumbent.

Figure 10. | The Large-screen Mobile Broadband Price Index by the MNO affiliation with the fixed incumbent and by the number of MNOs operating on the market, 2013-2016



This figure shows some difference in pricing with regard to the affiliation with the fixed incumbent operator. In general, fixed incumbents' subsidiaries seem to be pricing slightly higher than the others.

There is another important group of MNOs which are very interesting from competition policy point of view, the so called challenger players. The name of the category is very intuitive, however it is very difficult to identify players by challenger type of strategy and behavior.

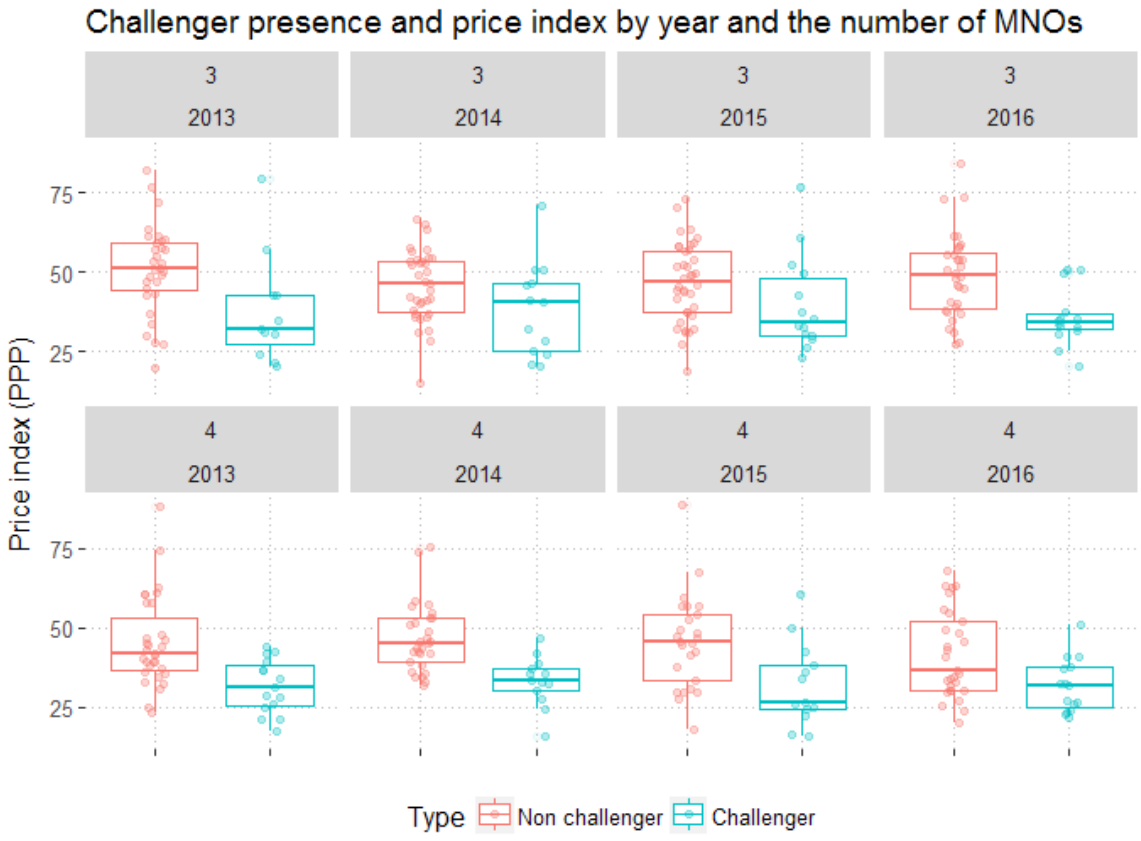
It is a popular idea that the presence of a "challenger", a non-mainstream player on the market is expected to make a difference in the intensity of price competition on a market. However, it is hard to give a good definition for a challenger. At first, it seems tempting to define it on the basis of observable a behavioral characteristics like playing an aggressive price strategy. Though a challenger usually plays a different strategy than established players and focuses on other market segments, especially on more price sensitive customers, this type of behavior is not easily observable and identifiable on all of the markets; moreover, it requires deep insight into the companies' strategies and decisions,

and the title assignment involves a considerable amount of subjective judgements. Avoiding these pitfalls and difficulties we choose another way of identifying an MNO as a challenger. Fixed incumbents mobile subsidiaries are trivially not challengers. Generally the other players who started their operations in the beginning of the 2G era are rightly considered as incumbents too on the current mobile market. Challengers are usually the latecomers, arriving no earlier than the end of the 2G era; and are not subsidiaries of an incumbent.

It is a consequence of our practical definition, that the challenger is a player whose parent is not an incumbent in any of the EEA countries. Typical challengers are Hutchison, Tele2, and some other more local players, like Bite in Latvia and Lithuania, Play in Poland, or Digi in Romania. By 2016, according to this classification, there are 22 markets among the 28 member states where there is at least one challenger.

The advantage of such a technical categorization is that it is objective, based on observable facts and does not involve judgement on the part of the researcher. The drawback may be that an operator can fall in this category despite it is not really behaving as a challenger on the market. However, examining the result of this classification the potential risk of this slight distortion is deemed very low.

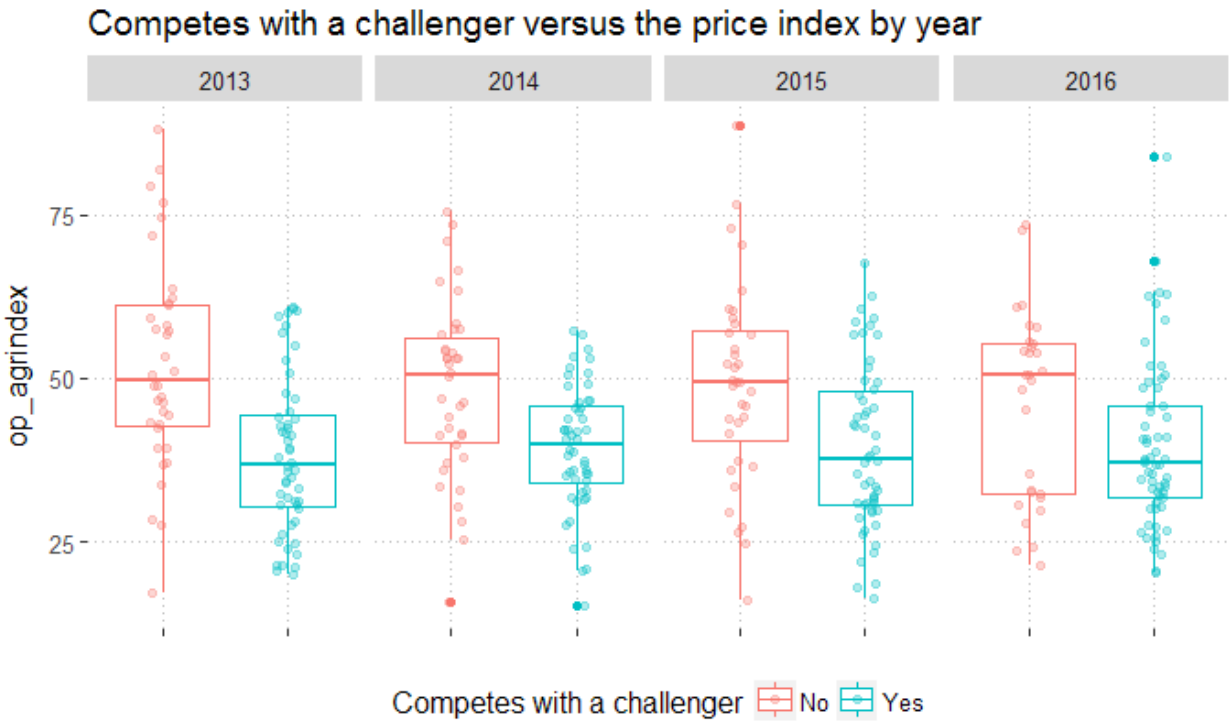
Figure 11. | The Large-screen Mobile Broadband Price Index by the MNO type (challenger/ non-challenger) and by the number of MNOs operating on the market, 2013-2016



Our data shows that challengers in general are pricing more aggressively than the other players. Moreover, there seems to be no big difference how they are pricing on 3 or 4 player markets. In this respect it is a good policy question to study further.

There is one additional effect of the presence of a challenger, namely the pricing behavior of the other players were induced to change. We can create a company level variable which tells whether ta company in question competes with at least one challenger or not. This effect is shown on the next figure without differentiating between 3 and 4 player markets.

Figure 12. | MNO level Large-screen Mobile Broadband Price Index in case an MNO competes with a challenger or not, by year 2013-2016



There seems to be some difference, but does not look very significant. It is partly explained by the definition of the differentiating variable. Many times challengers not compete with other challengers, so in many cases they are in the No group. The multivariate analysis helps in handling this controversy.

While in 2013 about only half of the operators had already launched LTE service or coverage was rather low, by 2016 LTE is present practically everywhere and does not seem to make any difference in pricing on average.

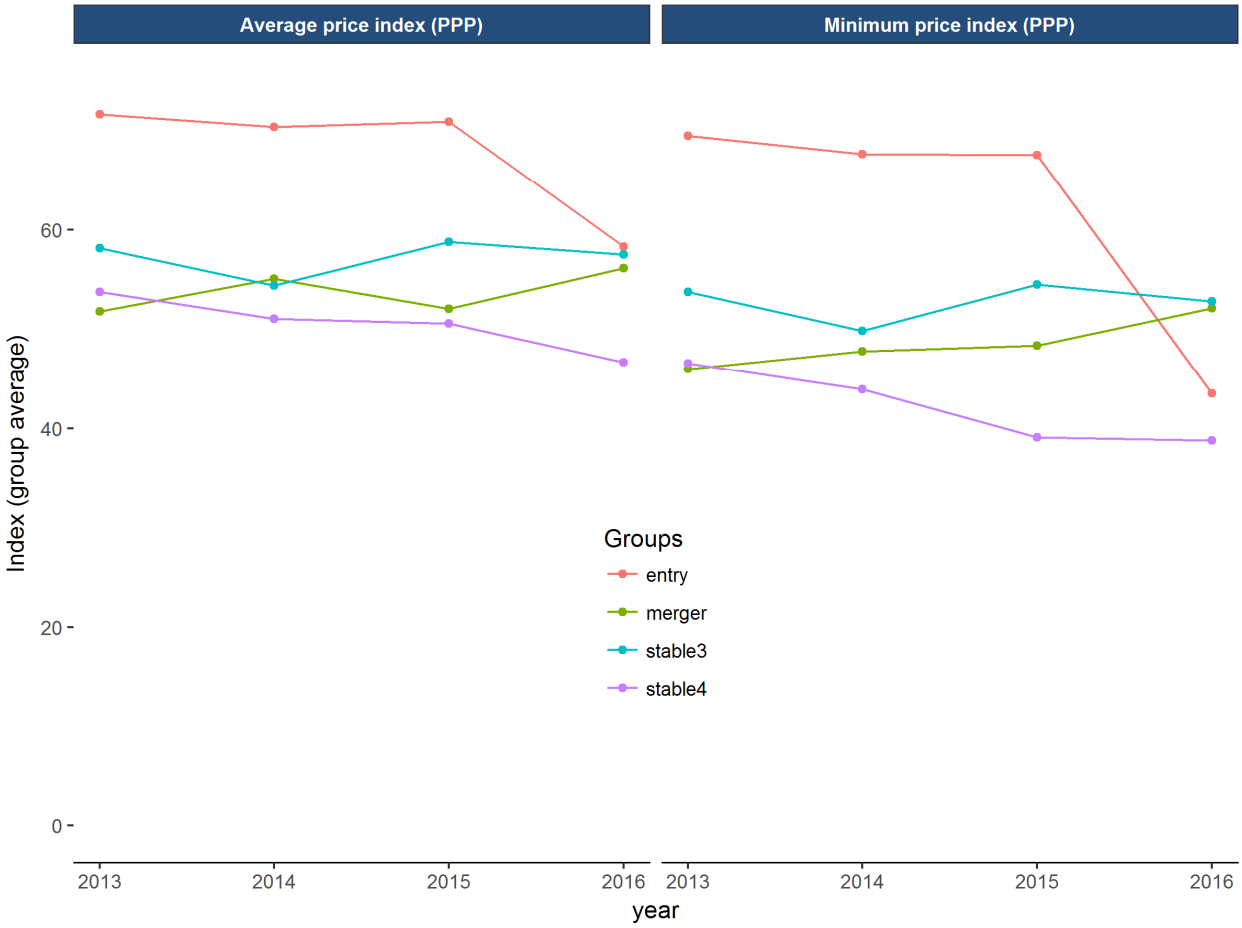
Having no other noteworthy categorical variables left, we reached the limits of this visual discovery. These results gave some insights, and we can see our data from different angles, but their common limit is that we can always look only at a small part of a rather complex picture.

Before turning to the econometric analysis we present some descriptive results regarding the overall price developments in countries where the market structure i.e. the number of players has changed since 2013. Because only few countries were affected the visual presentation tells more about the effects than the econometric analysis

Price changes under different or changing market structures

In the next figure we present the price changes of four different groups of countries. The first two groups are where there were 3 and 4 players respectively on the market throughout the whole observed period. The third group is where 4-to-3 mergers occurred: Austria, Germany and Ireland. The fourth group is where entry occurred at the end of the period, like in the Netherlands, Bulgaria and Slovakia.

Figure 13. | Country level Large-screen Mobile Broadband Comparative Price Index changes from 2013 to 2016 and the market structure



Source: Infrapont analysis

As we can see on Figure 13 the average price level has been decreasing on the 4 player markets while on the stable 3 player markets (on average) a slight increase has happened since 2013 on average. The difference between the price levels of the two groups of countries widened by 2016. Considering the small size of the groups this difference significant at the 10% level only with the PPP adjusted minimum price.

4-to-3 mergers seem to be resulting in price increases, and 3-to-4 entries with marked price drops. Unfortunately the small group size does not give support to strong statistical testing of these results. We rather choose to show trajectories of the individual county indices of countries which were affected by either merger or entry.

Price trajectories of those countries where entry or merger occurred

Figure 14. | Country level Large-screen Mobile Broadband Comparative Price Index changes from 2013 to 2016 – where merger or entry happened

Source: Infrapont analysis

The price level impact of the changing market structure is rather unambiguous in the case of entry. We see on both markets a significant and immediate price drop after the entry of the fourth mobile network player. Remarkable price decrease occurs not only with the minimum prices, which is quite evident, but also with the average market price level. The pattern for the Netherlands is a little bit different because in spite of the entry of Tele2 the price level decrease was moderate at best.

On the three markets where mergers occurred we cannot see an unambiguous tendency in the price developments. The German price level was among the highest in the EU even before the merger. Position of Germany has been worsened due to the price increase presumably as an effect of the merger. Considering this and also the

decreasing data allowance of the advertised plans, Germany is among of the worst performing market in comparison in the EU.

Price development in Ireland has not reflected any impact of the change in the number of MNOs. Irish prices are still decreasing in line with the EU average although the pace is lower.

Prices in Austria had increased suddenly and significantly in the first year after the merger. The increase was rather more moderate in the last two years. It is worth mentioning that the price level in Austria was extremely (perhaps unsustainably) low in 2013, and despite the significant increase since then it is still in the lower half in the EU (in PPP). Taking also into account that data allowance in Austria is rather high, this country is still one of the best performing markets in the EU.

Econometric Analysis

Using econometric tools, we can study the effects of more variables and their partial effects controlled for the others. The challenge of an econometric analysis is whether we can find and measure all of the relevant explanatory variables, and can avoid the omitted variable problem. Though we cannot be sure whether we have all relevant variables for the estimated model, the arising problems can be tested and handled accordingly. In the next section we present and discuss the result of a panel econometric analysis on two levels:

1. country level: where the studied entities are the countries, dependent variables are the country level indices and all of the variables are on country level
2. operator level: the studied entities are the operators, dependent variables are operator level price indices, and the key variables are operator level, but the control variables are on country level

For the multivariate analysis we have some continuous variables beside the formerly introduced categorical variables[18]. The most relevant explanatory variables are: GDP per capita, population density, mobile penetration, mobile and fixed broadband penetration and overall broadband penetration, and laptop usage data.

Categorical data on county or company level is measured exactly in the same time when the data collection happened. Country level control variables are usually produced as end of year penetration, coverage, etc. numbers. As the data collection happened in March, the previous year end data is the natural right choice.

First we present the results of the panel regressions with a more aggregated country level data. Then the finer operator level analysis is presented. We can examine similarities and differences according to the level used.

[18] Variable description (including source, summary statistics and the correlation matrix) is presented in the Annex

We want to estimate the following equation:

$$y_{it} = \mu + \sum_{i=1}^{k} \beta_i x_{it} + (u_i + \varepsilon_i)$$

The choice of the x_i explanatory variables is constrained by the availability of information on operator and country level. We are interested mostly in those variables which can be a concern of competition policy and/or sectoral regulation, namely: number of network operators, operator types, market position of the operator, the effect of other competitors (namely what type of the operators the studied operator competes with), and new technology and network deployment. Other variables are included to control for other relevant differences between countries like GDP per capita, population density, overall broadband penetration, etc.

In the country level model the explained variable is the country level minimum or average price index, of which we have 2 types for each: the *a)* and *b)* method of calculation[19]. We use the index based on PPP adjusted price, in order to control the country specific general price level. In the regressions we always use GDP per capita in log form. We use a basket availability dummy variable in the models where the explained variable does not take into account the availability of all baskets.

From the regression we left out three member states, Cyprus, Luxembourg and Malta because of their peculiarities, mostly because of their small size.

Using the Hausman-test for model selection, in all cases the random effect model proved to be more efficient and consistent. Robust standard errors with small sample correction are reported in the table (see next page).

- From the group of variables of interest the challenger variable is significant in all models. Being a challenger is associated with significantly lower pricing on average, more than 14 index points in each model. This challenger effect is larger with both types of the minimum price, and even larger with the average price index which penalizes the lack of the larger baskets in the supply.
- The number of operators is not significant, so the 3 and 4 player markets do not seem to make a difference if challenger presence is also controlled for.
- Parameter estimates for the variables mobile penetration are negative and significant, but mobile broadband penetration is not significant, however have negative effect sign as expected.
- The parameter for the GDP per capita variable is significant and negative in 3 of the four models.

[19] See page 18. for the details.

- Population density is significant in those models where the index incorporates the lack of all the 8 measured baskets. In other words the densely populated countries have higher prices and narrower choice
- Fixed broadband penetration is significant in the minimum index models

Our country level results suggest that the presence of a challenger on the market is associated with lower prices, while the number of operators does not seem to matter.

Table 3. | Country level linear panel regression results

	Dependent variable:			
	avix	minix	avix2	minix2
	(1)	(2)	(3)	(4)
loggdppopppps	-12.892**	-8.154	-13.300**	-8.579
	(5.761)	(5.443)	(5.688)	(5.370)
popdens	0.011	0.001	0.043**	0.033**
	(0.013)	(0.013)	(0.017)	(0.016)
mbbpen	-0.029	-0.060	-0.036	-0.076
	(0.064)	(0.072)	(0.073)	(0.080)
fbbpen	0.444	0.457*	0.430	0.496**
	(0.288)	(0.234)	(0.310)	(0.246)
mobpen	-0.130**	-0.117**	-0.140**	-0.137**
	(0.052)	(0.055)	(0.065)	(0.062)
opnum4	2.244	-1.993	-0.177	-3.892
	(3.145)	(3.190)	(2.747)	(2.969)
laptopnomaduse	-0.202	-0.202	-0.136	-0.144
	(0.170)	(0.143)	(0.159)	(0.147)
chal	-14.713***	-18.713***	-14.860***	-20.518***
	(4.383)	(4.562)	(5.002)	(5.495)
basketstatusincomplete	2.489	2.124		
	(3.607)	(3.855)		
Constant	205.640***	156.738***	210.482***	163.959***
	(55.293)	(53.957)	(53.757)	(52.460)
Effect	RE	RE	RE	RE
Observations	98	98	98	98
R^2	0.519	0.541	0.487	0.564
Adjusted R^2	0.470	0.494	0.440	0.525
F Statistic	10.534*** (df = 9; 88)	11.501*** (df = 9; 88)	10.532*** (df = 8; 89)	14.412*** (df = 8; 89)
Note:	*p<0.1; **p<0.05; ***p<0.01			

Results of the operator level panel estimates

Our database covers 4 years, and we have observations for operators in each year. However some operators merged and also newcomers entered the market, so there are operators of which we have fewer than four observations, therefore the panel is unbalanced.

Pooled regression with year dummies can be an option to start but it could not help much in the problem of unobserved heterogeneity between national markets. Moreover, changes between years were rather small on average.

Our panel is somewhat specific because the annually observed entities are the MNOs and all of them are present in a 3 or 4 players market. Pricing behavior in a particular market is not independent of the competitors' behavior. This effect must be controlled for. However, using country fixed effect or individual fixed effect models leave less space to the other variables not changing in time. In order to give a full picture, we present 3 models for each dependent variable. The first one is a random effect model without country effect (models 1 and 4). The second one is a random effect model with country dummies (models 2 and 5). The third one is a fixed effect model (models 3 and 6). Though the Hausman-test prefers the random effect models to the fixed effect one, it is informative to see also the results of a fixed effect estimation. It is interesting but not surprising (knowing the data), that there is no significant time effect in pricing.

The estimated equation is the same as we used in the country panel.

The next table presents the main results of the regressions, with heteroskedasticity robust standard errors are reported in the table.

We use here an ordinal market position variable was not used here because of its clear insignificance revealed in the model selection. Besides the other formerly used country variables, we use here operator level variables: like market position in an ordinal scale, challenger dummy and another dummy which measures whether the operator competes with at least one challenger on the market. Another dummy controls for the relationship with the fixed incumbent.

We had information on when the company started LTE service, so it was the modern technology availability variable in the model.

We omitted from the reported table the coefficients of the country dummies as well as the individual ones.

Table 4. | Operator level linear panel regression results

	Dependent variable:					
	op_agrindex			op_agrindex2		
	(1)	(2)	(3)	(4)	(5)	(6)
loggdppopppps	-10.152***	-4.561	1.558	-7.151	-35.137**	-34.801***
	(3.450)	(13.934)	(13.277)	(4.442)	(13.893)	(13.164)
popdens	0.016*	-0.502	-0.345	0.051***	-0.730	-0.620
	(0.009)	(0.447)	(0.417)	(0.014)	(0.486)	(0.483)
mbbpen	-0.018	0.023	0.040	-0.048	0.063	0.059
	(0.041)	(0.064)	(0.061)	(0.056)	(0.081)	(0.080)
fbbpen	0.297*	-0.419	-0.292	0.279	-0.704	-0.552
	(0.159)	(0.430)	(0.432)	(0.277)	(0.475)	(0.472)
mobpen	-0.063**	-0.006	-0.014	-0.086**	-0.031	-0.025
	(0.031)	(0.042)	(0.040)	(0.039)	(0.055)	(0.051)
opnum4	1.851	-0.131	3.404	1.053	-7.382***	-6.507**
	(1.996)	(2.775)	(3.117)	(2.233)	(2.838)	(2.699)
laptopnomaduse	-0.141		-0.065	-0.165		0.011
	(0.113)		(0.138)	(0.128)		(0.157)
challenger	-6.706***	-2.382		-11.712***	-3.386	
	(2.188)	(2.421)		(3.662)	(2.917)	
fix_incumbent	2.310	3.409*		-1.583	1.342	
	(2.270)	(1.903)		(3.079)	(1.660)	
position2	-4.004**	-3.554**	-6.481*	-1.485	-1.018	4.206
	(1.946)	(1.709)	(3.518)	(2.638)	(1.552)	(2.591)
position3	-5.680***	-4.668**	-9.640***	-4.528*	-2.465	-1.516
	(1.999)	(1.953)	(3.159)	(2.368)	(1.950)	(2.207)
position4	-12.508***	-11.893***	-13.518***	-8.611**	-6.581*	-5.413
	(3.556)	(3.581)	(4.475)	(4.260)	(3.513)	(3.377)
compwithchal	-8.550***	-1.985	-8.823**	-10.445***	2.895	1.507
	(2.428)	(2.904)	(3.980)	(2.888)	(3.046)	(4.680)
islte	-1.001	-1.345	-2.003	-6.154***	-4.238**	-5.887***
	(1.235)	(1.678)	(1.429)	(1.828)	(2.073)	(1.806)
Constant	160.132***	148.195		148.383***	507.577***	
	(33.252)	(137.972)		(42.216)	(143.828)	
Effect	RE	RE	FE	RE	RE	FE
Observations	331	334	331	331	334	331
R^2	0.335	0.471	0.078	0.363	0.632	0.171
Adjusted R^2	0.306	0.405	-0.317	0.335	0.586	-0.184
F Statistic	11.363***	7.132***	1.628*	12.880***	13.725***	3.968***
	(df = 14; 316)	(df = 37; 296)	(df = 12; 231)	(df = 14; 316)	(df = 37; 296)	(df = 12; 231)

Note: *p<0.1; **p<0.05; ***p<0.01

with models (2) and (5) country dummies are not presented

Model 1 produces somewhat similar results to the country level analysis, but it has to be interpreted in operator context:

Challenger operators pricing lower on average than their counterparts.

In pricing not the number of operators but the position of the player matters. Second and third operators pricing lower than the market leader, but they does not differ much from each other. The fourth operator is which competes with the lowest priced offers.

It is interesting that our competition context variable is also significant. Those players who compete with a challenger are pricing lower (independent from whether they are challengers or not).

The country level control variables have the same sign and similar significance than in the country level models.

In model 2 with country dummies, only market position remained significant, and one other variable came to the stage: being affiliated with the fixed incumbent. These players have higher prices on average.

In model 3, the individual fixed effect model, market position is significant but also the competition with a challenger variable. The latter one suggest that on average those players competing with challengers, pricing lower by almost 9 index points.

Model 4-6 having the second type of index as a dependent variable present similar results than its respective counterpart in the first three. What is interesting, that operators with LTE network seem having significantly lower index value. This presumably reflects the lack of supplying larger baskets by those who had no LTE.

In model 5 only the fourth position is associated significantly with lower price, not the others. In this model the number of operators on the market became significant. This may not be connected with pricing but rather the consequence of the incentive to provide larger baskets on the market. This is highly probable because this variable is not significant in model 2.

Something similar can be said about model 6, where even the fourth position loses its significance, while significance of having LTE and the number of operators on the market are still kept.

Discussion

Learning from past evidence is necessary to improve policy-making in any field. How many competitors can prevail on a market is a question from the very beginning in the telecom sector. Answers change by time, as our understanding grows with every stage in technology and market development. The problem is that merger decisions and regulation policy affects the future markets and if these decisions turn out to be erroneous, correction

is impossible or hard. This is why the evidence on the functioning of the markets is important for improved decisions.

Though we have some empirical evidence on the development of the mobile markets, few are from the new mobile data era. Our analysis of the European Union large-screen mobile prices tries to present new evidence on the mobile broadband markets. In this paper we addressed the issue whether the number of players, the type of them, and their competitive interaction on the market correlate with the observed prices of the large-screen mobile broadband prices. We also tried to challenge or confirm the widely held, but empirically not really well-founded notion among regulators that having four players is unequivocally better than having only three on the mobile markets.

Our study addresses this issue by comparing the 27 3 or 4-player national large-screen mobile broadband markets of the European Union. The panel database contains the individual public large-screen mobile broadband offers between 2013 and 2016.

The first challenge a researcher faces is how to collect and prepare the data in such a way that it is appropriate for a meaningful comparison. We used the basket method for ensuring comparability, because it has its own merits of being transparent and able to handle both the price and quantity features of the large-screen mobile broadband plans. The only arbitrariness in this exercise is the choice of the quantities defining the baskets. However, the studied basket structure can be adapted to the quantities of the typically supplied products. Although the difference between countries is substantial with respect to the data allowances of the supplied plans, the range of baskets is mostly appropriate to cover these differences.

The basket system is suitable to measure and compare "fixed" quantity products, but it is hard to form an overall assessment of the markets based on basket comparison only. The whole picture is rather complex. For a better and streamlined comparison we prepared basket-specific price indices and by averaging them we calculated an overall index which is capable of capturing the general pricing tendencies on the market. We can use similarly constructed index for country and operator level comparisons. We use purchasing power parity adjusted prices for the comparison of consumer prices in order to filter out the effects of large differences between the countries' price levels.

Simple price or index comparisons revealed some general tendencies of pricing on the large-screen mobile broadband markets. Prices on the 3 or 4-player markets do not differ significantly, and there is no direct evidence that 4 player markets perform unconditionally better in pricing.

A methodological issue which we tried to address is to differentiate between the market players (lacking market share data) in order to get types of competitors with different incentives, and test whether these objective differences are affecting pricing behavior. We defined (as objectively as we could) a special player category, the challenger, and checked

whether the presence of such a player makes any difference in the performance of the market.

We found that challenger players' pricing seems to differ from the others, and their presence usually associated with lower pricing and wider choice. We also found that the 4th players are pricing lower on average, than the others. Perhaps it is not only a coincidence that most of them are challengers too.

In a panel econometric analysis we studied the effects of some policy-related variables on the pricing of the operators while controlling for other influential factors. Both the country level and the operator level linear panel regressions suggest that challenger players' presence makes the large-screen mobile broadband markets more competitive, that is providing lower prices, wider choice, an larger sized (in GB) broadband plans. This is partly the result of the different challenger pricing, and also the change in the other competitors' behavior as a reaction to the challenger. Of course other factors like spectrum endowments or the challengers' access to the capital markets may constrain the challenger behavior.

The deployment speed of the LTE technology by operator seems to have some influence, however temporary, on pricing and the availability of larger sized baskets.

Finally, our results do not support the view that the mere number of players between 3 and 4 makes a big difference in itself, everything else held constant.

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Annex

A.1 Data sources

Variable	Source
avix, avix2: average price indices *minix, minix2:* minimum price indices	data is privately collected in March each year between 2013 – 2016 from operator web pages country level index calculation from the collected price data converted to Euro PPP
op_agrindex, op_agrindex2: operator price indices	data is privately collected in March each year between 2013 – 2016 from operator web pages operator level index calculation from the collected price data converted to Euro PPP
mbbpen: mobile broadband penetration *fbbpen*: fixed broadband penetration *mobpen*: mobile penetration, *laptopnomaduse*: laptop nomad use	EC Digital Agenda Scoreboard
loggdppoppps: GDP per capita on Purchasing Power Standard *popdens*: population density	Eurostat
opnum: number of MNOs	own calculation based on operator and market data
challenger: type of operator, dummy	operator webpages, own classification based on ownership information
chal: is there a challenger on the market, market dummy	own calculation from market and operator data
fix_incumbent: an operator dummy,	own classification for each operator (based on information on ownership and fixed incumbency)
compwithchal: an operator dummy, (based on information on competitors on a market)	own calculation based on operator and market data
position: position of an operator dummy,	NRA reports, other market reports
islte: providing LTE service dummy	GSA

A.2 Summary statistics of the country level regression variables

Variable	N	Mean	St. Dev.	Min	Max
avix	99	54.97	14.51	23.52	86.91
avix2	99	57.41	17.08	23.52	91.82
minix	99	28.84	14.21	10.18	71.01
minix2	99	32.72	20.24	10.18	84.07
year	99	2014.5	1.12	2013	2016
mbbpen	99	68.15	25.57	23.19	143.29
loggdppoppps	99	10.10	0.31	9.41	10.84
popdens	99	129.13	109.95	17.80	502.90
fbbpen	99	28.60	6.62	16.54	43.39
mobpen	99	140.54	27.88	105.67	234.99
opnum	99	3.46	0.50	3	4
laptopnomaduse	98	27.04	10.80	5.50	48.75
chal	99	0.72	0.45	0	1
bask_available	99	7.35	1.23	4	8

A.3 Correlation matrix of the country level regression variables

	avix	*avix2*	*minix*	*minix2*	*year*	*mbbpen*	*loggdppoppps*	*popdens*	*fbbpen*	*mobpen*	*opnum*	*laptopnomaduse*	*chal*
avix													
avix2	0.97												
minix	0.75	0.85											
minix2	0.71	0.84	0.98										
year	-0.07	-0.06	-0.01	-0.01									
mbbpen	-0.55	-0.51	-0.28	-0.25	0.37								
loggdppoppps	-0.22	-0.11	0.15	0.19	0.1	0.42							
popdens	0.36	0.49	0.54	0.59	0	-0.14	0.41						
fbbpen	-0.04	0.07	0.23	0.28	0.18	0.36	0.74	0.5					
mobpen	-0.55	-0.55	-0.39	-0.38	0.07	0.43	0.05	-0.31	0.03				
opnum	-0.16	-0.18	-0.32	-0.27	-0.02	0.19	0.15	0.03	0.08	-0.08			
laptopnomaduse	-0.28	-0.19	0.05	0.08	0.21	0.65	0.73	0.22	0.67	0.06	0.11		
chal	-0.7	-0.74	-0.74	-0.72	0.11	0.33	-0.04	-0.42	-0.08	0.34	0.3	0.03	
bask_available	-0.54	-0.73	-0.86	-0.94	-0.03	0.14	-0.27	-0.61	-0.35	0.3	0.15	-0.14	0.62

A.4 Summary statistics of the operator level regression variables

Variable	N	Mean	St. Dev.	Min	Max
op_agrindex	334	43.16	13.60	15.25	88.50
op_agrindex2	334	52.75	18.87	15.25	94.71
year	334	2014.5	1.12	2013	2016
mbbpen	334	69.13	25.33	23.19	143.29
loggdppoppps	334	10.11	0.31	9.41	10.84
popdens	334	129.73	106.25	17.80	502.90
fbbpen	334	28.60	6.74	16.54	43.39
mobpen	334	140.95	27.86	105.67	234.99
opnum	334	3.51	0.50	3	4
laptopnomaduse	331	27.19	10.94	5.50	48.75
challenger	334	0.31	0.46	0	1
fix_incumbent	334	0.28	0.45	0	1
compwithchal	334	0.63	0.48	0	1
position	334	2.22	1.00	1	4
islte	334	0.83	0.38	0	1

A.5 Correlation matrix of the operator level regression variables

	op_agrindex	*op_agrindex2*	*year*	*mbbpen*	*loggdppoppps*	*popdens*	*fbbpen*	*mobpen*	*opnum*	*laptopnomaduse*	*challenger*	*fix_incumbent*	*compwithchal*	*position*
op_agrindex														
op_agrindex2	0.78													
year	-0.06	-0.12												
mbbpen	-0.44	-0.43	0.36											
loggdppoppps	-0.18	-0.03	0.08	0.42										
popdens	0.29	0.48	0.0	-0.14	0.4									
fbbpen	-0.03	0.08	0.17	0.37	0.74	0.47								
mobpen	-0.41	-0.46	0.09	0.45	0.09	-0.31	0.07							
opnum	-0.19	-0.08	-0.04	0.21	0.14	0.02	0.06	-0.06						
laptopnomaduse	-0.22	-0.14	0.19	0.65	0.73	0.21	0.68	0.09	0.1					
challenger	-0.46	-0.46	0.02	0.18	-0.04	-0.27	-0.05	0.25	0.04	-0.01				
fix_incumbent	0.24	0.09	-0.01	-0.05	-0.03	-0.04	-0.03	0.0	-0.1	-0.05	-0.42			
compwithchal	-0.38	-0.48	0.06	0.32	-0.03	-0.35	-0.07	0.35	0.29	0.02	0.08	0.11		
position	-0.32	-0.17	-0.01	0.08	0.02	-0.01	-0.02	0.02	0.22	0.01	0.43	-0.44	-0.19	
islte	-0.04	-0.11	0.37	0.28	0.3	0.1	0.31	0.07	-0.04	0.22	-0.08	0.13	0.11	-0.19