Study for Energistyrelsen

Competition and investment in the Danish mobile market

[non-confidential version]

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24 May 2019

Imprint

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Executive summary

In March 2019, the Danish Energy Agency (DEA) awarded licences to three companies for the use of spectrum in the 700MHz, 900MHz and 2300MHz bands.[1]This spectrum is expected to support the provision of high capacity mobile services as well as the development of specialised applications. In particular 700 MHz frequencies could be used to deploy 5G. Further spectrum, for example in the 3,5 GHz band, is expected to become available to mobile operators before the end of 2020.

The Danish mobile market currently features four mobile network operators, two of which are involved in an extensive network sharing arrangement (including spectrum sharing as well as RAN sharing). The investment required for 5G deployment which makes use of 3.5 GHz or even milimeter frequencies (e.g. 26 GHz) is likely to lead to an densification of networks and could raise questions around the need for closer collaboration or (at a last resort) a merger between existing operators engaged in the joint venture, or other players not currently involved in network sharing.

In this study we assess the effects of network sharing on competition and investment, and discuss potential scenarios for network sharing in a 5G environment.

The assessment is based on interviews with operators in the Danish market, literature review, data analysis, and case studies of other markets which have featured varying degrees of sharing amongst mobile network operators.

Implications of 4G network sharing on competition and investment

There is a wide range of literature which considers the impact of *consolidation* in mobile markets on competition and investment. However, the results differ. WIK concluded in a 2015 study for Ofcom on this subject that no general conclusions could be reached, and that analysis was needed of the conditions in the market concerned.[2]

As regards, network sharing, there is relatively compelling evidence to support the potential for cost reduction,[3] and limited evidence that it leads to detrimental effects on competition.[4]

1 https://www.telegeography.com/products/commsupdate/articles/2019/03/29/hi3g-tdc-tt-netvaerket-winners-in-spectrum-auction/?utm_source=CommsUpdate&utm_campaign=11f0f8f95f-CommsUpdate+29+March+2019&utm_medium=email&utm_term=0_0688983330-11f0f8f95f-8874781.

2 WIK (2015) competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications.

3 Estimates differ, but for example Molleryd (2014) https://www.econstor.eu/bitstream/10419/101392/1/795277237.pdf finds a potential to reduce operating costs for the radio access network by more than 40%. Vodafone has suggested that cost savings could range from 40-50% (full sharing) through roaming (30% to 40%) to passive sharing (15% and 25%). Cost savings with passive sharing are estimated to be higher in rural areas than in urban areas.

4 See for example Molleryd (2014). Dasgupta (2017) suggests that “the overarching lesson from our reviews of JVs and the economic literature is that there is no “one size fits all” prescription for the competition policy analysis of JVs in the telecommunications sector.” https://www.econstor.eu/bitstream/10419/169456/1/Dasgupta-Williams.pdf.

Our analysis of mobile market dynamics in Denmark and four other European countries tends to confirm this view. In particular, we did not find that the two countries which engaged in the most extensive forms of mobile network sharing (Denmark and Sweden)[5] experienced negative effects on pricing or quality in the period following the introduction of the sharing agreements, or compared with other countries which had less extensive network sharing arrangements such as France and Spain. Indeed, consumer outcomes in the mobile markets in Denmark and Sweden, including 4G availability and download speeds tend to compare favourably with the other countries considered, while prices for data-intensive bundles lie in the mid-range.

The perspective of stakeholders

Feedback from stakeholders interviewed for this study,[6] suggests that Danish mobile operators do not see a short term consumer demand for 5G specifically (although there is increasing demand for higher bandwidths for consumer applications). Rather, most operators agree that the service demand of residential customers can be met through existing LTE or LTE advanced networks, at least in the near future. However, as in many other countries, Danish operators see 5G as providing opportunities to target specific industry sectors and to support developments such as as self-driving cars, VR/AR applications and mass IoT adoption.

Following the recent auction results, it is commonly acknowledged that TDC is best placed to achieve a rapid deployment of 5G based on the spectrum acquired. More extensive sharing, potentially even leading to two networks, is seen as desirable or necessary in the context of 5G deployment by some players, at least in certain circumstances or areas.

The role of intelligence in the core network, and the importance of low latency mean that operators consider that national roaming is unlikely to enable effective competition in a 5G context. MOCN models are considered more suitable, with consideration needed of sharing in the transmission network. The opportunities available for network sharing via 5G network slicing are also of interest for some players.

There is widespread demand from mobile operators for guidance from the NRA and competition authorities on what might be considered as reasonable approaches to network sharing in the context of 5G.

Implications for network sharing in a 5G context

Initially, the additional investments required for 5G might be limited because mobile operators will still be investing in LTE (deploying single RAN technology), with the intention to migrate towards 5G at a later stage. Thus the implications of 5G on network sharing may be limited, at least at the outset.

5 In both Denmark and Sweden, network sharing has involved spectrum sharing as well as active RAN sharing on a nationwide basis for 4G.

6 The study team interviewed representatives from the four Danish MNOs between March-April 2019.

However, as the next phase of 5G deployment proceeds, pressure may arise for further consolidation at the network level and/or deeper network sharing arrangements from the following sources:

- Certain applications such as **autonomous driving** will require comprehensive nationwide coverage (including along highways), which is best-served via frequencies below 1GHz. Operators with limited availability of spectrum in this band may require network sharing in order to operate efficiently, and would likely need MOCN to achieve the service levels required.

- 5G deployment in **rural areas** will likely require the upgrade of backhaul capacity to fibre and in time, the potential deployment of additional sites. This may further limit the economic viability of multiple parallel deployments in these areas.

- There may be **constraints in site sharing in urban areas**. Although efforts have been made to address planning constraints through the Danish 5G Action plan, there may still be challenges in maintaining multiple technologies on a single site, and in some cases, the addressable market may be insufficient to support the business case for parallel deployment of small cells. Active infrastructure sharing (with or without spectrum pooling) could provide a solution in cases where these challenges persist.

As discussed above, analysis conducted for this study suggests that extensive mobile network sharing has occurred in 4G without apparent detriment to competition or investment. However, the case studies do not provide concrete answers on what the implications might be for network sharing in a 5G context. Firstly, the case studies typically involve the sharing of three mobile networks between four mobile operators. There is limited empirical evidence of the effect on investment and competition of additional sharing (towards one or two networks), as may be sought in the context of 5G deployment in some areas.

There are also differences between 4G and 5G, which could affect the outcomes in each case.

1. 4G has mainly been focused on supplying mass-market mobile broadband, but 5G is likely to be focused additionally on specific use cases which require significant spectrum holdings. Thus **additional spectrum sharing in a 5G context may deliver additional innovation benefits** which would not apply to 4G.

2. The **fact that the 5G business case (and particularly revenues) are likely to rely on new use cases may increase the incentives for investment to offer new services**, even in the absence of parallel competing networks.

3. Competition and investment may not be the only factors that need to be considered in a 5G network sharing (or consolidation) scenario. Some of the critical use cases for 5G also require redundancy and resilience. In particular

redundancy implies that there should, if possible, be at least two nationwide networks available.

4. One of the innovations inherent in 5G is the capability for network slicing. **Network slicing could be seen as a new mechanism to support infrastructure sharing, while maintaining the independence of each operator to differentiate on quality and price**. This is however, dependent on the standards and specifications established for network slicing and the pricing mechanisms established.

Broadly speaking, these factors tend to support the potential for 5G to support a greater degree of network sharing without detriment to investment or competition than in the 4G context. However, the impact is likely to depend on the precise conditions in which sharing takes place, and the need for redundancy implies that at least two networks should be maintained if possible.

Conclusions

In conclusion, 5G investment is likely to create a number of drivers for consolidation in the number of networks for specific purposes or in certain areas.

The pressure for consolidation could be directly influenced by the manner in which spectrum is assigned in 3.5 GHz and 700 MHz – i.e. by permitting the acquisition by a single player of large spectrum bands. However, such a strategy might result in excessive control over investments and a limitation on the incentives for competition and innovation. Thus, there are valid reasons to design auction processes to avoid individual operators having control over significant portions of frequency.

An alternative would be to design auctions so as to enable a more even distribution of frequencies according to need, but to open the door towards further network sharing.

For 5G, our analysis suggests that the degree and nature of network sharing may go beyond what was required in the context of 4G e.g. requiring an MOCN model (when previously this may have been efficient, but optional), or entailing spectrum pooling amongst a greater number of players than are currently engaged in sharing – especially in the context of rural coverage. National roaming solutions may be less suited to supporting certain applications.

In this context, it worth recalling that LTE is and will be in the medium term, the backbone of competition. 5G deployment might, in the initial phase, be constrained to hot spots and corporate networks. As long as there is effective competition based on LTE, some freedom could be given to operators to develop business models and exploit the opportunities of 5G. At the point where a nationwide deployment of 5G becomes economically feasible, the amount of spectrum assigned to mobile operators will become more crucial and the duplication of infrastructure constrained. In this event, regulatory guidance on infrastructure sharing could be a vital tool to provide certainty and safeguard competition.

Such guidance could inter alia address questions on how further consolidation in networks (from 3 to 2) through network sharing might be viewed by the authorities, respectively in rural and urban areas, attitudes towards MOCN and the degree to which sharing could be envisaged beyond the RAN and into the transmission network. The role of network slicing in 5G network sharing, as well as associated pricing and terms to ensure independent operation, could also be considered.

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1 Introduction

In March 2019, the Danish Energy Agency (DEA) awarded licences to three companies for the use of spectrum in the 700MHz, 900MHz and 2300MHz bands.[7] This spectrum is expected to support the provision of high capacity mobile services as well as the development of specialised applications. In particular 700 MHz frequencies could be used to deploy 5G. Further spectrum, for example in the 3,5 GHz band, is expected to become available to mobile operators before the end of 2020.

The Danish mobile market currently features four mobile network operators, two of whom are involved in an extensive network sharing arrangement (including spectrum sharing as well as RAN sharing). As spectrum in 700 MHz has been awarded to the joint venture TT-net (owned by Telenor and Telia Denmark), it is expected that this structure could be maintained in a 5G environment.

However, equally, the investment required for 5G deployment making use of 3.5 GHz or even milimeter frequencies (e.g. 26 GHz) which will most likely lead to an densification of networks could raise questions around the need for closer collaboration or (at a last resort) a merger between existing operators engaged in the joint venture, or other players not currently involved in network sharing.

In this study we assess the potential effects of different scenarios in the Danish mobile market (especially as relates to 5G) on investment, competition and consumer outcomes.

The assessment is based on interviews with operators in the Danish market, literature review, data analysis, and case studies of other markets which have featured varying degrees of sharing amongst mobile network operators.

- Chapter 2 discusses the current structure of the Danish mobile market and potential developments in the context of 5G.
- Chapter 3 summarises findings from recent literature and company reports on the implications of network sharing for investment and market outcomes.
- Chapter 4 describes the history of network sharing and consolidation in four European markets and highlights potential insights that may be relevant for 5G.
- Chapter 5 summarises the key messages from interviews conducted with the four mobile network operators.
- Chapter 6 discusses relevantconsiderations for 5G network sharing in the Danish context, in light of the analysis in previous chapters.

2 The Danish mobile market

In this chapter, we provide an overview of the history and current status of the Danish mobile market. Based on an analysis of market data and insights from interviews with

7 https://www.telegeography.com/products/commsupdate/articles/2019/03/29/hi3g-tdc-tt-netvaerket-winners-in-spectrum-auction/?utm_source=CommsUpdate&utm_campaign=11f0f8f95f-CommsUpdate+29+March+2019&utm_medium=email&utm_term=0_0688983330-11f0f8f95f-8874781.

mobile network operators, we then identify future trends, and potential scenarios for the mobile market structure that might be relevant as the market moves towards the deployment of next generation 5G technology.

Key findings are:

- There are four mobile operators active on the Danish mobile market, but three mobile networks, due to the comprehensive network sharing arrangement between Telia and Telenor.
- The availability and quality of 4G networks in Denmark is high. Retail prices are competitive compared with other markets, although price declines have slowed (or in some cases reversed) in recent years.
- Available data does not suggest that network sharing has limited investment in the market, or resulted in parallel conduct amongst the operators engaging in network sharing.

2.1 Mobile network operators in Denmark

There are 4 mobile network operators active in Denmark, TDC, Telenor, Hi3G and Telia Denmark.

TDC Group is the largest telecommunications company in Denmark. In 1995, the regional companies were merged into Tele Danmark, and the first nationwide cable TV company, Tele Danmark Kabel TV was created.[8] Five years later, in 2000, Tele Danmark changed its name to TDC. TDC was partly privatized in 1994 and fully privatized in 1998.

Telenor is the second largest mobile operator in Denmark and as TDC an integrated mobile operator for both residential and business customers. Telenor entered the market back in the early 1990s, first as Sonofon and since 2006 as Telenor. Since 2012 Telenor implemented a Network Sharing Agreement with Telia via a joint venture TTN. The agreement comprises the sharing of the physical RAN-infrastructure (masts and antennas), as well as frequency resources. In connection with the Network Sharing Agreement Telenor, like Telia,is obliged to offer wholesale services to other mobile operators.

Hi3G entered the market and launched its 3G network in 2001. In contrast to the other MNOs, Hi3G is a pure mobile operator. Hi3G offers residential and business mobile services (both voice and data). Hi3G has the highest consumption of data in Denmark per subscriber. Furthermore Hi3G is host to the service provider Immobility.

Telia Denmark is the fourth largest mobile network provider, present since early liberalisation. Telia Denmark entered the market in 1995 as a fixed provider offering a full range of services. In 2001 Telia entered the mobile market and restructured the business to focus on mobile, with fixed as a subsidiary service. Telia has around 1.3m mobile subscribers. There is an emphasis on offering bundles to support customer loyalty. Telia focuses not just on mobile and broadband, but also TV and insurance. Telia serves both

8 TDC Website.

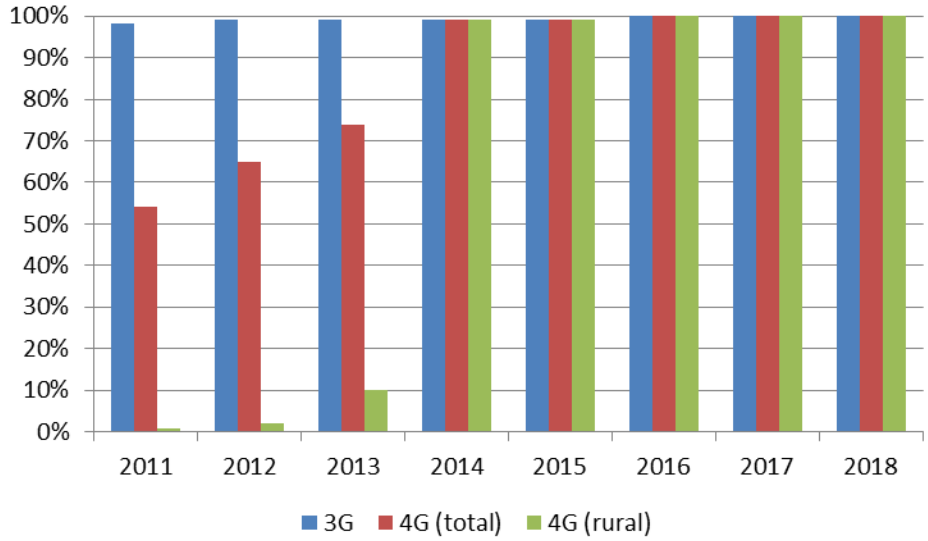
residential and business customers. For broadband services Telia relies on wholesale access products supplied by TDC.

2.2 Mobile network deployments

3G spectrum auctions took place in 2001 and 2005. Between 2007 and 2010 the now-defunct NITA (National IT and Telecom Agency) started a refarming process for 900 MHz and 1800 MHz bands.[9] In 2010 the 2,5 GHz spectrum range was also auctioned. In June 2012 the Danish Business Authority held an auction for 800MHz spectrum, which TDC used to secure a 4G licence for 2x20 MHz lots in the band. TTN (Telenor and Telia's joint network) acquired 2x10 MHz lots in the 800MHz spectrum in the auction. Denmark's fourth player, Hi3G, did not aquire 800MHz spectrum. However, in September 2012, it launched its 4G network across 15 of Denmark's largest cities using 1800MHz and 2600MHz spectrum.[10] It should be noted, that all spectrum licenses issued are technologically neutral. Thus it is up to the mobile operators to choose which spectrum is used for which technology (i.e. 2G, 3G 4G and or 5G).

Today 3G and 4G services are widely available in Denmark. The total 4G coverage reached 50% in 2011, and full population coverage was achieved in 2016.

Figure 2-1: Mobile broadband coverage in Denmark, 2011-2018



Source: DEA.

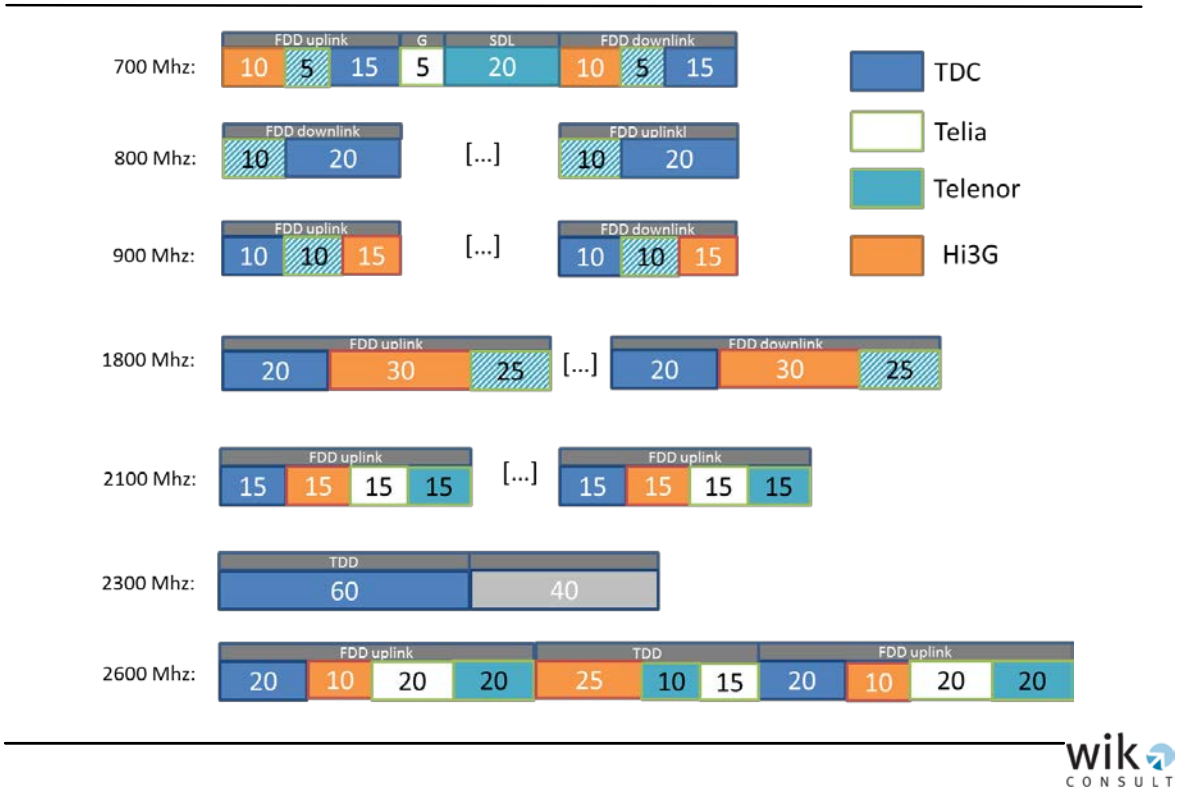
At the level of individual MNOs, TDC, Telenor and Telia provide 100% 4G population coverage, while Hi3G provides 98%.

9 https://www.gsma.com/spectrum/wp-content/uploads/2012/07/refarmingcasestudydenmark20111124.pdf.

10 https://www.zdnet.com/article/its-4g-but-they-dont-like-to-talk-about-it-how-denmarks-lte-rose-from-the-ashes-of-a-price-war/.

The following figure shows which operator uses which spectrum band for their respective services. The figure shows the status of March 2019, which does not yet include the latest auction results. These are described below.

Figure 2-2: Denmark Mobile Frequencies (Status: May 2019)



Source: https://www.spectrummonitoring.com/frequencies/#Denmark

During the latest auction, TDC won 14 of the 20 blocks in the 700 MHz, 900 MHz and 2300 MHz frequency bands, representing 60 MHz out of the available 100MHz. Hi3G acquired two 10 MHz blocks in the 700 MHz and 900 MHz bands. Telia and Telenor, bidding via the TTN joint venture, secured two 5 MHz blocks in the 700 MHz band and two 10 MHz blocks in the 900 MHz band.

2.3 Mobile network sharing and access agreements

Hi3G has made use of a national roaming agreement since they entered the market in 2001. In the beginning, Hi3G had an agreement with TDC on 2G and then with Telia regarding 2G and 3G. Today, Hi3G's national roaming provider is TDC – on 2G, 3G and 4G in areas with limited coverage (e.g. TDC with better indoor coverage).

In 2012 Telenor and Telia Denmark reached an agreement for network sharing via a joint venture (The TT Network/TTN) through which they jointly (50/50) own, control and develop the RAN-infrastructure (Radio Access Network) needed for their respective mobile businesses. The RAN sharing agreement comprises the sharing of the physical RAN-infrastructure (masts and antennas), and frequency resources. The cooperation via the network sharing agreement concerns all mobile technologies (2G, 3G, LTE, and

LTE-advanced) and covers the entire Danish territory. The purpose of the parties' agreement was to optimize their respective businesses by obtaining efficiency gains, i.e. cost reductions and the creation of a better network in terms of better coverage and technology. The The Danish Competition and Consumer Authority (DCCA) found that the network sharing agreement did entail a better and more efficient network for Telia's and Telenor's individual businesses. The DCCA concluded that this improved coverage and improved availability of technology for the parties' respective networks would be beneficial to consumers.

In the context of the network sharing agreement, Telenor and Telia were obliged to provide wholesale services to access seekers. The following table shows host MNOs and their respective access seekers. In most cases, access seekers are service providers (resellers). Lycamobile is the only real MVNO on Telia's network, *[confidential]*.

Table 2-1: Host MNOs and their respective access seekers

Host MNO	Access seeker	Type of agreement (MVNO, reseller)	Market share trends from launch to 2018
Telenor	Lebara	Reseller	*[confidential]*
Telia	Lycamobile	MVNO	*[confidential]*
Telenor/TDC	Uni-tel	Reseller	*[confidential]*
Telia	MobileValue	Reseller	*[confidential]*
Telenor/TDC	Ipvision	Reseller	*[confidential]*
Everybody else below 0,3 % of the market			

The following figure shows the current number of sites per operator in Denmark. Before the network sharing agreement Telenor and Telia each had around *[confidential]* sites. Today their shared network consists of *[confidential]* sites, i.e. 15% fewer sites than before their partnership. This illustrates the synergy effects through network sharing.

Figure 2-3: Number of sites per operator in Denmark

[confidential]

Source: WIK.

Two years after their network sharing agreement Telia and Telenor wished to further intensify their cooperation through a merger. In April 2015 the European Commission[11] opened an investigation in highlighting concerns that the deal could lead to higher prices

11 Under Danish DG COMP Commissioner Margrethe Vestager.

and less innovation. Moreover the Commission had doubts that the two remaining rivals, TDC and Hi3G, would provide sufficient competitive constraints. After the doubts were communicated by the European Commission, Telia and Telenor announced that they had withdrawn their application to merge their remaining Danish activities into one company.

Following the rejection of the merger application by the Commission, both companies continue to operate through the network sharing agreement.

2.4 Market structure and competition

2.4.1 Infrastructure competition

In Denmark four to five MNOs have been operating in the market since 1998.[12] Since 2003 the Danish mobile market consists of four MNOs.[13] However, following the network sharing agreement between Telenor and Telia in 2012, there are only three networks at the wholesale level: TDC, TTN and Hi3G. Further consolidation, whether through a merger or an expanded network sharing agreement, has so far failed due to competition concerns raised by the competition authority.

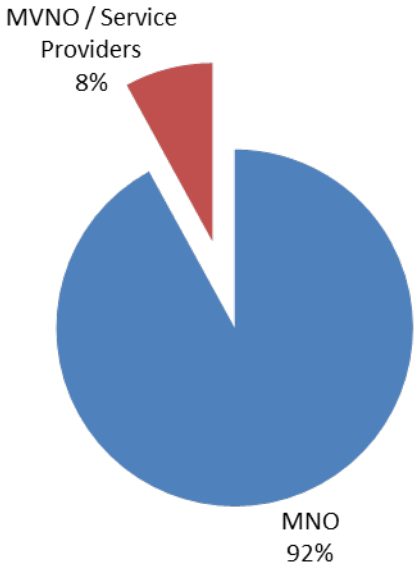
The mobile market in Denmark has traditionally been characterised by the existence of a large number of Service Providers, but limited real MVNOs. MVNO access was originally mandated under SMP regulation on TDC and Sonofon in 2000,[14] and persisted on commercial terms following the withdrawal of access regulation. Today, MVNOs and Resellers have a retail market share of approximately 8 %, which is comparable to MVNO shares in other EU countries.

12 https://www.pfs.is/library/Skrar/Innflutt/PDF/Norr%C3%A6n%20GSM%20sk%C3%BDrsla%20-%20loka%C3%BAtg%C3%A1fa.pdf.

13 https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/CISP(2014)2/FINAL&docLanguage=En.

14 https://www.berec.europa.eu/doc/publications/erg_06_45_report_on_mobile_access_market_competition.pdf.

Figure 2-4: Share of MVNOs and MNOs in Denmark 2018

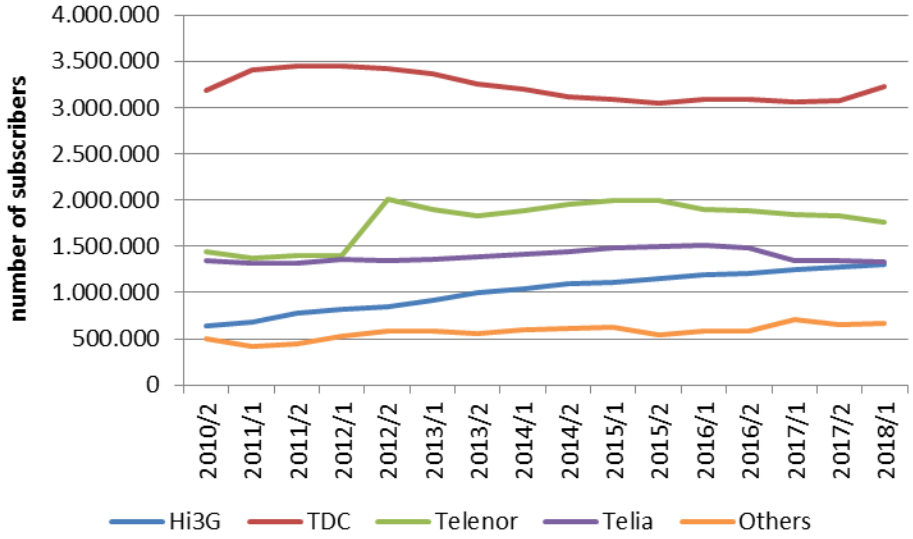


Source: WIK based on DEA.

2.4.2 Retail competition

Figure 2-5 shows the development of the number of subscribers of mobile operators in Denmark since 2010. While TDC subscribers remain at a high level over time, Telenor in particular made significant progress in 2012, possibly because of the network sharing agreement with Telia. Hi3G also continued to expand its customer base between 2010 and 2018, almost reaching the level of Telia subscribers.

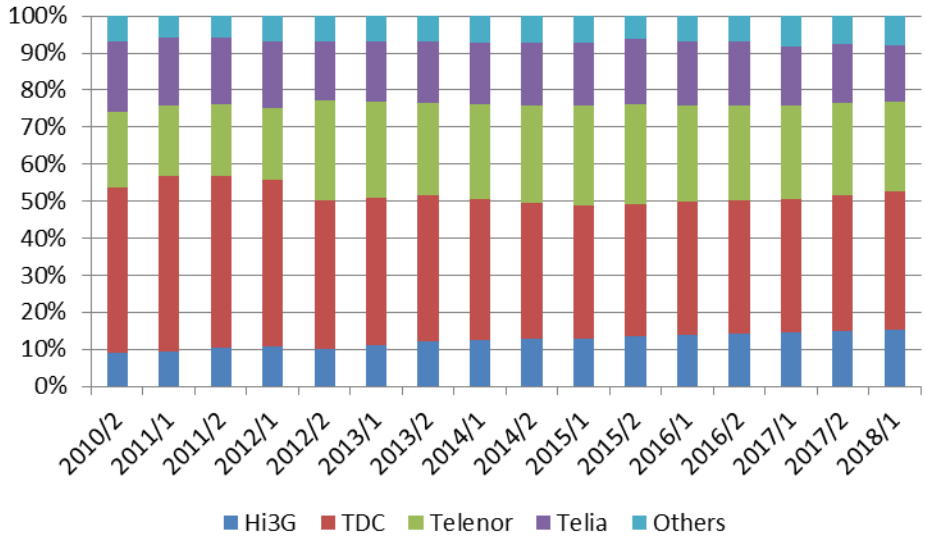
Figure 2-5: Number of subscriber developments (MNOs), 2010-2018



Source: WIK based on DEA.

The development of market shares based on the number of subscribers shows a relatively stable market structure with slightly decreasing market shares for the incumbent TDC since 2011 and an increase in Hi3G market shares.

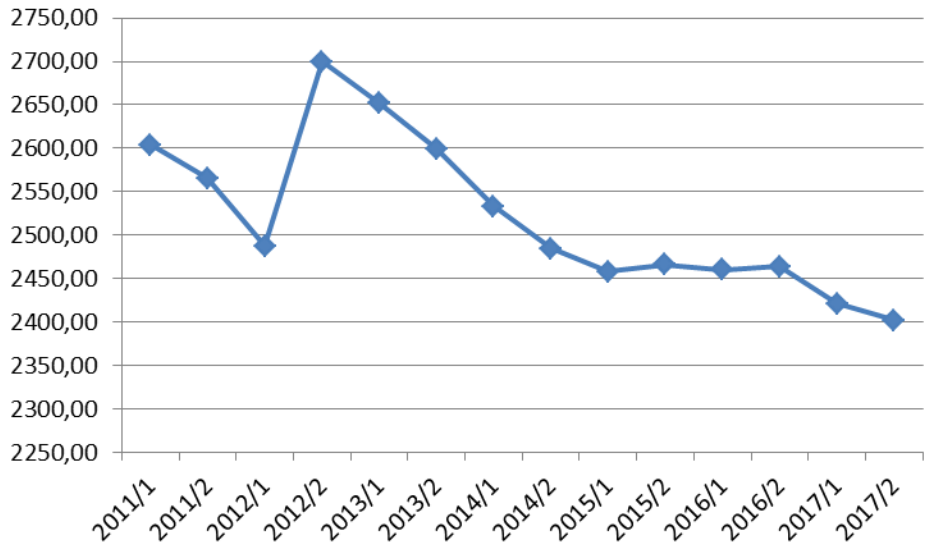
Figure 2-6: Market shares based on subscribers in the Danish mobile market, 2010-2018 (in half years)



Source: WIK based on DEA.

Competition between MNOs can be measured by the Hirschman-Herfindal Index (the sum of the squared market shares, multiplied by 10.000[15]) and the number of MNOs. The HHI is calculated on the basis of subscriber numbers.[16] The network sharing agreement in 2012 led to a short term increase of the HHI of 200 points. This reversed the previous downward trend in the HHI as Figure 2-7 shows: Since then, that is between 2012 and 2017, the HHI has declined constantly, reflecting that the smaller MNOs were able to increase their market share at the expense of the incumbent TDC.

Figure 2-7: Herfindahl-Hirschman-Index (HHI) in the Danish mobile market, 2011-2017



Source: WIK.

2.5 Financial performance

2.5.1 Revenues

Overall mobile revenues in Denmark have decreased by almost 25% between 2011 and 2017 as Figure 2-8 shows. *[confidential]*.

15 Thereby the HHI gives proportionately greater weight to the market shares of the larger firms.

16 The closer a market is to a monopoly, the higher the market's concentration and the level of the HHI and the lower its competition. According to the US Department of Justice markets with an HHI of less than 1,500 are considered to be a competitive marketplace, markets with an HHI of 1,500 to 2,500 to be a moderately concentrated marketplace, and markets with an HHI of 2,500 or greater to be a highly concentrated marketplace.
https://www.sciencedirect.com/topics/economics-econometrics-and-finance/concentration-ratio.

Figure 2-8: Mobile retail and wholesale revenues, 2011-2017

[confidential]

Source: WIK based on DEA.

Along with declining total revenues, average revenues per user in Denmark have also been falling since 2011 as is shown in Figure 2-9. *[confidential]*

Figure 2-9: Development monthly ARPU in DKK, 2011-2017

[confidential]

Note: * Up until 2015 both retail and wholesale revenues is included.

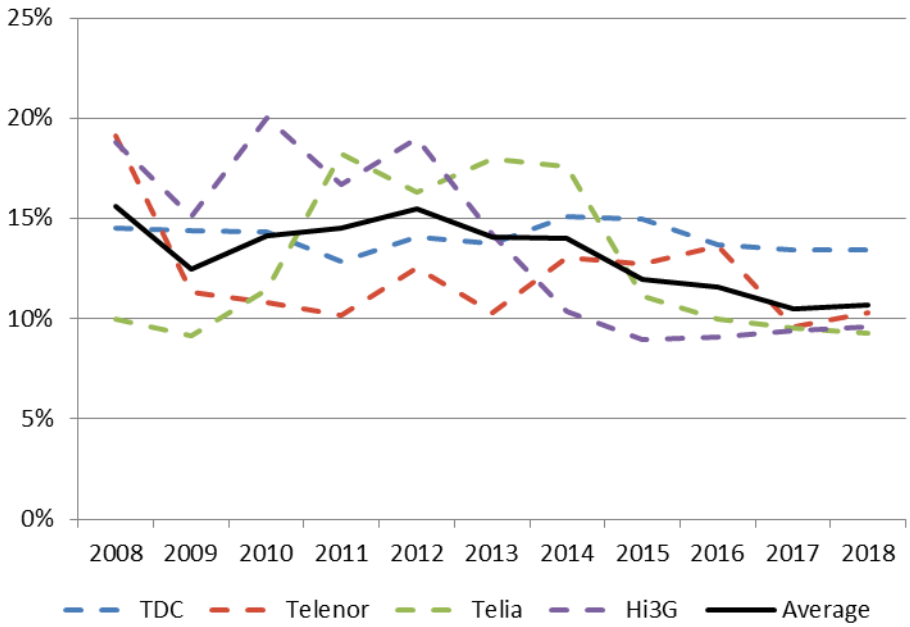
Source: WIK based on DEA.

2.5.2 Investments

Investment is typically reported through the CAPEX/revenue ratio and CAPEX per subscriber. CAPEX figures must be interpreted with care, as CAPEX measurements in different countries may be based on different methodologies, in particular as regards the treatment of spectrum acquisitions. Moreover, CAPEX comparisons between MNOs or between countries may be misleading if limited to a single year. CAPEX follows a cyclical pattern, since technological change is implemented in successive generations of technologies. CAPEX is closely correlated to periods in which there are network deployments and upgrades. Finally, it is useful to relate CAPEX to subscribers or revenue, in order to adjust for different market sizes in international comparisons.

Figure 2-10 shows that investments by all providers initially increased after 2010 in connection with the 4G roll out. However, following the network sharing agreement, *[confidential]*, which coincides with the removal of mast sites which were duplicated. Telia mainly experienced initial costs due to the consolidation while savings and benefits have been apparent from 2014 onwards. *[confidential]* The extent to which this is related cannot be clearly determined. Compared to the other three providers, Hi3G has comparably few infrastructure sites. Instead, Hi3G has entered into roaming agreements with TDC and Telia (see also chapter 2.3). A cyclical increase in capex could be expected as deployments occur following the auction of 700 Mhz and 26 GHz spectrum bands.

Figure 2-10: CAPEX / revenue ratios of MNOs in Denmark, 2008-2018

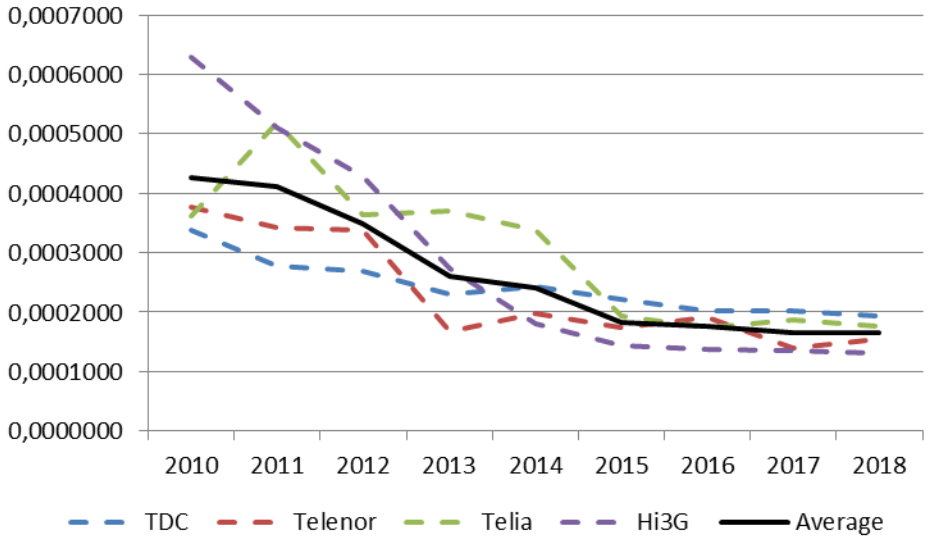


Source: WIK based on Newstreet.

Another way of expressing investment is through the CAPEX/subscriber ratio.[17] This again clearly shows that investments have been declining since 2011, especially due to falling CAPEX figures of MNOs. In relation to subscribers, these are declining, especially for the three smaller operators in the market, while TDC shows an increase at least until 2014. It should be noted in this regard that comparability before and after 2014 is only possible to a limited extent due to changes in measurement methods.

17 Frontier for example outlines that they consider capex/subscriber to be a superior measure of investment to capex/revenue . (see https://www.gsma.com/publicpolicy/wp-content/uploads/2015/05/Assessing_the_case_for_in-country_mobile_consolidation.pdf).

Figure 2-11: CAPEX / subscriber ratios of MNOs in Denmark, 2010-2018



Source: WIK based on Newstreet.

2.5.3 Profitability

Profitability is measured by the EBITDA to revenues ratio (EBITDA margin):

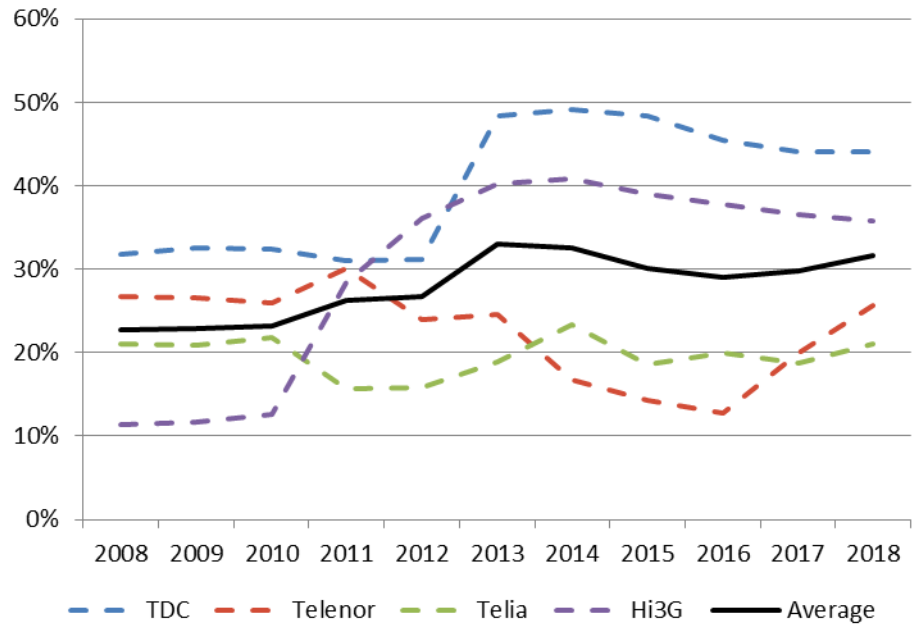
$EBITDA\ margin = \frac{EBITDA}{Revenues}$, where

$EBITDA = \ Earnings\ before\ Interest, Tax, Depreciation\ and\ Amortisation$

$Revenues = \ Retail\ and\ wholesale\ revenues, incl.\ from\ sales\ of\ terminal\ equipment$

The development of the profitability of operators has varied over the last 10 years. While TDC has been able to extend its lead over the others, Hi3G succeeded in overtaking Telenor and Telia. Between 2012 and 2014, Hi3G quadrupled its profitability. Meanwhile its EBITDA margin has declined to some extent, but is still at a much higher level than it was 10 years ago. In contrast, the EBITDA margins of Telenor and Telia are now at a comparable level to 10 years ago. On average, the EBITDA margin in Denmark rose by almost 10 percentage points.

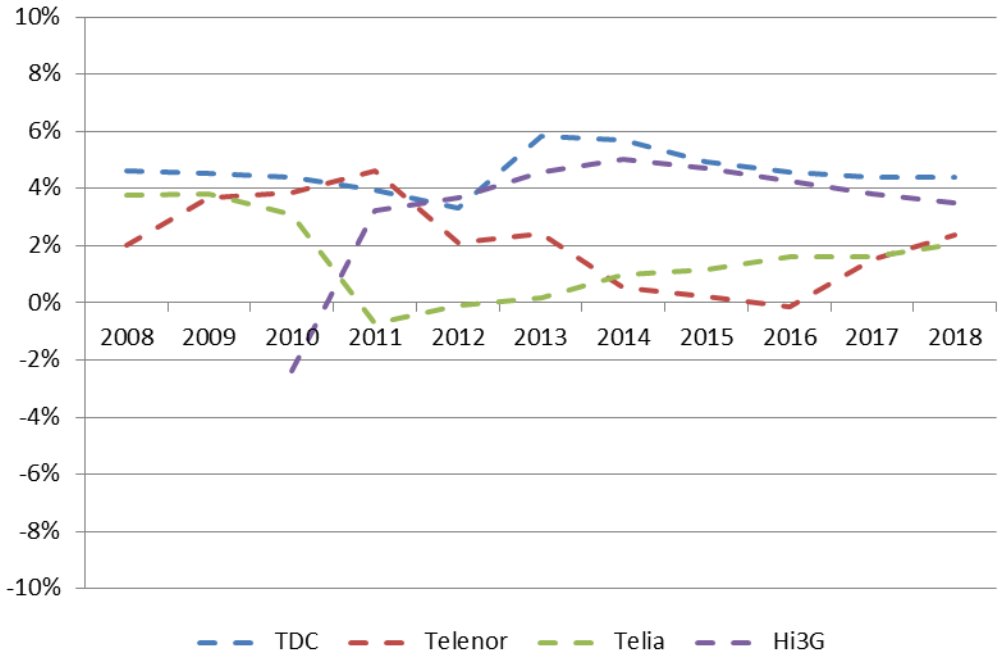
Figure 2-12: EBITDA margin of MNOs in the Danish mobile market, 2008-2018



Source: WIK based on Newstreet.

As EBITDA excludes CAPEX the following figure illustrates Free Cash Flow as percentage of the revenues. FCF is generally calculated as operating cash flows (OCF) less capital expenditures. Capital expenditures are required each year to maintain an asset base at a very minimum, and to lay a foundation for future growth. When OCF exceeds this type of reinvestment into the business, the company is generating FCF. As Figure 2-13 shows, FCF ratios have been relatively low for Telenor and Telia compared to TDC and Hi3G since 2012, possibly an effect of the network sharing agreement.

Figure 2-13: Free Cash Flow (FCF) / revenue ratio of MNOs in the Danish mobile market, 2008-2018



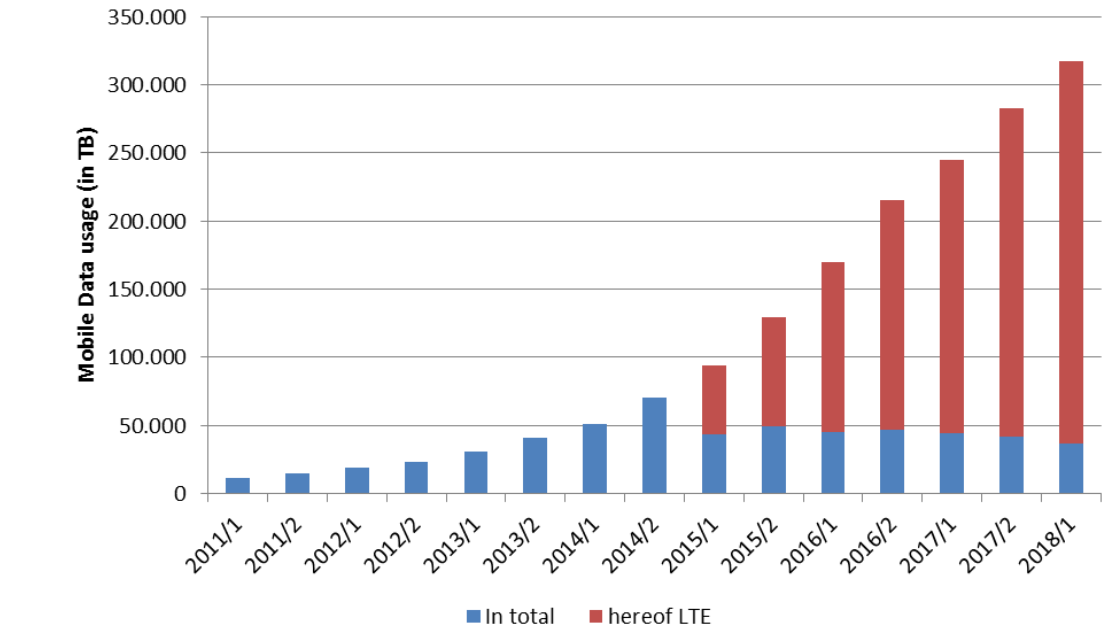
Source: WIK based on Newstreet.

2.6 Retail outcomes

2.6.1 Mobile broadband usage

Mobile broadband usage has increased significantly as shown in Figure 2-14. In 2018 the mobile data usage amounted to around 318.000 TB, 30 times higher than in 2011. The share of LTE based usage amounts to almost 90%.

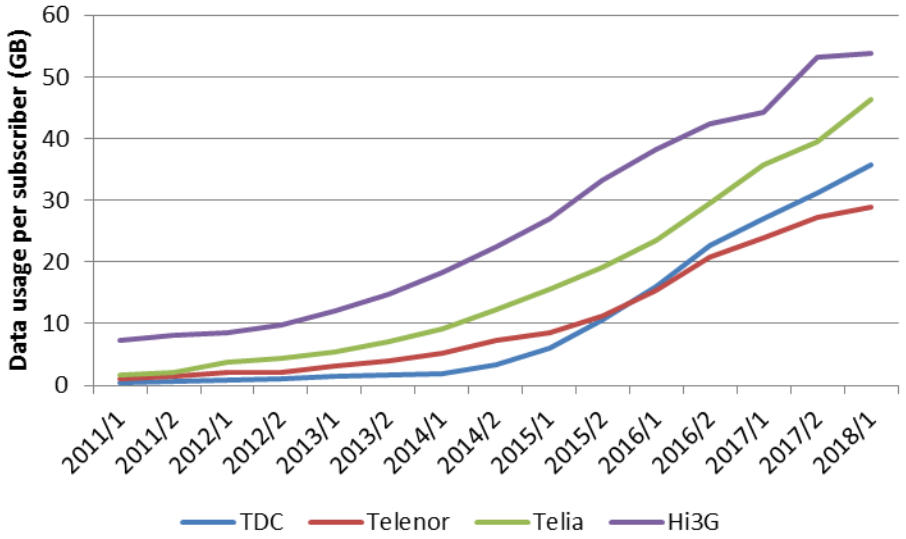
Figure 2-14: Total mobile data usage (in TB), 2011-2018 (by half year)



Source: WIK based on DEA.

As regards the development of broadband data usage per operator and subscriber the following figure shows that in 2011 Hi3G was the operator with most data usage. This is not surprising as Hi3G was the first operator to provide 3G positioning itself as mobile broadband company. To this day, they have retained their status as data providers. However, overall, data usage has increased for all providers.

Figure 2-15: Mobile data usage per operator and subscriber (in GB), 2011-2018



Source: WIK based on DEA.

2.6.2 Prices

According to a study by the European Commission Denmark's price level with regard to mobile broadband and telephony is relatively low compared to other EU countries. The study shows that prices in Denmark are about 10 to 50% below the EU average.[18]

18 European Commission (2017), Study on Mobile Broadband Prices 2017, p. 60 (see http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=50378).

Figure 2-16: Mobile price comparison Denmark vs. EU, 2017

USAGE BASKET	PROVIDER AND OFFER	EUR/ PPP	EU AVERAGE
100 MB, 30 CALLS, 100 SMS	Telenor - FRI+ 10GB	15.27	14.11
500 MB, 100 CALLS, 140 SMS	Telenor - FRI+ 10GB	15.27	17.61
1 GB, 300 CALLS, 225 SMS	Telenor - FRI+ 10GB	15.27	23.62
2 GB, 900 CALLS, 350 SMS	Telenor - FRI+ 10GB	15.27	31.39
2 GB, 30 CALLS, 100 SMS	Telenor - FRI+ 10GB	15.27	23.92
5 GB, 100 CALLS, 140 SMS	Telenor - FRI+ 10GB	15.27	31.80
5 GB (DATA ONLY)	Telenor - 5 GB	10.14	16.73
10 GB (DATA ONLY)	TDC - 10 GB	12.48	21.77
20 GB (DATA ONLY)	TDC - 20 GB	15.27	33.12

Source: European Commission.

[confidential]

Figure 2-17: Development Monthly subscription Mobile 300 Minutes, 2009-2018

[Confidential]

Source: WIK based on DEA.

3 Effects of competitive models on investment: a literature review

In this chapter, we assess available literature concerning the impact of different competitive models on investment and competition in mobile markets.

There is an abundance of literature on the implications of mobile consolidation on investment. These include studies by WIK (2015) for Ofcom (which included econometric analysis), as well as the BEREC (2018) report on post-merger market developments, and academic studies.

Analysis of the effects of mobile *network sharing* on investment are more sparse, but relevant reports include the BEREC (2018) report on infrastructure sharing, OECD (2015) report on wireless market structures and network sharing, consulting reports and industry analysis such as the GSMA report on mobile infrastructure sharing as well as academic research.

Key findings are:

- There is a wide range of literature which considers the impact of *consolidation* in mobile markets on competition and investment. However, the results differ. WIK concluded in a 2015 study for Ofcom on this subject that no general conclusions could be reached, and that analysis was needed of the conditions in the market concerned.[19]

- Industry reports suggest that cost savings can be a key motive for network sharing and roaming agreements. Estimates on the degree of cost saving possible vary, but Vodafone has suggested that cost savings could range from 40-50% (full sharing) through roaming (30% to 40%) to passive sharing (15% and 25%). Cost savings with passive sharing are estimated to be higher in rural areas than in urban areas.

- Regulators have been broadly positive towards certain aspects of network sharing. However, some regulators express concern that some kinds of mobile network sharing agreements (especially those which are more extensive in nature geographically or through the inclusion of spectrum) could limit incentives to deploy next generation mobile infrastructure and limit innovation and service differentiation. It should be noted that these concerns have been expressed in the context of 3G and 4G networks, and may need to be reconsidered in the context of 5G, for which spectrum sharing might be an efficient tool to provide new innovative services a single operator cannot offer individually due to limited bandwidth.

- Molleryd concludes that despite an extensive usage of network sharing, competition on the retail market prevails. Although there is a risk of effect from collaboration on the downstream market, the social benefits associated with larger coverage and improved capacity has so far given extensive support for network sharing.

19 WIK (2015) competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications.

- Neumann and Plückebaum (2017) conclude that the need for a significant denser mobile radio access network structure in a 5G environment will challenge the prevailing paradigm of infrastructure competition in mobile markets. They question whether a market structure with three or four independent mobile operators and radio access networks could support a doubled or tripled number of base stations in a 5G environment, as might be required if there is significant bandwidth demand or a need for extensive coverage.

3.1.1 Consolidation

The effects of changes in market structure in the mobile market on investment have been widely debated and are ambiguous. BEREC (2018) and Houpis et al. (2016) emphasise the importance of multiple competitors in the network market. They argue that a lack of competition leads to under provision and higher prices for consumers. However, Houngbonon & Jeanjean (2016), found that too little competition can harm investment as well as too much due to an inverted-U curve of the relationship. Moreover, they warn that investments could increase in the short-run but drop in the long-run if new firms enter the market. Furthermore, regulatory intervention could have negative effects on dynamic efficiencies in the mobile market. that investments They conclude that investments are maximised for a level of competition of 60-63% relating to the Lerner-Index.

In a 2015 study by WIK for Ofcom,[20] WIK conducted econometric analysis based on time series data from 12 countries. Key conclusions were that econometric analysis did not support the claims of mobile operators that consolidation was associated with higher levels of investment, but neither did it confirm that consolidation was linked to weaker consumer outcomes. Rather, it concluded that other factors including demand-side drivers, spectrum assignment and associated coverage obligations probably provided a greater explanatory role. The study noted that developments in which Germany and Ireland in which consolidation had been approved subject to the provision of mobile bitstream were of interest, but it was too early at that time to gauge the impact.

3.1.2 Network sharing

In already tight oligopolistic mobile markets in Europe competition authorities have reservations when it comes to a further consolidation of the market through mergers.

Network sharing, however, has been viewed more positively and is considered relevant by many regulators for 4G and upcoming 5G networks in less dense areas. The OECD (2015) advocates voluntary sharing of intfrastructure while BEREC (2018) notes that infrastructure sharing can be an important device to distribute 5G and discourages policy interventions because sharing is often driven by the market on its own.

Reasons for market driven infrastructure sharing are the need for national roaming of new entrants which have to roll-out a sufficient network as quickly as possible, cost pressures and a lack of sufficient space in urban areas to deploy sites independently.

20 https://www.wik.org/fileadmin/Studien/2015/Competition_and_investment_mobile_telecommunications.pdf.

National roaming is also emphasised by Kim et al. (2018) as the only significant tool to reduce CAPEX and OPEX in the short- and/or long-run.

That said, some NRAs have expressed concerns that network sharing and roaming agreements (especially those which are more extensive in nature) could limit incentives to deploy next generation mobile infrastructure and limit innovation and service differentiation. Theoretical economic analysis, however, does not provide final and conclusive results on this hypothesis. Rather, the impact of sharing on network investment and market outcomes needs a careful analysis of the market scenario in which sharing occurs and on the type of sharing.

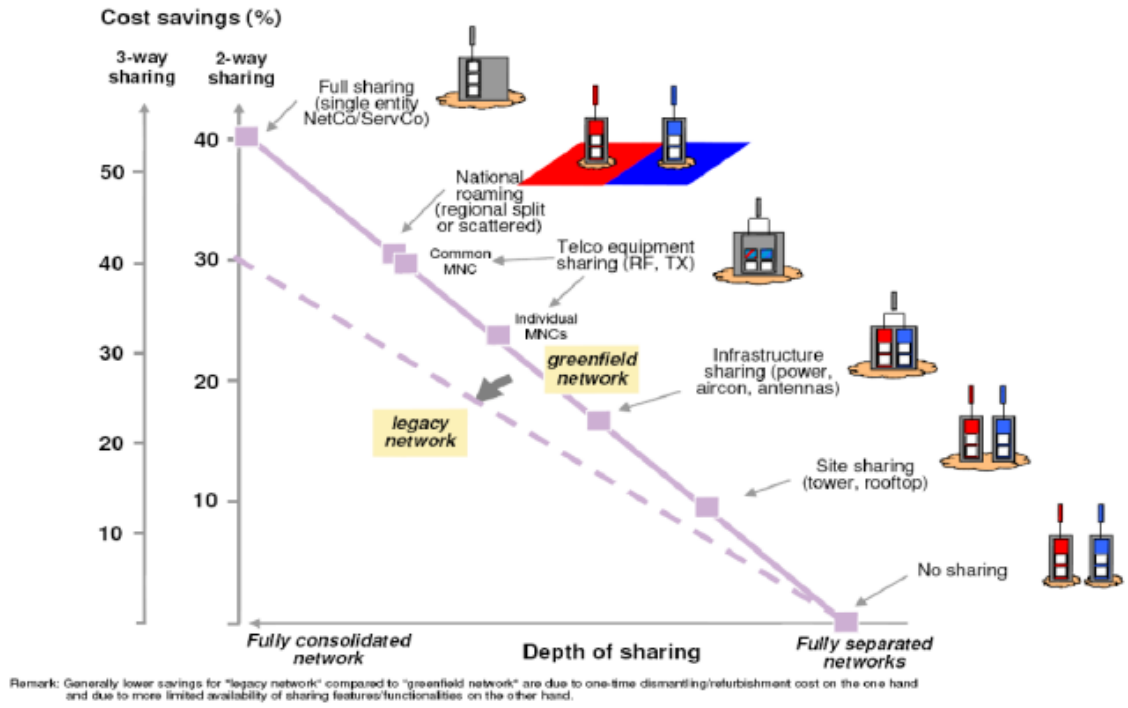
According to the BEREC (2018) report, passive sharing is widely used and recognized in the EU. Passive sharing is defined as sharing of the passive elements of network infrastructure (mast, sites, cabinet, power, air-conditioning). On the other hand there is active network sharing which is defined as the sharing of active elements in the radio access network (e.g. antenna, radio network controller (RNC)). Currently most active sharing agreements with joint deployment are commercially driven. The majority of active sharing agreements with joint deployment are organised in the form of a joint venture.

The realisation of cost savings is generally the main motive for establishing network cooperation and the joint use of network elements. Savings can be realized in investments and operating costs. The extent of potential savings depends on whether sharing is agreed in a brownfield or greenfield situation. In a greenfield situation, network sharing is arranged before the infrastructure is built. In this case, both partners can achieve greater savings compared to the situation where one or both operators have built infrastructure and then the decision to share is made. Nevertheless, it remains to be observed in the market that in a large number of cases sharing is only agreed in a brownfield situation. This follows from the observation that cost pressure is greater in more mature markets than in emerging ones. Then it becomes more urgent to exploit all remaining cost-cutting opportunities.

The relevance of cost savings also depends on whether network cooperation takes place in congested or congested areas. In areas in which the radio cells are (predominantly) capacity-driven, RAN sharing and roaming are unlikely to generate savings. This is not the case in areas where the expansion is (predominantly) coverage-driven. The cost savings with passive sharing are therefore estimated to be higher in rural areas than in urban areas. There are estimates (GSMA 2012) according to which passive sharing can save 30% of CAPEX. With a cost share of these network elements of 50%, this results in potential total cost savings of 15%.

There are a number of estimates of cost savings associated with sharing. However, these are often not very transparent and are hardly or not comprehensible from the point of view of the calculation approach. An estimate by Vodafone shows possible savings across the continuum from fully separated networks to fully shared networks. The latter marginal solution generates potential cost savings of 40% to 50%. National roaming can save 30% to 40% of costs. For the individual operator, this naturally also depends on the fee structures and cost sharing rules. The advantages of passive sharing are between 15% and 25%.

Figure 3-1: Potential cost savings through network sharing



Source: Vodafone in BEREC (2011).[21]

Overall network cooperations in form of network sharing agreements can be an alternative to a merger between two MNOs. Such cooperations enable the respective operators to internalize most of the relevant cost savings without destroying the competitive relationship between the MNOs involved.

Academically oriented papers which have looked at the effects of mobile network sharing on competition and investment have generally not found evidence of negative effects. In a 2013 conference paper, Molleryd and Markendahl[22] note that "Despite an extensive usage of network sharing - where competitors are collaborating - competition on the retail market prevails. A potential spillover from network collaboration on the downstream market is a risk, and a factor that competition authorities are monitoring very closely. However, the social benefit with larger coverage and improved capacity has so far given extensive support for network sharing which has become an established practice within the market for electronic communications." The authors observe that operators have been able to lower their network operation costs, but this did not translate into improved profits. They conclude that network sharing off-set part of the profitability gap, and that profits would have been lower in the absence of network sharing.

21 BEREC-RSPG report on infrastructure and spectrum sharing in mobile/wireless networks, BoR (11) 26, RSPG11-374, June 2011.

22 Molleryd, Markendalh (2013) The role of network sharing in transforming the operator business: Impact on profitability and competition https://www.econstor.eu/bitstream/10419/88459/1/774089377.pdf.

In a 2017 conference paper by Dasgupta and Williams,[23] the authors conclude (in similar vein to WIK (2015)'s conclusions concerning consolidation) that "the overarching lesson from our reviews of JVs and the economic literature is that there is no "one size fits all" prescription for the competition policy analysis of JVs in the telecommunications sector. Indeed, it is precisely the highly case-specific nature of the potential competitive effects from JVs that makes a "rule of reason" analysis (as under competition law) the appropriate vehicle for evaluating of these JVs.

Turning to implications for 5G Neumann and Plückebaum (2017) conclude, that the need for a significant denser mobile radio access network structure in a 5G environment will challenge the prevailing paradigm of infrastructure competition in mobile markets. It is questionable whether a market structure with three or four independent mobile operators and radio access networks can support any need for a doubled or tripled number of base stations in a 5G environment (if required as a result of increased demand for bandwidth or extensive network coverage). HSBC (2017) also points out the challenge that 5G will have on the existing infrastructure paradigm in mobile markets.

In the context of 5G Neumann and Plückebaum (2017) note that regulatory and competition authorities will have to pay greater attention to network cooperation agreements through virtualization of network functions. According to the authors such concepts will become prevailing as 5G develops.

23 Dasgupta and Williams (2017): Network sharing: co-operating, co-opting and competing https://www.econstor.eu/bitstream/10419/169456/1/Dasgupta-Williams.pdf.

4 European case studies

As literature does not provide conclusive results on the effects of network sharing on investment and competition, we have analysed four case studies within Europe which feature different degrees of consolidation, entry network sharing and roaming, in order to assess whether any patterns are visible within or between these countries that might have been influenced by these developments.

While Sweden, like Denmark, has featured extensive network sharing for 4G deployment including spectrum sharing, network sharing arrangements in France have been limited to RAN sharing in certain regions, while in Spain, only national roaming has been pursued.

Moving beyond network sharing arrangements, the effects of four to three consolidation can be seen in Germany, while the effects of entry by a disruptive player can be seen in France.

Key findings are that:

- Competition Authorities in different countries have taken different approaches towards network sharing. While more permissive approaches have been pursued in Sweden and Denmark,[24] authorities in France[25] and Germany[26] have taken a more cautious approach to spectrum sharing in particular. The authorities in Spain have also taken action against a 4G roaming agreement that they considered was detrimental to investment incentives.

- The evidence does not suggest that the two countries which engaged in the most extensive forms of mobile network sharing (Denmark and Sweden)[27] experienced negative effects on pricing or quality in the period following the introduction of the sharing agreements, or compared with other countries which had less extensive network sharing arrangements such as France and Spain. Indeed, consumer outcomes in the mobile markets in Denmark and Sweden, including 4G availability and download speeds tend to compare favourably with the other countries considered, while prices for data-intensive bundles lie in the mid-range.

- A limitation of the analysis is that in all cases network sharing involved consolidation from four to three 4G networks, but there were no cases involving consolidation down to two 4G networks

24 Although they involved extensive sharing (including spectrum), the JVs in Sweden and Denmark were cleared by the competition authorities, albeit with remedies in the case of Denmark.
25 In 2016 Guidelines, the French authority ARCEP concluded that passive infrastructure sharing would be supported throughout the territory, active sharing could be relevant “in some parts” providing negative impacts could be counteracted, spectrum sharing should be limited to zones of very limited population density and roaming should be confined to less densely populated areas in view of its negative impact on investment.
26 In a 2010 paper, the German authority BNetzA noted that passive sharing was permissible, as was RAN sharing (subject to conditions). Spectrum sharing would affect the principle of competitive independence, but would be examined case by case, and could be relevant in closing broadband coverage gaps.
27 In both Denmark and Sweden, network sharing has involved spectrum sharing as well as active RAN sharing on a nationwide basis for 4G.

4.1 France

4.1.1 Mobile operators, entry and consolidation

France provides an example of disruptive market entry, which took the market from 3 to 4 network operators.

In 2001, 3G spectrum was awarded to three mobile network operators (MNOs): Orange, SFR, and Bouygues Telecom. Motivated by the desire to encourage competition in the mobile telecommunications sector, the French regulatory authority, ARCEP, granted a fourth 3G radio spectrum license to Free Mobile in 2010. Free mobile subsequently launched commercial services in 2012.[28]

4.1.2 Network sharing agreements[29]

France also features one network sharing agreement and a roaming agreement, which have been subject to the oversight and intervention of the French regulatory authority.

4.1.2.1 Free Mobile / Orange roaming agreement

One of the two main network sharing agreements in France is the national roaming agreement between Free Mobile (4th mobile operator and last entrant) and Orange. It is a 2G/3G roaming agreement allowing Free Mobile's customers on Orange's network and was initially signed for a 6 year period (up to 2018).

The agreement was signed in 2012 to provide a platform on which Free could launch services, while still deploying its network. However, it soon proved to be controversial with competitors, as they argued that it had allowed Free to offer market-leading rates without committing to investments in network infrastructure.[30]

4.1.2.2 SFR / Bouygues Telecom

The other sharing agreement in France is between Bouygues Telecom and SFR. It involves active sharing of their networks (in 2G/3G/4G) on 85% of the territory (57% of the French population) and involved a temporary 4G roaming of SFR's customers on part of Bouygues Telecom's network.[31]

The agreement was reached in 2014, and took the form of a joint venture which would target the whole of France, but excluding the 32 largest urban areas that had more than 200,000 inhabitants as well as "blind spots" not covered by either operator. At the time of the agreement, the deployment was expected to be completed by the end of 2017.[32]

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28 Bourreau et al (2017) Market entry and fighting brands: the case of the French Mobile Telecommunications Market https://www.cresse.info/uploadfiles/2017_pa15_pa3.pdf

29 Details in this section are drawn from the 2018 BEREC Report on infrastructure sharing (BoR(18) 116)

30 https://www.mobileworldlive.com/featured-content/home-banner/french-regulator-review-iliad-orange-roaming-agreement-report/

31 2018 BEREC Report on infrastructure sharing (BoR(18) 116)

32 http://telecoms.com/219312/bouyges-telecom-and-sfr-enter-into-network-sharing-agreement/

The operators involved argued that they would maintain independence because they would conduct network research independently as well as independently setting prices and reaching commercial deals. Each operator would maintain control over their backbone network and frequencies.

Their aim was to reap €300m per year in cost savings by 2017-18.[33] The agreement was approved by the French competition authority later in 2014, and this decision was upheld on appeal in 2016.

4.1.2.3 Perspective of the competition and regulatory authorities

In 2013, the French competition authority issued an opinion on the conditions under which mobile network sharing should be permitted.[34] In particular, it identified the following three criteria for assessing the impact of these agreements on competition:

1. The degree of co-operation between the parties to the agreement: it noted that while the sharing of passive infrastructure involves little exchange of information, frequency sharing "severely limits partners' autonomy and their ability to differentiate themselves in terms of quality of service or coverage". The competition authority concluded that active infrastructure sharing "lay somewhere in the middle".

2. Market power jointly held by the partners, which depends on their size, strength and complementarity, as well as the ability of other market participants to respond either individually or collectively

3. The characteristics of the areas covered by the agreement and their population density. The authority noted that in sparsely populated areas, network sharing would lead to significant cost savings supporting expanded coverage, but that fewer cost savings could be expected from network sharing in densely populated areas

The authority concluded that it would not a priori exclude any type of network sharing in sparsely populated areas, but that frequency sharing agreements would need careful examination. In densely populated areas however, the authority would have strong reservations about spectrum sharing, and would also recommend that active (RAN) sharing should be controlled and limited, because it involves the exchange of sensitive information, especially in very dense areas, where frequent exchange of detailed information about subscriber usage would be needed to size networks. It would however be "less risky" in semi-densely populated areas, as exchange of precise information would not be so important in deploying a joint network.

Regarding roaming, the authority noted that it could help to support new entry, but that it should be time limited as it constituted a risk to competition.

Following the adoption of legislation that permitted ARCEP to request changes in sharing agreements between mobile operators[35] ARCEP produced Guidelines on

33 https://www.reuters.com/article/france-telecommunications-regulator/update-1-regulator-allows-bouygues-sfr-network-deal-to-go-ahead-idUSL6N0RQ4CY20140925

34 http://www.autoritedelaconcurrence.fr/user/avisdec.php?numero=13a08

mobile network sharing in 2016,[36] and invited operators to modify, if necessary the existing sharing agreements to comply with its guidelines.

The Guidelines observe that network sharing could reduce cost and support more rapid investment, especially in less dense areas. It could also achieve environmental benefits through avoiding the duplication of passive infrastructure.

However, ARCEP noted the risk that network sharing could undermine infrastructure competition and technical innovation in the deployment of new generation technologies.

ARCEP concluded that:

- Passive infrastructure sharing would be supported, throughout the territory
- Active sharing could be relevant in certain parts of the territory, providing that negative impacts could be counteracted by benefits to end-users
- Spectrum sharing should be a priori limited to zones of very limited population density
- Roaming should be confined to less densely populated areas in view of its negative impact on investment

In response to ARCEP's guidelines, Free Mobile and Orange agreed in June 2016, to phase out roaming, based on a progressive speed throttling for Free Mobile's roaming customers from January 2017 to the end of 2020.[37]

Bouygues Telecom and SFR also amended their 2G/3G/4G network sharing agreement, to include the termination of 4G roaming of SFR on Bouygues Telecom network by the end of 2018.

In addition, the operators agreed to indicate to ARCEP the incremental deployment (increased 2G/3G coverage as well as accelerated 4G coverage) they expected, as a result of the sharing agreement, compared with standalone deployment, and committed to provide detailed information about the progress with their deployemnt compared with forecasts.

ARCEP concluded that these commitments met the requirements as laid out in the Guidelines.

4.1.2.4 Market structure trends

The following chart shows trends in market shares for French mobile operators. The disruptive effect on a previously stable market structure of the entry of Iliad/Free can clearly be seen from 2011 onwards. It is also noticeable that from 2016 onwards, market shares appear to stabilise once more, although these trends would need to be confirmed with analysis of subsequent periods.

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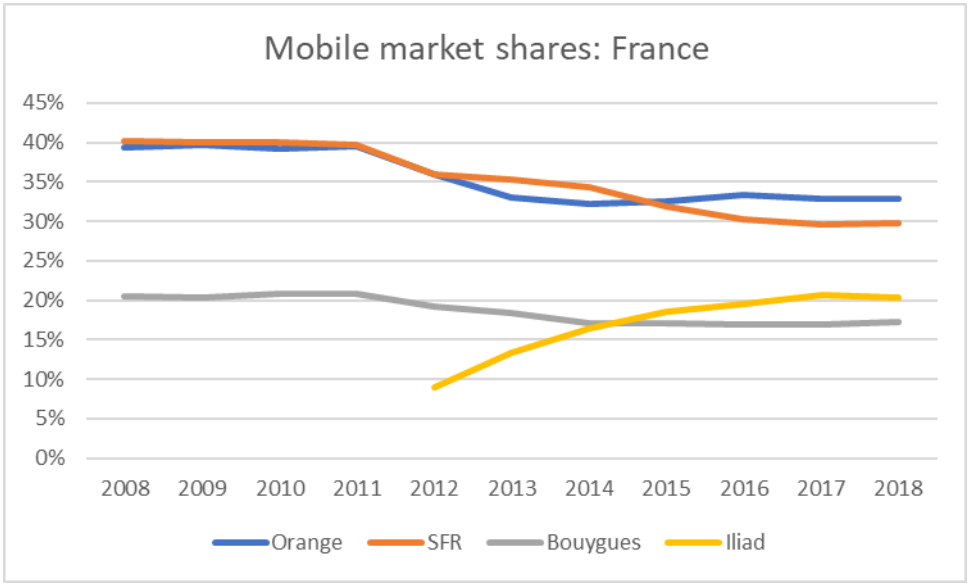
35 National law (law n° 2015-990)

36 https://www.arcep.fr/uploads/tx_gspublication/2016-05-25-partage-reseaux-mobiles-lignes-directrices.pdf

37 2018 BEREC Report on infrastructure sharing (BoR(18) 116)

Figure 4-1: Mobile market shares in France, 2008-2018



Source: WIK based on Newstreet.

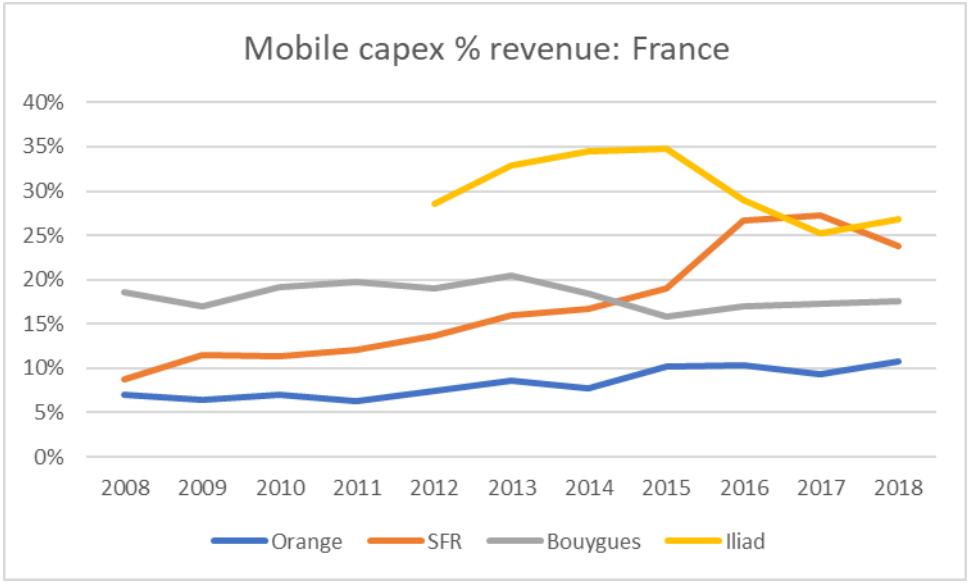
Data gathered by the European Commission shows that as of the end of 2016, more than 50 MVNOs were present on the French market with a total market share of 9%.[38]

4.1.3 Effects on investment

Data on capex shows that following the network sharing agreement around 2014, there was a continued upward trend in investment by SFR, although Bouygues' capex fell both in absolute terms and as a proportion of revenue. The data also shows a ramp-up in investment by Iliad, with levels stabilising from 2015 onwards.

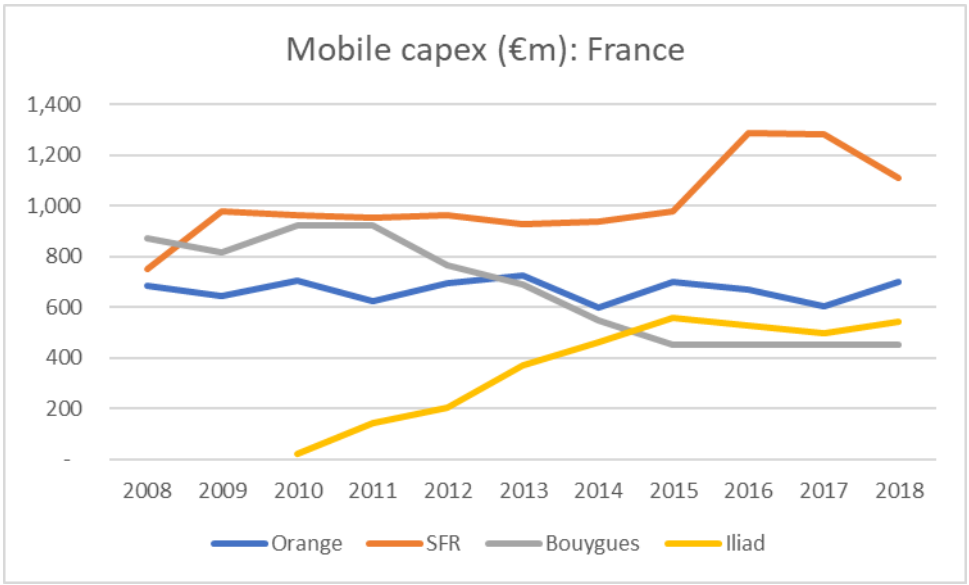
38 http://ec.europa.eu/newsroom/document.cfm?doc_id=44445

Figure 4-2: Mobile CAPEX/revenue in % in France, 2008-2018



Source: WIK based on Newstreet.

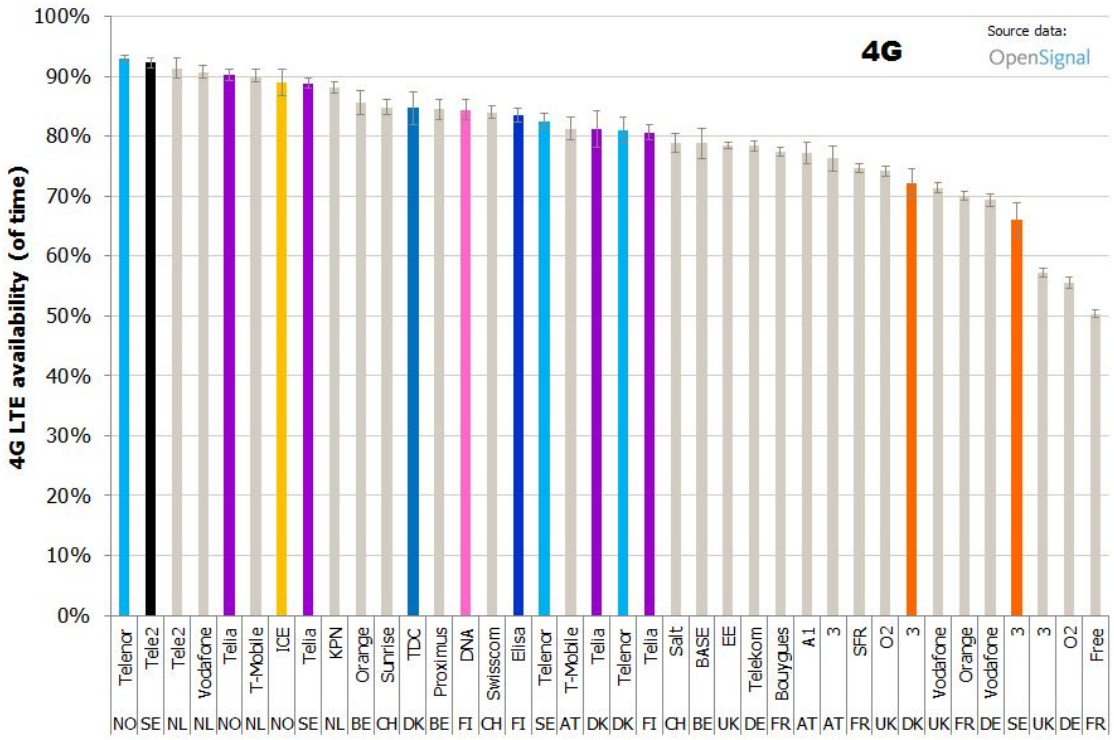
Figure 4-3: Mobile CAPEX in € million in France, 2008-2018



Source: WIK based on Newstreet.

Data from tefficient shows that, as of 2017, availability of 4G in France fell below most other European countries examined such as Scandinavian countries as well as Denmark, Belgium and Switzerland. On the other hand, France ranks similarly to Germany and the United Kingdom, which have certain common features in terms of surface and spread of population (France is the largest country considered in this panel, and its population is more spread out than in Scandinavian countries for instance, making it harder for operators to ensure a high availability of 4G over time, especially when travelling). Interestingly, however, the best 4G availability within France was reported by Bouygues and SFR, partners in the network sharing agreement.

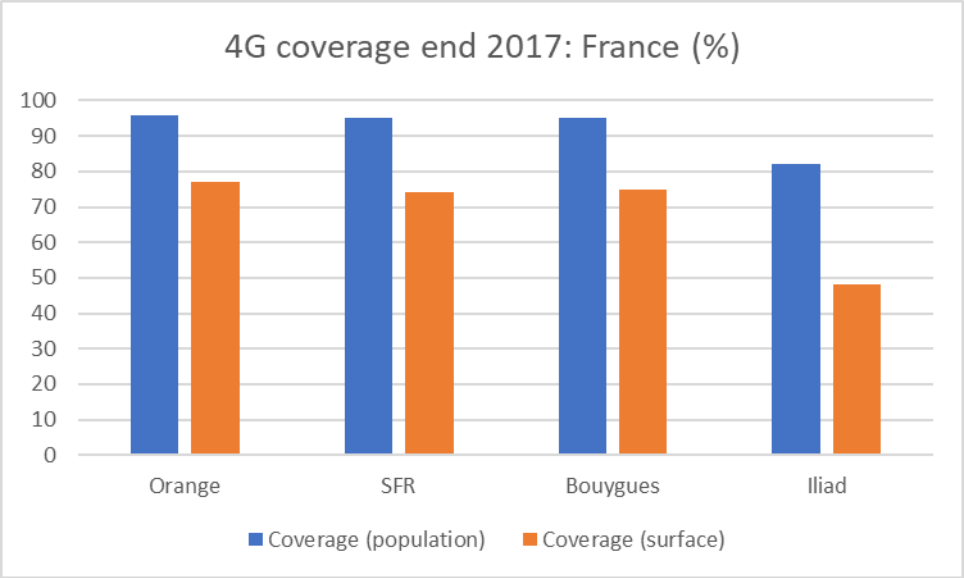
Figure 4-4: 4G availability in the EU



Source: tefficient.

Data on 4G network coverage in France in 2018 (see below) also highlights how network sharing enabled Bouygues and SFR to keep pace with incumbent Orange, while coverage by the fourth operator Iliad, lagged behind.

Figure 4-5: 4G coverage by operator in France



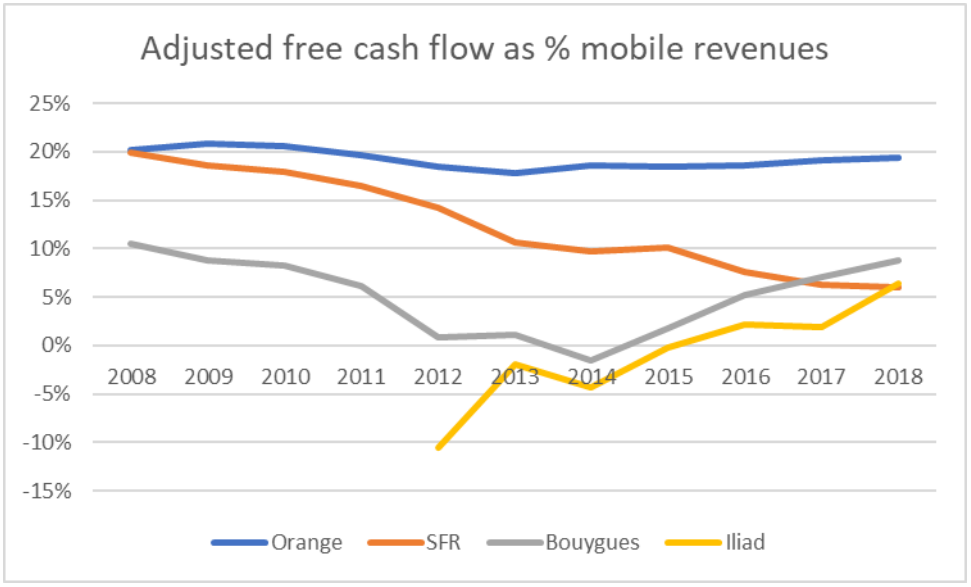
Source: News report based on operator statements[39]

4.1.3.1 Effects on profitability

Data on cash flows as a proportion of revenues (a measure of cash from operations less capital expenditures), shows that the performance of the two smaller MNOs, SFR and Bouygues, was in decline even prior to the disruptive entry of Iliad in 2012. Further declines followed Iliad's entry. It is notable that the performance of Bouygues against this measure improved from 2014 onwards. However, that of its network sharing partner, SFR, continued to decline.

39 https://www.thelocal.fr/20180416/which-is-the-best-phone-and-internet-operator-in-france

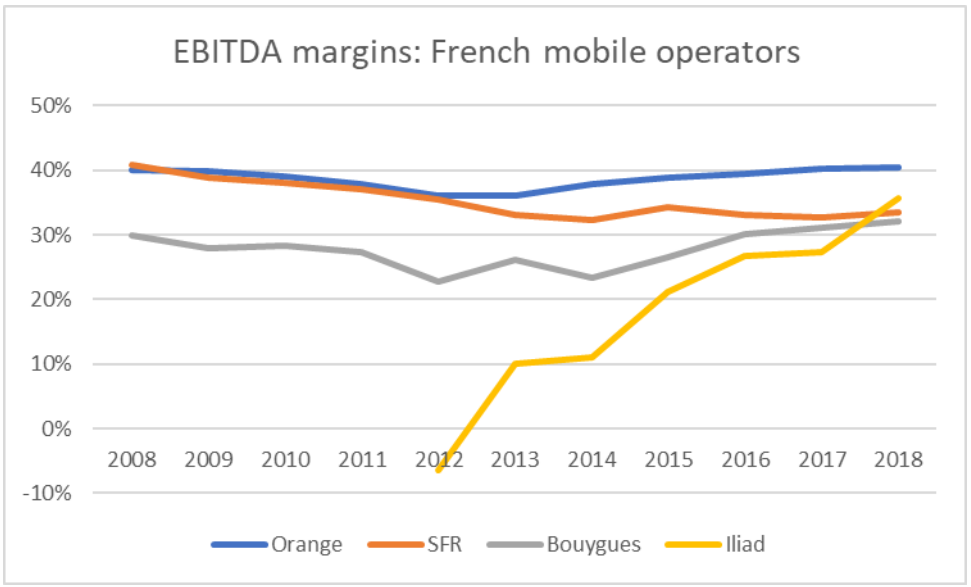
Figure 4-6: Adjusted free cash flow % of mobile revenues, 2008-2018



Source: WIK based on Newstreet.

Data on EBITDA margins provides a similar picture of improved fortunes for Bouygues from 2014 onwards, with SFR stabilising its position at that time.

Figure 4-7: EBITDA margins of mobile operators in France, 2008-2018



Source: WIK based on Newstreet.

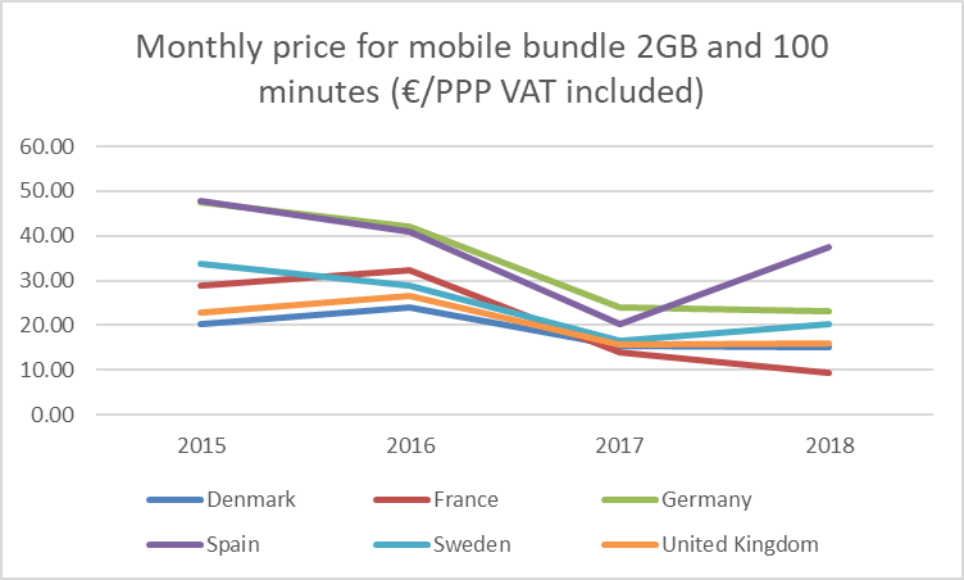
4.1.3.2 Effects on consumer outcomes

Figures available from the European Commission[40] show that take-up of mobile broadband in France is lower than the other countries considered (with the exception of Germany). However, there was relatively high data usage amongst those subscribing to mobile data (2,618MB per month per subscriber)[41] – second only to Sweden in the sample examined. This also represents the largest increase, with mobile data consumption in France increasing 10 fold since 2013. The majority of the increase occurred following deployment of 4G networks in 2014.

The average actual mobile download speed recorded by Ookla in France was 40.3Mbit/s in 2018. This was below the levels recorded in Denmark and Sweden, but significantly above those in Germany and the UK. Reported speed increased nearly two-fold since 2014.

By 2018, France had the lowest prices for mobile bundles including 2GB data of the countries examined. Prices relative to the other countries fell between 2016 and 2018, suggesting that the network sharing arrangements, as amended following the ARCEP Guidelines of 2016 do not appear to have had a negative effect on pricing competition.

Figure 4-8: Monthly price for mobile bundle 2GB and 100 minutes (€/PPP VAT included)



Source: WIK based on OECD

40 European Commission Digital Agenda Scoreboard

41 WIK-Consult based on Cisco, VNI widget forecast

4.2 Spain

4.2.1 Mobile operators, entry and consolidation

Spain is one of the most developed mobile markets in Europe with a Smartphone density of 92% (2017).[42] The four large network operators: Telefonica, Vodafone, Orange and MásMovil (Yoigo) are sharing the market with increasingly important MVNOs (Mobile Virtual Network Operator).

Telefónica distributes its mobile services under its major telecommunications brand *Movistar*, which has been active in Spain since the launch of GSM services back in 1995. Today, Movistar is the largest mobile operator in Spain with about 16 million subscribers, which equals a market share of roughly 30%. It offers GSM/2G service at 900 and 1800 MHz, UMTS/3G at 900 and 2100 MHz and LTE at 800, 1800 and 2600 MHz. In 2017 Telefónica claimed that it reaches 89% of the Spanish population with its 4G network.

Orange España has been operating under this name since 2006. Before 2006, the network was known as “Amena“, which today is the brand name for a low-cost offer of Orange’s portfolio that is only available on the internet. With 13.7 million customers, Orange is the second largest Spanish mobile operator with a market share of about 25.7 %. Orange’s network serves a number of mobile virtual network operators such as MásMovil, Carrefour Móvil and others. Orange has deployed GSM/2G networks at 900 and 1800 MHz, UMTS/3G networks at 900 and 2100 MHz and LTE/4G at 800, 1800 and 2600 MHz. The operator claimed in 2017 that its 4G network reached 93 % of the Spanish population.

Vodafone (España) has been present on the Spanish mobile communications market since the year 2000. At the time the British Vodafone Group acquired Airtel Móviles which had operated in Spain since 1994. Today, Vodafone reports 12.5 million mobile customers, adding up to a market share of about 23.5% and making Vodafone the third largest operator in the country. Vodafone‘s mobile network in Spain offers GSM/2G service at 900 and 1800 MHz, UMTS/3G at 900 and 2100 MHz and LTE at 800, 1800, 2100 and 2600 MHz. In 2017 Vodafone España claimed to offer the best LTE coverage in Spain reaching 94% of the population.

Yoigo (Grupo MásMovil) was the last mobile operator to enter the Spanish market. The company was founded in the year 2000 under the name Xfera. It finally started its operations in 2006 offering only a UMTS/3G network at 2100 MHz. During that time, the Swedish TeliaSonera acquired the majority of shares and introduced the new brand name *Yoigo*. In June 2016, the former MVNO (mobile virtual network operator) MásMovil bought the company. The current customer base of Yoigo is 6.7 million subscribers, which equals a market share of 12.6 per cent. Yoigo operates UMTS/3G at 2100 MHz as well as LTE/4G at 1800 MHz.

42 Deloitte (2017), Global Mobile Consumer Survey, 2017 España.

4.2.2 Network sharing agreements

As with many other countries, Spain has imposed a general passive infrastructure sharing obligation following the transposition of the broadband cost reduction directive.[43]

According to BEREC[44] since 2006 there has also been an active infrastructure sharing agreement between Orange and Vodafone without spectrum sharing. The sharing and joint deployment agreement is limited to rural areas with less than 25.000 inhabitants. This is an agreement without a formal joint venture, where each MNO (Orange and Vodafone) roams onto its partner's network in rural areas.

Yoigo (MásMovil) had entered into a national roaming agreement for 2G and 3G with Telefónica until 2016. In 2013, Yoigo and MasMovil reached further agreements including an arrangement for MasMovil to access Yoigo's 4G network, which was due to reach 48% of the population by the end of 2013.[45] The arrangement enabled Telefonica to launch 4G services, which was not otherwise possible due to limitations in accessing suitable frequencies.[46] The agreement also enabled Yoigo to make use of Telefonica's transport network for the provision of 4G and included the sharing of antennas, which were subsequently sold to Abertis. However, in a decision reached in 2015, the CNMC fined the two companies on the basis that the roaming agreements between MasMovil and Telefonica had anti-competitive effect.[47] In relation to the 4G roaming agreement, CNMC noted that this "restricts competition by limiting the coverage quality independence between the operators" and represented a reduction in competitive pressure in relation to the use of 4G networks.

After the takeover by Grupo MásMovil, the deal with Telefónica was cancelled and since January 2017 Yoigo migrated to using Orange Espana's 2G and 3G network in those areas where it does not have its own infrastructure.[48]

Compared to the other countries considered in this study, the network sharing agreements in Spain are comparatively limited, and have not been considered to raise any significant issues regarding investment or competition.

4.2.3 Market structure trends

With around 56 million subscribers Spain is one of the largest mobile network markets in Europe. As previously mentioned, Telefónica's Movistar has the most subscribers, while Vodafone and Orange are constantly competing for the second rank. With the takeover of Yoigo by Grupo MásMovil the fourth operator has been able to steadily expand its

43 Broadband Cost Reduction Directive – Directive 2014/61/EU of the European Parliament and of the Council of 15 may 2014 on measures to reduce the cost of deploying high-speed electronic communications networks http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0061&from=pl.

44 BEREC (2018), Report on infrastructure sharing BoR (18)116.

45 https://www.teliacompany.com/en/news/press-releases/2013/8/teliasoneras-subsidiary-yoigo-and-telefonicas-movistar-in-network-sharing-agreement-to-provide-better-services-to-more-customers/ Yoigo took advabtage of its 1,800MHz band licence acquired in 2011 to launch 4G services.

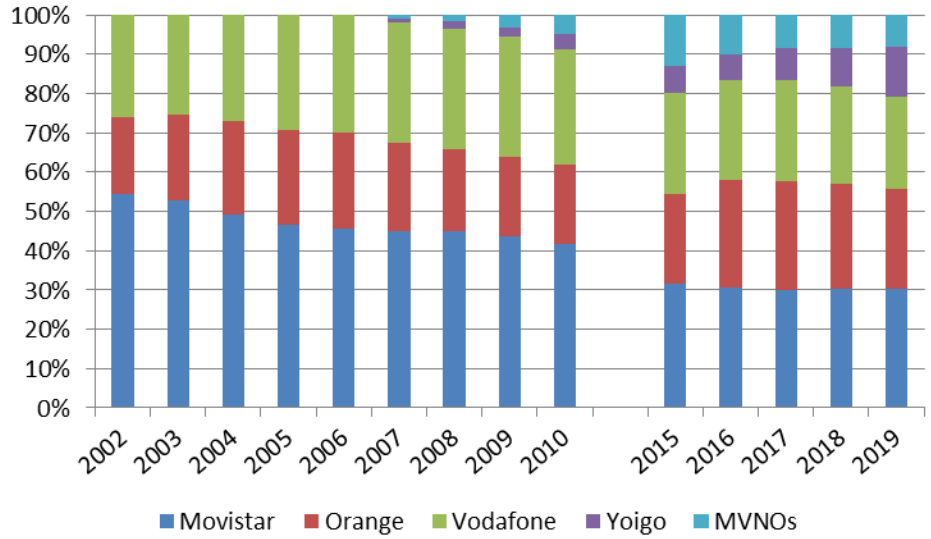
46 http://www.rtve.es/noticias/20130801/movistar-usara-red-servicios-telefonia-4g-yoigo/728842.shtml.

47 https://www.telegeography.com/products/commsupdate/articles/2015/07/22/cnmc-fines-telefonica-espana-and-yoigo-over-roaming-agreements/.

48 https://www.telegeography.com/products/commsupdate/articles/2016/12/15/masmovil-strikes-deal-with-telefonica-relating-to-yoigo-pepephone/, https://www.cnmc.es/sites/default/files/671207_9.pdf.

number of subscribers. The following figure illustrates the current market shares, also showing that MVNOs play an important role in Spain with a 8% market share.

Figure 4-9: Market shares based on subscribers in Spanish mobile market, 2005-2010 and 2015-2019



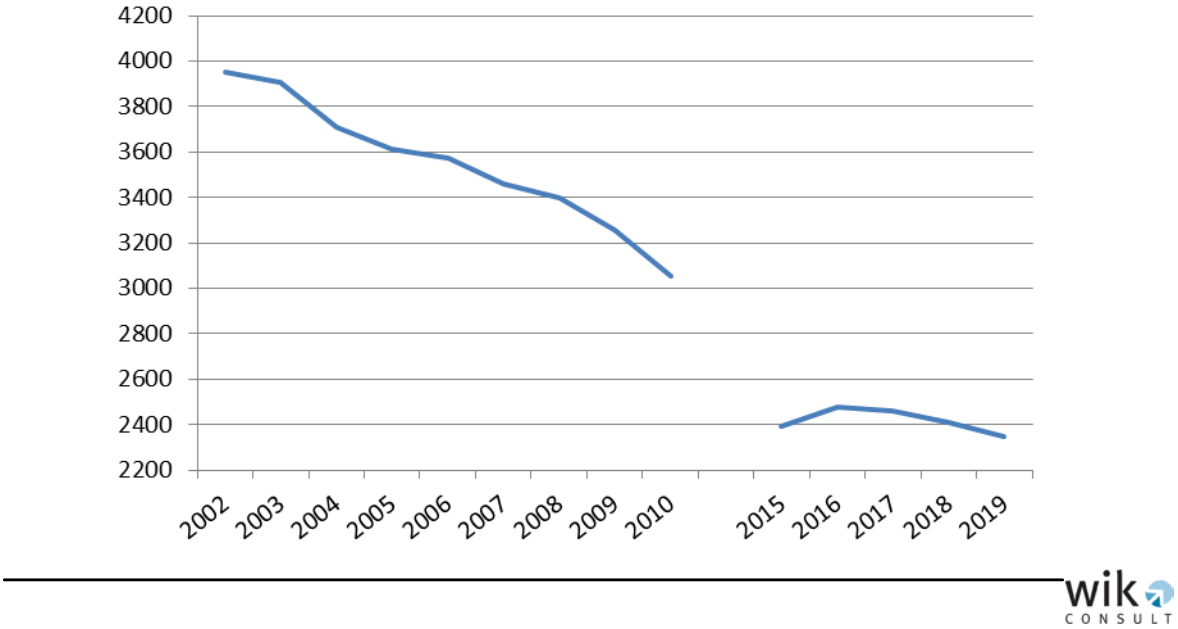
Source: WIK based on CNMC.[49]

With the entry of mobile operator Yoigo in 2006 the number of mobile network operators in Spain increased from 3 to 4. Competition since then has become more intense as seen in Figure 4-9. Yoigo has been able to gain market share, especially at the expense of Telefónica.

With increasing market shares of the fourth supplier Yoigo and the MVNOs, the HHI has continuously decreased. From just under 3.950 with three suppliers in 2002 to under 2.345 in January 2019.

49 https://www.cnmc.es/sites/default/files/1554515_7.pdf and current statistics http://data.cnmc.es/datagraph/jsp/inf_men.jsp.

Figure 4-10: Herfindahl-Hirschman-Index (HHI) in Spanish mobile market, 2002-2010 and 2015-2018



Source: WIK based on CNMC.

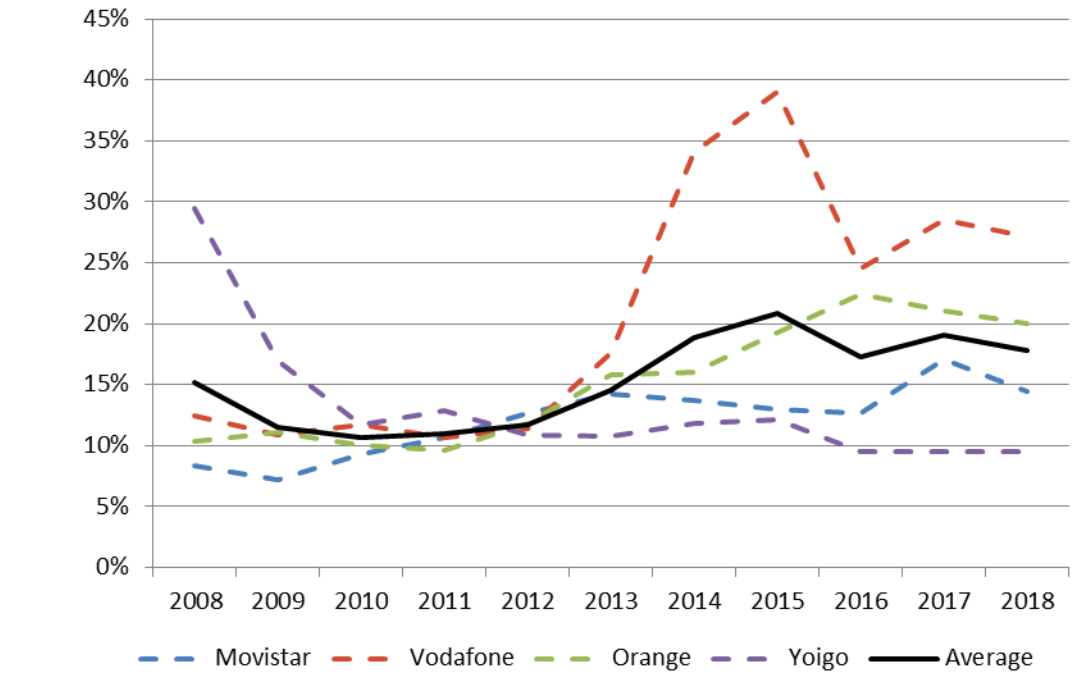
4.2.4 Effects on investment

Following the spectrum auction of 800 MHz for the roll out of LTE in Spain, CAPEX margins of all operators increased. It must be noted that a pre-auction phase ensured spectrum for the fourth player, Yoigo, leaving only three bidders for the three 800 MHz licenses in the main auction. Vodafone's comparatively high investments in the period until 2016 are also likely to be related to the merger of Vodafone and the broadband TV provider ONO in 2014.

Another possible reason for the difference in capex in the period following 2013 between Movistar and Yoigo on the one hand and Orange and Vodafone on the other, may have been the 4G network sharing arrangement agreed between Movistar and Yoigo in 2013. Increases in Movistar's capex ratio can be seen in 2016 following the termination of the sharing agreement after it was found by the regulator to be anti-competitive. In 2016 Telefónica expanded its 4G coverage to approximately 95% of the population. Telefonica noted that 5,000 cell sites were connected to the 800MHz band to cover 3,596 Spanish municipalities and a further 2,500 cell sites were to be added by the end of 2016.[50]

50 https://www.telegeography.com/products/commsupdate/articles/2016/06/13/telefonica-vodafone-spain-expand-4g-coverage/.

Figure 4-11: CAPEX/revenue ratios of MNOs in Spanish mobile market, 2008-2018



Source: WIK based on NewStreet.

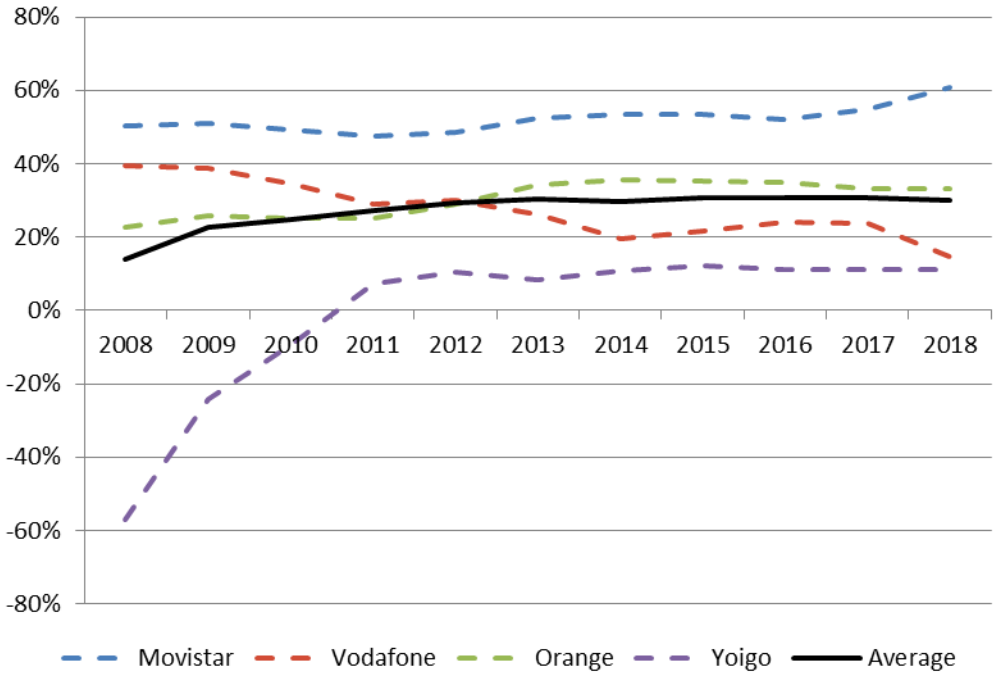
Spectrum suitable for 5G was auctioned in 2019. Telefonica, Orange Spain and Vodafone Spain participated for the country's auction of 200 MHz in 5G-suitable frequencies. Vodafone Spain won the largest allocation on offer, securing 90 MHz in the 3.7GHz band for €198 million. Telefonica paid €107 million for 50 MHz across the 3.5GHz-3.8GHz bands, while Orange Spain paid around €132 million for 60 MHz also across the frequency range offered.[51] Yoigo competed in the auction but did not add any further 5G-suitable spectrum to the 80 MHz it obtained earlier this year from two separate deals. It remains to be seen to what extent this will have an impact on investments.

4.2.5 Effects on profitability

As far as EBITDA margins are concerned, these are in line with the operators' market shares in Spain. Movistar achieved the highest profitability over the entire period under review, while Orange replaced Vodafone as the second most profitable provider in 2012. This may be related to the investment costs associated with the acquisition of ONO by Vodafone. Yoigo has been generating profitable margins after a negative trend since 2011.

51 https://www.mobileworldlive.com/featured-content/home-banner/operators-spend-e438m-in-spain-5g-spectrum-auction/.

Figure 4-12: EBITDA / revenue margins of MNOs in Spanish mobile market, 2008-2018

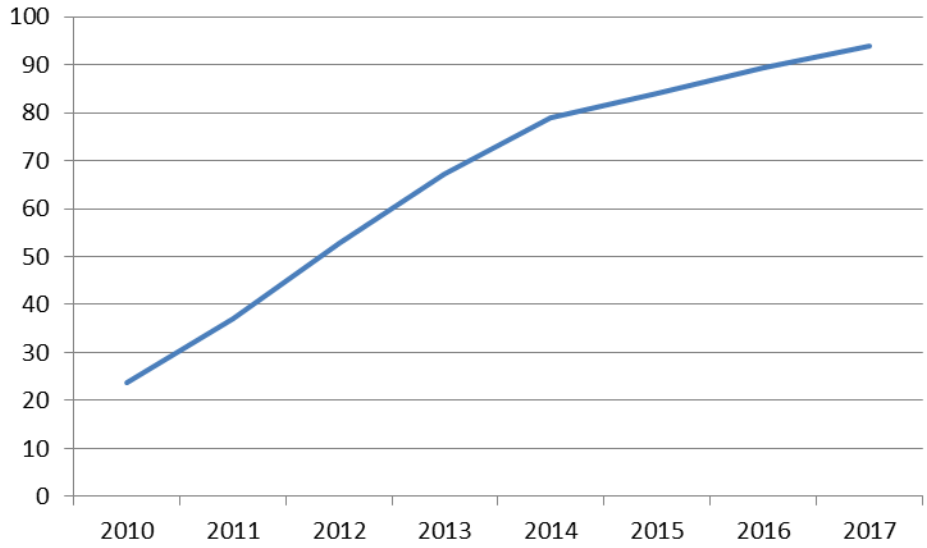


Source: WIK based on Newstreet.

4.2.6 Effects on consumer outcomes

Mobile data usage become very important in Spain over the past years. Figure 4-13 shows that the share of mobile broadband users among all mobile users has increased from 23% in 2010 to 94% in 2017.

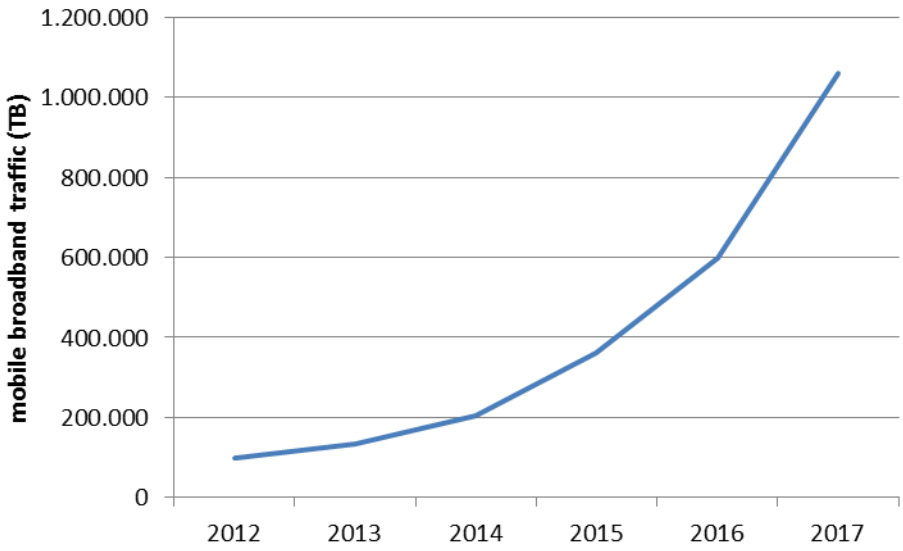
Figure 4-13: Share of mobile broadband users in Spain, 2010-2017



Source: CNMC.

Together with the increased number of mobile data users the traffic of mobile data has increased exponentially as Figure 4-14 shows.

Figure 4-14: Mobile broadband traffic development in Spain, 2012-2017



Source: CNMC.

Overall there has been a tendency of including more data into the mobile service packages and reducing prices as the following figure shows. In recent years special rates have emerged as the "Sinfin" of Yoigo (32 €/month for 30 GB data and unlimited calls[52]), focused on users very demanding with data rates. Although prices offered by the three operators listed in the table below appear similar, especially in later years, the content of the offers differs.

Table 4-1: Mobile combinations of minutes, data and prices between 2010 and 2016 in Spain

MOVISTAR	Minutes	Data	Price (per month)	VODAFONE	Minutes	Data	Price (per month)	ORANGE	Minutes	Data	Price (per month)
2010	0	1 GB	29,50 €	2010	350	100 MB	29,38 €	2010	300	100 MB	23,60 €
2011	0	2 GB	29,50 €	2011	150	100 MB	23,60 €	2011	200	200 MB	23,60 €
2012	0	1 GB	24,20 €	2012	150	100 MB	24,20 €	2012	100	1 GB	26,20 €
2013	250	1 GB	20,00 €	2013	200	600 MB	18,00 €	2013	150	1 GB	19,40 €
2014	200	1,1 GB	22,00 €	2014	200	1,1 GB	22,00 €	2014	150	1 GB	19,95 €
2015	200	1,5 GB	25,00 €	2015	200	1,5 GB	25,00 €	2015	150	6 GB	25,25 €
2016	0	2 GB	15,00 €	2016	0	1,5 GB	14,00 €	2016	0	1GB + (zerorating)	11,95 €

Source: https://elandroidelibre.elespanol.com/2017/02/evolucion-tarifas-datos.html

4.3 Germany

4.3.1 Mobile operators, entry and consolidation

Until 2014, there were four operators present in the German mobile market. Telekom and Vodafone (named Mannesmann Mobilfunk formerly) were the first entrants into the market. E-Plus and Telefónica (formerly known as Viag Interkom) followed in 1994 and 1998 respectively. Both operators were assigned spectrum in the 1800 MHz band, whereas Telekom and Vodafone operated their networks with 900 MHz frequencies. Those frequencies are commonly used by mobile operators to cover large areas because of the propagation characteristics. Usually 1800 MHz frequencies are used to provide additional capacity.

Since 2014 threre are only three mobile network operators active in Germany: Telekom Deutschland, Vodafone and Telefonica. E-Plus which used to be considered as the “maverick” in the German market was bought by Telefónica in 2014. Germany is thus an important example of a wave of consolidation that occurred in certain mobile markiets (also including Austria and Ireland) around that period.

Although there are only three network operators present in Germany, as a condition to obtain approval for the merger, Telefónica commited to enter into capacity-based wholesale agreements with up to three Upfront Mobile Bitstream Access MVNOs. These agreements foresee that the MVNO(s) can purchase against an upfront payment up to 30 % of the total capacity of the merged company’s network for up to 10 years after the completion of the proposed transaction.

52 https://www.yoigo.com/tarifas-moviles/internet-movil-ilimitado.

Furthermore, Telefónica commited to concluding an agreement with a new MNO entrant or with the upfront MVNO, to facilitate the entry of a new fourth MNO into the German market. Specifically, Telefónica commited to make the following offers: (a) a spectrum offer consisting of the lease of spectrum in the 2.1GHz band and 2.6GHz band; (b) a national roaming offer; (c) a divestiture of sites offer; (d) a passive radio network sharing offer; and (e) a sale of shops offer.

In January 2019, the German service provider 1&1 Drillisch, which acquired MVNO access rights on Telefonica's network in the context of the merger, announced that it planned to acquire spectrum in 2 GHz and 3.5 GHz to become the fourth mobile operator in Gemany.[53] 1&1 Drillisch successfully applied for the ongoing spectrum auction which is currently taking place in Mainz.

4.3.2 Network sharing, roaming and access

Network sharing has played a limited role in the German mobile market. Telekom and Vodafone favour infrastructure competition models for mobile deployment. Among the mobile operators who entered the market later, only Telefónica sought infrastructure sharing. Telefónica and Telekom concluded a national roaming agreement thourgh which Telefónica's customers were allowed to roam onto Telekom's network in unserverd areas. The agreement was terminated in 2009. No other form of active infrastructure sharing has been present in the German market. After the UMTS auction in 2000, E-Plus and Quam, one of the two new entrants of the year 2000, struck a deal to share infrastructure. However, before the contract led to any operational activities in terms of a shared deployment, Quam left the market. Since then, German operators have focused on passive infrastructure sharing, but not engaged in other forms of sharing, aside from the Telefonica roaming agreement previously described.

From the very beginning German mobile operators were obliged to co-operate with service providers. In addition, E-Plus was keen to offer access to its network for MVNOs operating a core network. The role played by MVNOs expanded following the MVNO access commitments made by Telefonica in the context of its merger with E-Plus.

4.3.3 Regulatory framework of infrastructure sharing in Germany

In a "thesis paper"[54] published in 2001 addressing possible shared use of wireless infrastructures based on the 3G standard, the Bundesnetzagentur set out the conditions under which sharing would not raise concerns. The Authority stressed that the new sharing solutions developed by the manufacturers guarantee both the functional integrity of the networks and the competitive independence of the licensees.

Prior to this basic positioning, the thesis paper set out six principles or guidelines for network sharing:

53 https://www.telegeography.com/products/commsupdate/articles/2019/01/25/11-drillisch-confirms-plans-to-participate-in-5g-auction/.

54 Regulierungsbehörde für Telekommunikation und Post: Thesenpapier Infrastruktur-Sharing, Auslegung der UMTS-Vergabebedingungen im Hinblick auf neuere technische Entwicklungen, Bonn 5. Juni 2001.

(1) The shared use of passive infrastructure (e.g.land, masts, antennas, cables and combiners) is permitted.

(2) The sharing of Site Support Cabinets (SSCs), i.e. several No-de Bs in one SSC, is permitted.

(3) It is possible to use logically separated Node B in one and the same unit instead of physically separated Node B, provided that functional control and competitive independence are guaranteed.

(4) The use of logically separated RNCs in one and the same unit is permitted under similar conditions as under (3).

(5) Shared use of the core network (in particular of MSCs) is not permitted. This leads to frequency pooling.

(6) Transitional arrangements for the joint use of MSCs are not permitted.

The further liberalisation of the possibilities of network sharing was then further specified in a key issues paper published in 2010[55], which further developed the 2001 thesis paper. The key issues paper first lists the permitted forms of shared use of network elements. These are

- Site sharing,
- Site Support Cabinet Sharing,
- RAN sharing (subject to certain conditions).

The generally permissible forms of network sharing are the same as those already defined for UMTS in the 2001 thesis paper.

These forms of network sharing are permissible without further regulatory prior approval if the defined framework conditions are considered. However, competitive independence could not be restricted and infrastructure competition had to continue to be guaranteed. The competition authority could still examine individual cases on a case-by-case basis.

In principle, sharing without authorisation is limited to passive sharing. Nonetheless, the BNetzA opened up the possibility of further shared use on a case-by-case basis. This includes the sharing of frequencies. In the opinion of the BNetzA, however, this affects the principle of competitive independence of network operators. In this respect, the effects on competitive independence should be examined in each individual case before the admissibility of the sharing model could be confirmed. The BNetzA indicated that it is in favour of sharing frequencies to close broadband coverage gaps. This would make it possible to achieve the highest possible transmission rates. The competitive effects were estimated to be limited due to the time and geographical limitations of such frequency pooling.

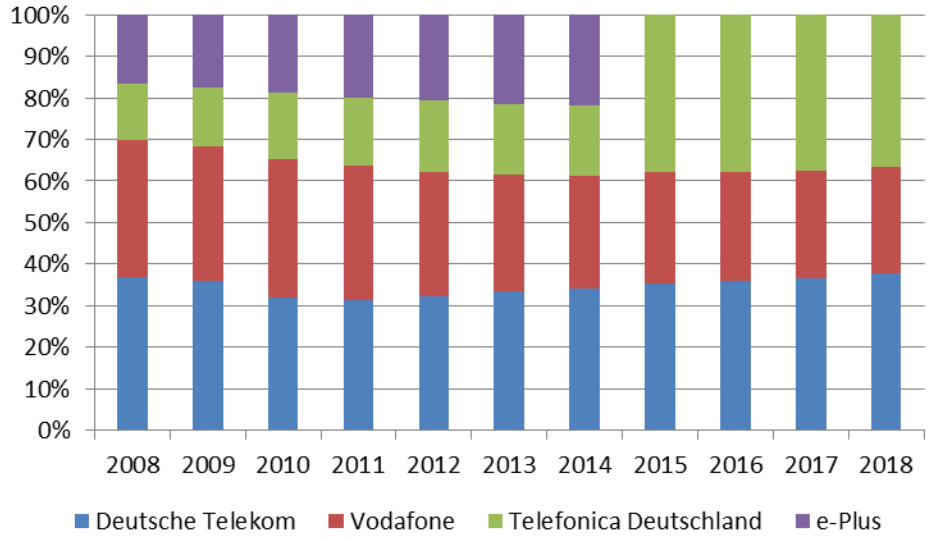
55 https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/InfrastructureSharing/InfrastructureSharingThesispaperpdf.pdf;jsessionid=26D9C2D46260A12203C6C3F0A2D6C993?__blob=publicationFile&v=2.

Although the wording of the coverage requirement and the envisaged flexibility to allow new forms of network sharing might have facilitated active sharing, this did not happen because mobile operators see more disadvantages than advantages in active infrastructure sharing. The operators pursued completely different strategies for the use of the acquired 800 MHz frequencies. For instance, after the assignment of 800 MHz frequencies in 2010. Vodafone saw a relevant business opportunity and competitive differentiation in a rapid network build-up. Telefónica was initially not interested at all in the use of the 800 MHz frequencies.. T-Mobile followed Vodafone with a lower intensity in network expansion. The two companies had different geographic expansion priorities, but did not rule out overlapping coverage.[56] Despite the (in principle generous) offer of BNetzA for network sharing, this offer was not accepted in the market.

4.3.4 Market structure trends

Pre-merger competition was largely driven by the asymmetric market shares of the four operators, where notably E-Plus played the role of a maverick and where Telefónica also launched innovative and aggressive offers. Both Telefónica and E-Plus played an important competitive role in terms of pricing as well as in terms of the innovative nature of offers. The Commission had concerns that after the merger the three remaining companies would have less incentive to compete. Indeed, as a result of the merger, market shares of the three remaining players have become more symmetrical, with Telefónica becoming the market leader (Figure 4-15).

Figure 4-15: Market shares based on subscribers in German mobile market, 2008-2018



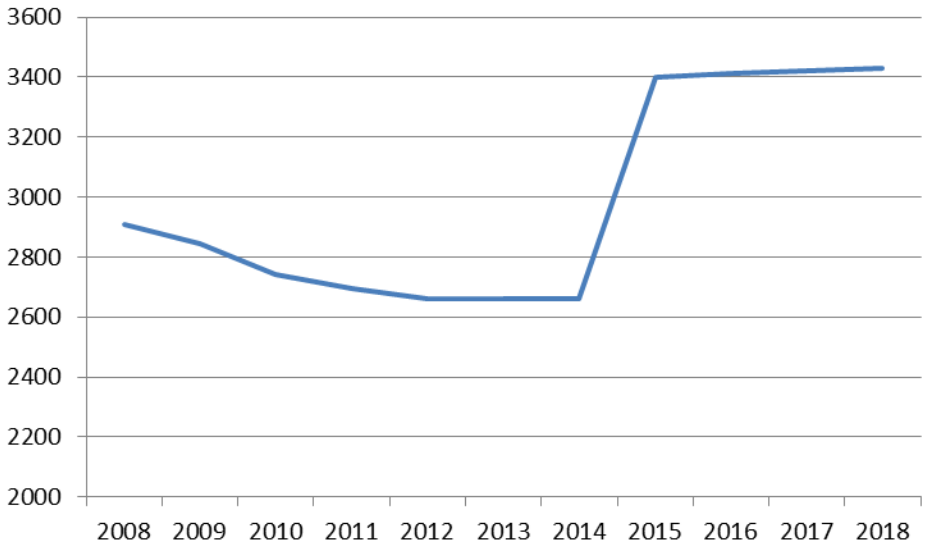
Source: WIK based on Newstreet.

56 WIK (2015).

Doubts about the merger between Telefónica and E-Plus were raised amongst other things because the commitment to divest spectrum to a new entrant was not relevant, because no such entrant materialized in the May 2015 spectrum auction. With the ongoing 5G auction (ongoing since Mid March 2019) Drillisch is now bidding for spectrum, but it not yet clear whether there will be a fourth MNO in the near future. The terms of Drillisch's MVNO agreement in which it paid up front for capacity,[57] were designed to provide incentives for it to compete for new customers to fill up the capacity acquired. However, as it relies on the capabilities of its host, there is limited potential to differentiate the quality of its service offering.

Before the merger occurred, the German mobile market was characterized by a long-term trend of a declining HHI, as Figure 4-16 shows. The merger between E-Plus and Telefónica reversed this trend and led to an increase of the HHI almost 800 points (from 2662 to 3400) on the basis of 2014 market shares.

Figure 4-16: Herfindahl-Hirschman-Index (HHI) in German mobile market, 2008-2018

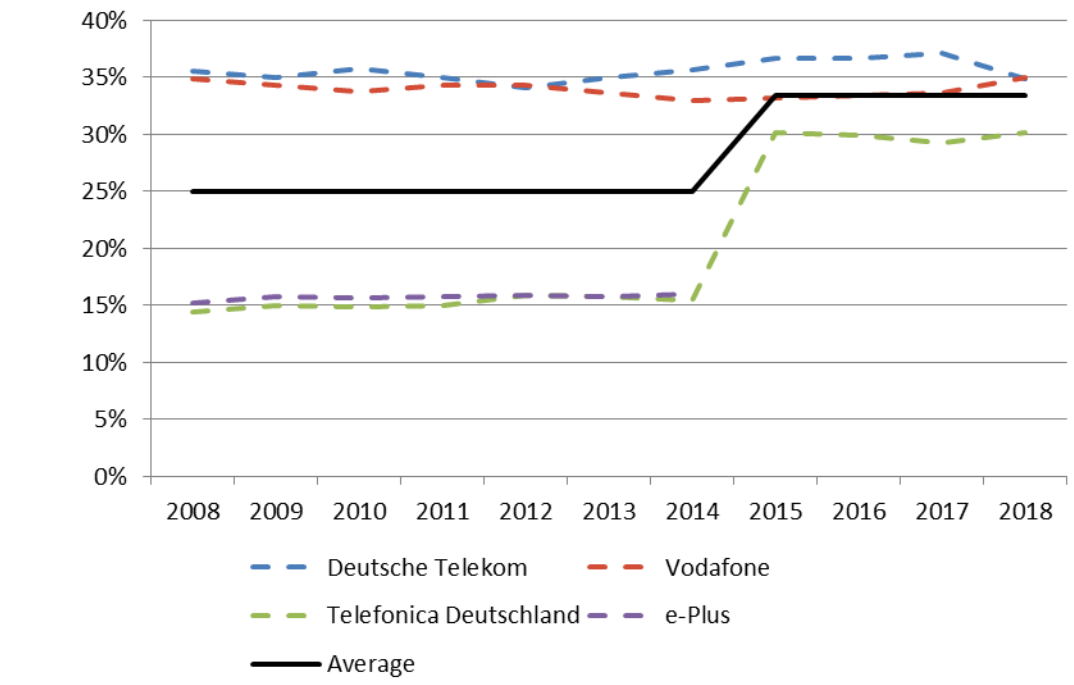


Source: WIK based on New Street.

Overall customer numbers are rising and the demand for higher-quality tariffs is growing - these developments naturally support the providers' mobile service revenues. Regulatory effects such as the reduction of termination charges and the new roaming regulations have put these sources of revenue under pressure since 2016. However, the revenues of the three players have been stable, and even in some cases increased slightly since the merger in 2014.

57 In the past Drillish acquired capacities of Telefónica as a consequence of commitments of the 2014 merger. Upgrades of Telefónica's network and service qualities are also made available to Drillisch. In contrast to a standard MVNO agreement which is usage based, the agreement with Drillisch is capacity based and requires an upfront payment with no ongoing usage payments.

Figure 4-17: Revenue development of operators in Germany, 2008-2018

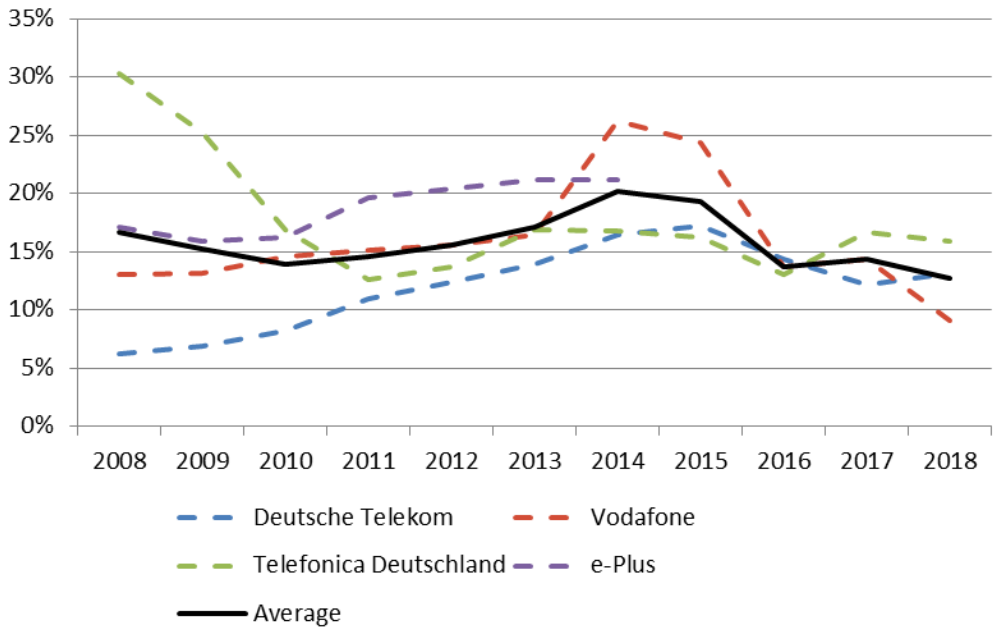


Source: WIK based on Newstreet.

4.3.5 Effects on investment

The CAPEX figures in Figure 4-18 predominantly show the impact of the 2010 multiband spectrum auction. After 2010 (in Telefónica's case 2011), CAPEX/revenue ratios increased as all operators started to invest into the roll-out of 4G networks and make use of the acquired spectrum. In case of operators that acquired 800 MHz spectrum (T-Mobile, Vodafone, Telefónica), obligations to cover areas that previously had no broadband coverage at all played an important role. No increase of investments can be observed after the latest spectrum auction of 700 MHz, 900 MHz and 1500 MHz in 2015. One reason for that is that the migration period for broadcasters to free up 700 MHz spectrum ended in 2019. 900 MHz is used for GSM and nowadays for NB-IoT, hence made no additional investment necessary. Only Telefonica's CAPEX/revenue had a slight increase after 2015, which may reflect a subsequent effect of the merger and the need to integrate the two networks and improve network coverage.

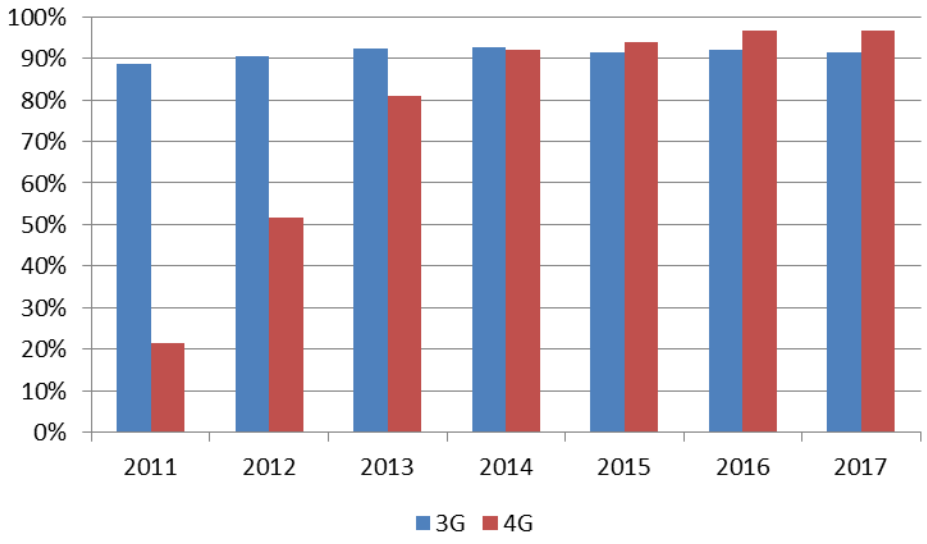
Figure 4-18: CAPEX / revenue ratios of MNOs in German mobile market, 2008-2018



Source: WIK based on NewStreet.

Figure 4-19 shows the overall 4G mobile coverage development confirming that network deployment occurred and therefore capex increased after the 800 MHz auction in 2010.

Figure 4-19: 3G and 4G Mobile Coverage Development, 2011-2017



Source: European Commission, Digital Scoreboard.

Looking at 4G deployments at the level of individual operators, during the first two years Vodafone set the pace. However, today Deutsche Telekom is the operator with the largest LTE coverage of approximately 98 percent (Nov. 2018). Vodafone currently reaches around 90 percent of German citizens (~ 72 million) with LTE. And Telefónica, after initially falling back in terms of expansion, is catching up with around 80% population coverage (see Figure 4-20).

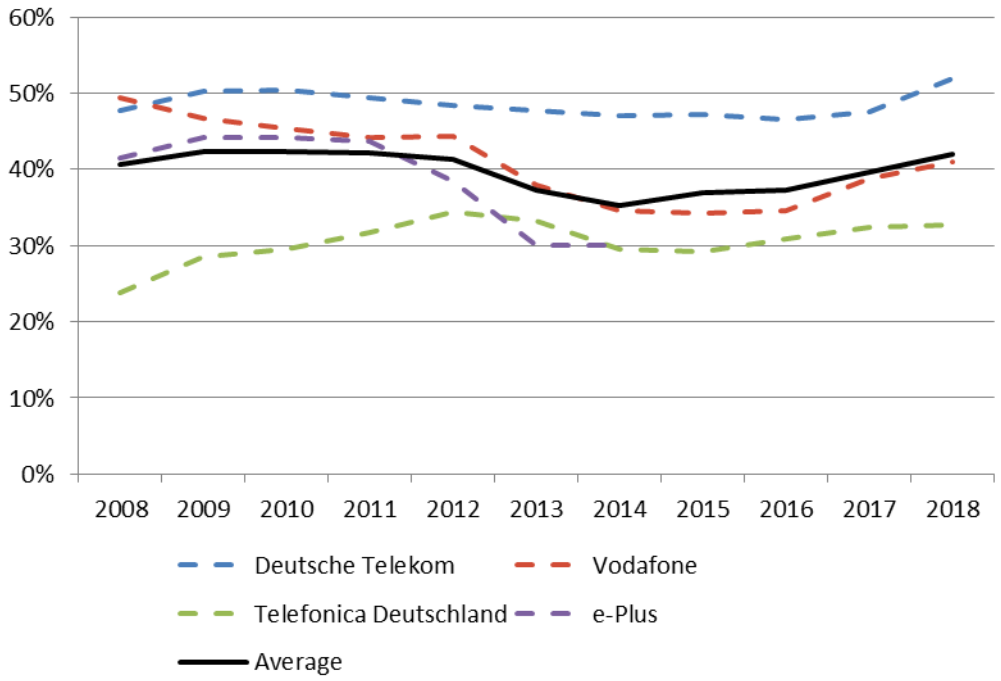
Figure 4-20: Status of LTE rollout by operator in Germany, 2018

Source: https://www.lte-anbieter.info/verfuegbarkeit/lte-verfuegbarkeit-testen.php.

4.3.6 Effects on profitability

Before the merger, EBITDA margins were closely linked to market shares. The market leader Deutsche Telekom had the highest EBITDA/revenue ratio followed by Vodafone, E-Plus and Telefónica. Since 2012 EBITDA margins of the three smallest operators decreased and the profitability differences between Vodafone and Telefónica and Deutsche Telekom increased. However, in the years following the merger in 2014, MNO margins began to recover. (Figure 4-21).

Figure 4-21: EBITDA / revenue margins of MNOs in German mobile market, 2008-2018



Source: WIK based on NewStreet.

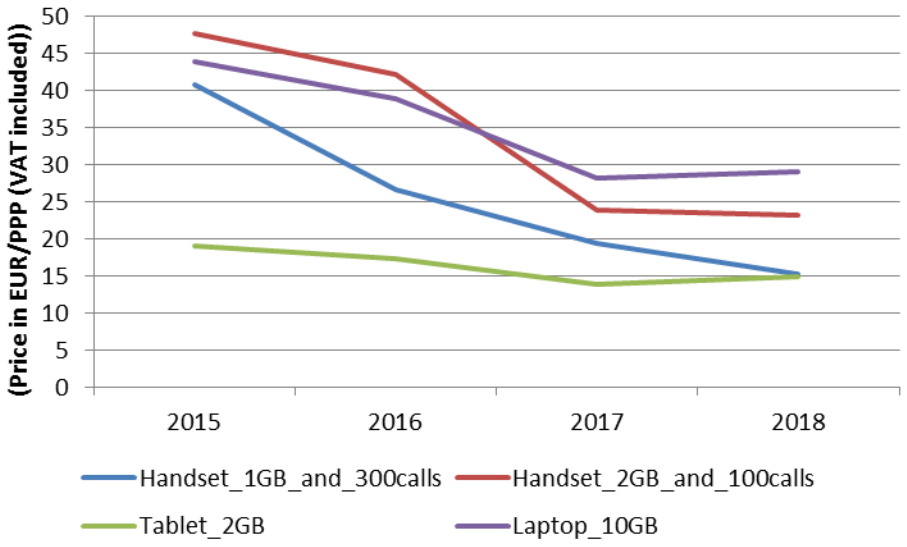
4.3.7 Effects on consumer outcomes

According to current figures from the Federal Statistical Office, prices for wireless telecommunications services are currently (2019) at the same level as at the end of 2017. After initially falling in 2018, they rose by 0.5 points from August last year to January 2019. For the first time since the base year 2015, prices for mobile communications rose again since August last year.[58]

This coincides with data analysis from the European Commission, which are shown in Figure 4-22. Prices have decreased since 2015 until 2017 and since than have remained stable.

58 https://www.handytarife.de/?verbraucherpreise-fuer-mobilfunk-steigen.

Figure 4-22: Price development for different mobile products in Germany, 2015-2018



Source: European Commission.

According to information from the Federal Statistical Office, the price index contains a large number of different prepaid and postpaid customer tariffs of mobile operators. The increase in the wireless telecommunications sector is mainly attributed to increased basic charges for individual tariffs, which were only partially compensated by improved capacity (data volume increases) in their calculation models.

It is noticeable that, after the 2010 spectrum auction, there was no increase in the price index. One reason that operators did not pass on added spectrum costs to consumers is likely to be the competitive environment with four market players.

4.4 Sweden[59]

4.4.1 Mobile operators, entry and consolidation

There are four mobile network operators in Sweden: TeliaSonera, Tele2, Telenor and Hi3G.

In the 1970s, Sweden became one of the first countries in the world to introduce a second mobile operator to compete with the incumbent. A third operator joined in the context of the licensing process for GSM.

59 Information in this chapter has been compiled from the OECD (2015) report on Wireless Market Structures and Network sharing, Molleryd and Markendahl (2013) The role of network sharing in transforming the operator business, BEREC (2018) Report on Infrastructure sharing, PTS market data and an interview with PTS conducted in March 2019.

The market expanded to four players in 2000, when 3G licenses were issued. Unusually however, the incumbent Telia, which had a market share of around 50%, was unsuccessful in the 3G auction. Instead, the previously existing MNOs Tele2 and Telenor were joined by Hi3G and Orange, although Orange subsequently withdrew from the market and did not commence deployment.

The following table, drawn from a 2015 OECD report on wireless market structures and network sharing[60] shows the history of the auction process, market entry and agreements by mobile network operators in Sweden.

Table 4-2: Auctions, entry and agreement amongst mobile network operators in Sweden

	TeliaSonera	Tele2	Telenor	Three
History	It was founded by a merger between Telia and Sonera in 2002, both of which were national dominant carriers in Sweden and in Finland respectively.	The company first started fixed telephony in 1993 and merged with a competitive mobile operator Comvik in 1997.	One of the first GSM operators in the country (Europolitan) was aquired by Vodafone and then purchased by Telenor in 2006.	It was established in 2000 by Hong Kong-based Hutchison Whampoa and Swedish Investor AB
Market shares in 2000	51%	32%	17%	-
3G: Spectrum allocations and network developments				
Spectrum licensed in 2001	-	15 MHz in 1920-80 Mhz 15 MHz in 2110-70 MHz 5 MHz in 1900-20 MHz	15 MHz in 1920-80 Mhz 15 MHz in 2110-70 MHz 5 MHz in 1900-20 MHz	15 MHz in 1920-80 Mhz 15 MHz in 2110-70 MHz 5 MHz in 1900-20 MHz
Network sharing JV	**Svenska UMTS AB, 2001**		**3G Infrastructure Services AB, 2001**	
Service launch	Mar 2004	Jun 2004	Feb 2004	May 2003
Coverage in January 2005	86%	86%	84%	84%
Mobile voice and data: Market share in June 2008	43%	32%	18%	6%
MBB: Market share in June 2008	40%	22%	15%	21%
LTE: Potentially available spectrum and network developments				
FDD 2600 MHz, May 2008	40 MHz	40 MHz	40 MHz	20 MHz
TDD 2600 MHz, May 2008	-	-	-	50 MHz (purchased from Intel in Dec 2010)
FDD 800 MHz, Mar 2011	20 MHz	20 MHz		20 MHz
FDD 900 MHz, May 2011	20 MHz	15 MHz	15 MHz	10 MHz
FDD 1800 MHz, Oct 2011	70 MHz	70 MHz		-
Network sharing JV	-	**Net4Mobility, Nov 2011**		-
Service launch	Dec 2009	Nov 2011	Nov 2011	Dec 2011
Time on LTE measured by OpenSignal, Feb 2014	57%	93%	85%	N/A
Mobile voice and data: Market share in June 2013	39%	29%	17%	11%
MBB: market share in June 2013	34%	25%	23%	15%

Source: OECD (2015).

4.4.2 Network sharing agreements

The Swedish mobile telecom market is characterised by three network sharing arrangements, with distinct agreements applying to 3G and 4G technologies.

60 OECD (2015) Wireless market structures and network sharing https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/CISP(2014)2/FINAL&docLanguage=En.

Figure 4-23: Mobile network sharing agreements in Sweden

Source: Molleryd and Markendahl (2013).

4.4.2.1 TeliaSonera and Tele2

Following Telia's failure to secure 3G spectrum, the company merged with Sonera to form TeliaSonera, a deal which was finalised in 2002. In 2001, Telia also concluded a joint venture with Tele2 (Sunab), which enabled Tele2 to take advantage of Telia's network assets to deploy 3G, while enabling TeliaSonera to provide a 3G service without a spectrum licence. Under this agreement, the Radio Access Network including spectrum and backhaul were shared in addition to passive infrastructures, but the operators maintained their own core networks.TeliaSonera and Tele2 launched 3G-based services in March and June 2004 respectively.

4.4.2.2 Vodafone (now Telenor) and Hi3G

Around the same time, the other winners of the 3G spectrum licences formed a JV (3G Infrastructure Services), to facilitate their deployment. Shared components included passive infrastructure including masts and sites, as well as active elements such as backhaul. Some spectrum resources were also shared. Under the terms of approval for the JV, licence holders were required to cover 30% of the population with their own network, while the reminaing 70% (mainly smaller cities and rural areas) could be served by 3GIS.

4.4.2.3 Tele2/Telenor: Net4Mobility

In the context of 4G deployment, in 2011 Tele2 and Telenor formed a joint venture entitled "Net4mobility". Under this venture, the two competing operators jointly acquired 4G spectrum and contributed existing licenses in the 900MHz, 1800MHz and 2600MHz

bands. The agreement also included RAN sharing, but the operators mained separate core networks.This JV thus covered both 2G and 4G technologies, but not 3G, which was subject to the previous agreement between Tele2 and Telia. The JV made significant use of municipal wholesale only passive fibre networks for backhaul, further enabling them to accelerate their 4G deployment.

When PTS approved the transfer of 900 MHz and 2600 MHz from Tele2 and Telenor to N4M, a complaint was filed under Article 101 TFEU and its national equivalent. The main argument was that a high concentration of spectrum would give Telenor and Tele2 the possibility to offer more advanced services (higher speed), and therefore a competitive advantage over other mobile operators. However, the Swedish Competition Authority did not uphold this complaint.[61]

4.4.2.4 Response by the Competition authority

The presence of the two JVs for network deployment means that in practice, for a significant portion (although not all) of the territory, there were two mobile networks in operation in Sweden for 3G services, supporting three spectrum licence holders (and four network-based mobile service providers) at the retail level. The Competition Authority granted Tele2 and Telia an exemption from the prohibition against anti-competitive co-operation, but only after changes were made to the provisions around investment decisions and the distribution of network capacity to ensure that the two players would maintain a degree of autonomy around investment decisions.[62] The agreement amongst the other mobile operators in relation to 3G was cleared.

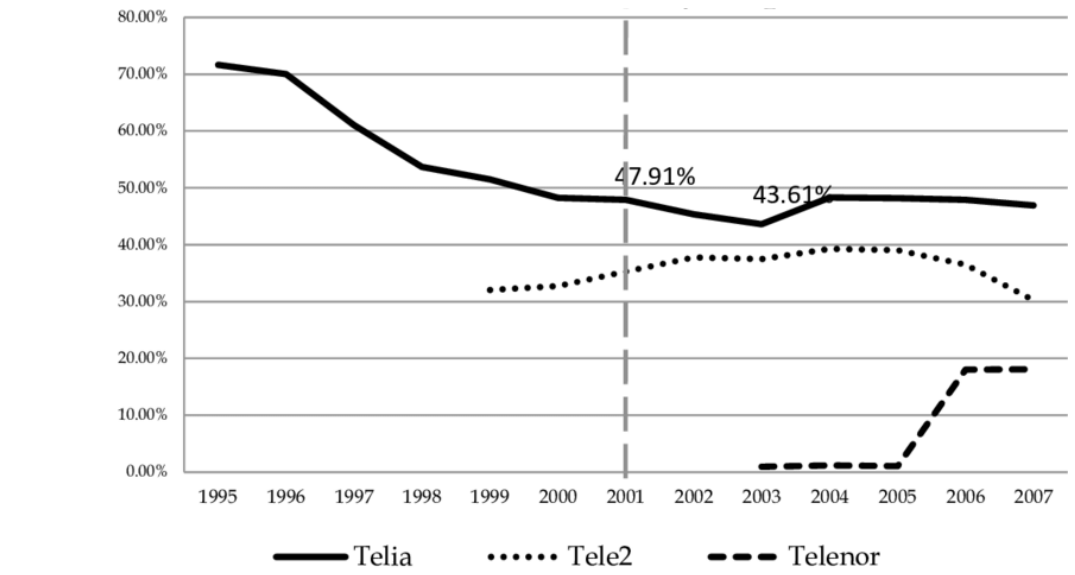
The Swedish competition authority also investigated the 2011 joint venture between between Tele2 and Telenor, leading to the creation of Net4mobility. The Authority approved the arrangement, noting that the joint venture concerned a relatively small share of each operator's total costs for the supply of mobile phone and broadband services, and that rapid technological developments would make it difficult for companies to sustain anti-competitive collaboration.[63] It should also be noted that conclusions on the implications for competition also reflected the entry of a new player Three, that was expected to provide a disruptive effect in mobile broadband services supported by 4G.

4.4.3 Market structure trends

The following figure shows how Swedish mobile market evolved in the period of 2G and 3G deployment. The market share of incumbent Telia, continued to decline in the period immediately following the 2001 3G auction in which it failed to secure spectrum. However, a noticeable increase in market share can be seen from 2003 onwards following the conclusion of the joint venture agreement with Tele2 that enabled Telia to offer 3G-based services.

61 BEREC (2018) report on infrastructure sharing https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8164-berec-report-on-infrastructure-sharing.
62 http://www.konkurrensverket.se/globalassets/english/publications-and-decisions/competition-in-sweden-2004.pdf.
63 http://www.konkurrensverket.se/beslut/09-0374.pdf.

Figure 4-24: Market share of the leading three Swedish mobile operators 1995-2007

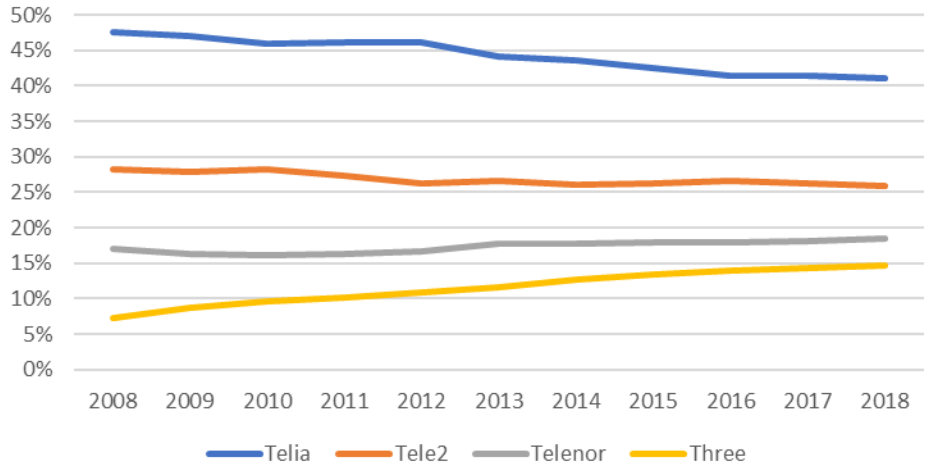


Source: Mobile Number Portability, evaluating the Swedish mobile market.[64]

The further progression of retail market shares from 2008 onwards is shown in the following figure. It shows that the market share of incumbent Telia has been in gradual decline, while there has been significant growth in the market share of the new entrant Three. The market shares of Tele2 and Telenor, have remained roughly stable since the creation of the joint venture in 2011.

64 https://www.researchgate.net/publication/252823439_Mobile_Number_Portability_Evaluating_the_Swedish_Mobile_Market.

Figure 4-25: Market share of Swedish mobile operators, 2008-2018



Source: WIK-Consult based on Newstreet.

MVNOs play a limited role in the Swedish market. As of H1 2018, PTS reports that there were 46 MVNOs in the market. MVNO agreements have been made with all MNOs, but the total retail market share for MVNOs was less than 5%.[65]

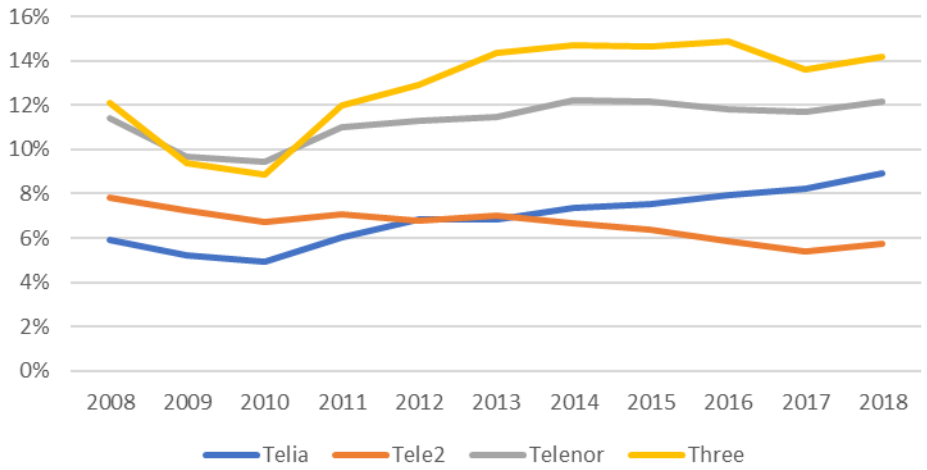
4.4.4 Effects on investment

The following chart shows the evolution of mobile capex as a proportion of revenues from 2008 onwards. The reduced capex following 2008 could reflect the impact of the global financial crisis, as well as the end of the lifecycle for 3G and preparation for future 4G investments. Increases in capex from 2010 onwards are likely to reflect in part the investments in 4G deployment. However, it is notable that Tele2's capex, which was already relatively low, declined as a proportion of revenue further after that period.

The highest capex as a proportion of revenues was reported by new entrant Three, which constructed its own 4G infrastructure with more limited revenues as result of its lower subscriber base.

65 Data from PTS (2017) as reported at https://www.oecd-ilibrary.org/docserver/9789264302259-4-en.pdf?expires=1553248286&id=id&accname=guest&checksum=AA4FAD15F870CF10B3937D09AF3A853C.

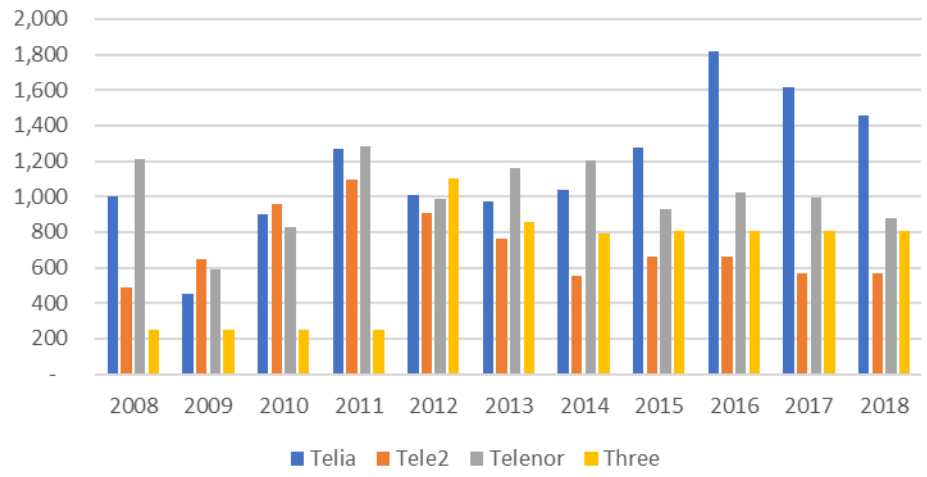
Figure 4-26: Sweden: mobile capex as % mobile revenues



Source: WIK-Consult based on Newstreet.

A further analysis of the absolute levels of Capex per operator in the Swedish telecom market shows that, after increasing capex in the period 2010-2012 – presumably in connection with 4G deployment, Tele2's capex declined to relatively low levels, while Telenor's capex was maintained at significantly higher levels despite its lower market share. The reasons are unclear, but suggest distinct strategies by the two companies (at least beyond the network sharing agreement).

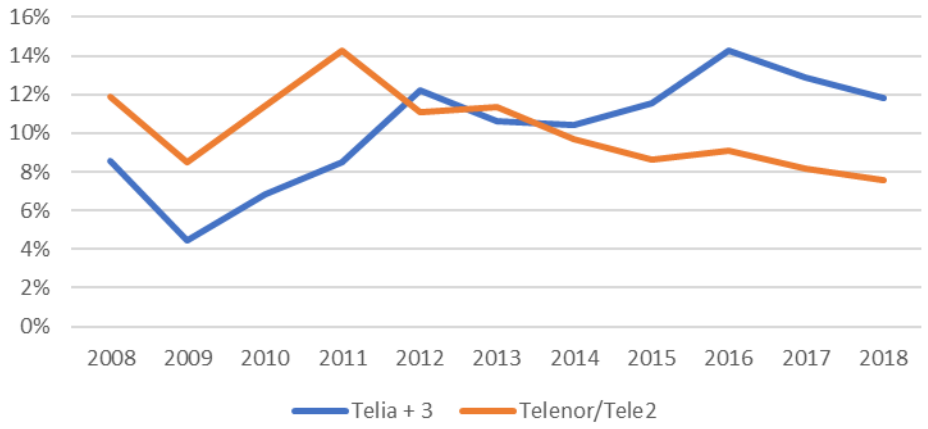
Figure 4-27: Sweden: mobile capex (m SEK)



Source: WIK-Consult based on Newstreet.

The following figure shows the capex of the 4G JV partners combined, compared with the capex as a proportion of revenues deployed by those not involved in 4G network sharing. It is interesting to note that capex intensity of those not involved in sharing increased following the award of 4G spectrum, whereas capital intensity of the operators involved in the JV declined.

Figure 4-28: Sweden: capex ratios for network sharing partners compared with other mobile operators

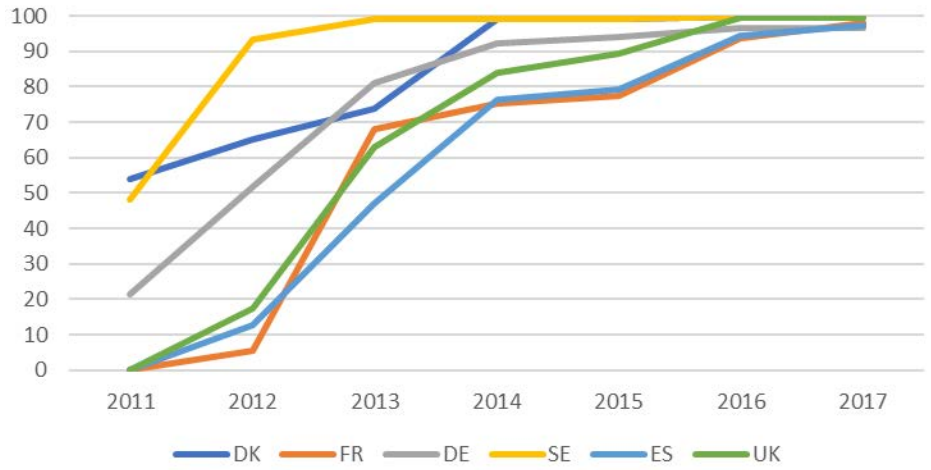


Source: WIK based on Newstreet.

Sweden was one of the first countries in Europe to achieve near full coverage of 4G.[66] Authorities believe a number of factors have contributed to this coverage, including lower costs as a result of allowing infrastructure sharing, sound spectrum management and the extensive geographical availability of fibre networks to provide backhaul.[67]

66 European Commission Digital Agenda Scoreboard.
67 OECD 2018 report on “Infrastructure for the Digital economy in Sweden” https://www.oecd-ilibrary.org/docserver/9789264302259-4-en.pdf?expires=1553248286&id=id&accname=guest&checksum=AA4FAD15F870CF10B3937D09AF3A853C.

Figure 4-29: 4G coverage trends (% households)

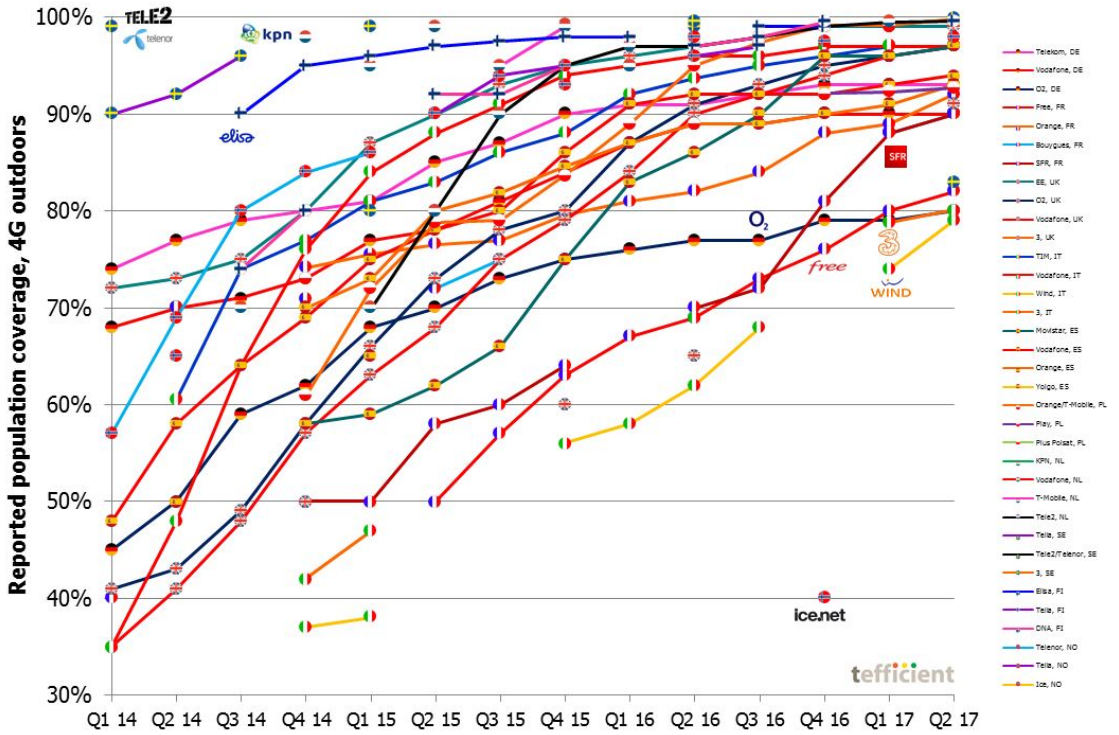


Source: WIK-Consult based on European Commission Digital Agenda Scoreboard.

Illustrating the potential efficiency of the network sharing arrangement, Telenor Sweden reported in the first of 2013 that Net4mobility had reached a population coverage of 99% and geographic coverage of 70%. As can be seen in the diagram below, this level of coverage surpassed that achieved by other operators in Sweden and elsewhere. Net4mobility's coverage was reported to have extended to 99.9% four years later, and 90% of the national territory.[68]

68 https://tefficient.com/european-4g-mission-accomplished/.

Figure 4-30: 4G coverage trends by operator

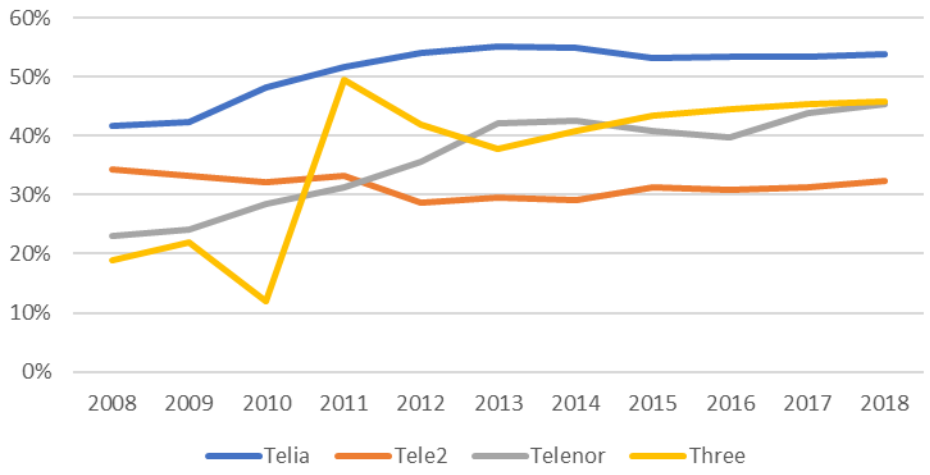


Source: teffient

4.4.5 Effects on profitability

The EBITDA margins of three of Sweden's four mobile operators lie above 45%. In contrast, EBITDA margin's of the four Danish mobile operators lie below 45%. The trajectories of mobile profitability of the JV partners Tele2 and Telenor diverge before and after the JV agreement.

Figure 4-31: EBITDA margins: mobile operators in Sweden

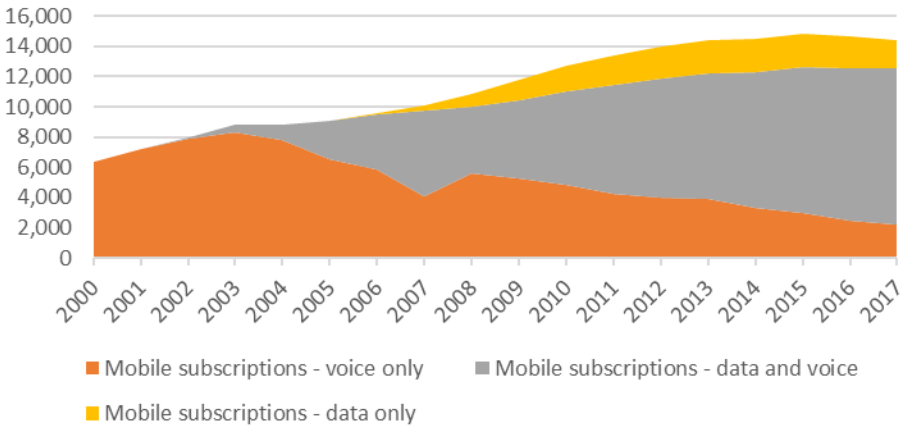


Source: WIK-Consult based on Newstreet.

4.4.6 Effects on consumer outcomes

Swedish customers were early adopters of mobile data. The first subscriptions for mobile data appear in 2002. As of the end of 2017, 84% of mobile subscriptions included a data package.[69]

Figure 4-32: Sweden - trends in mobile voice and data subscriptions



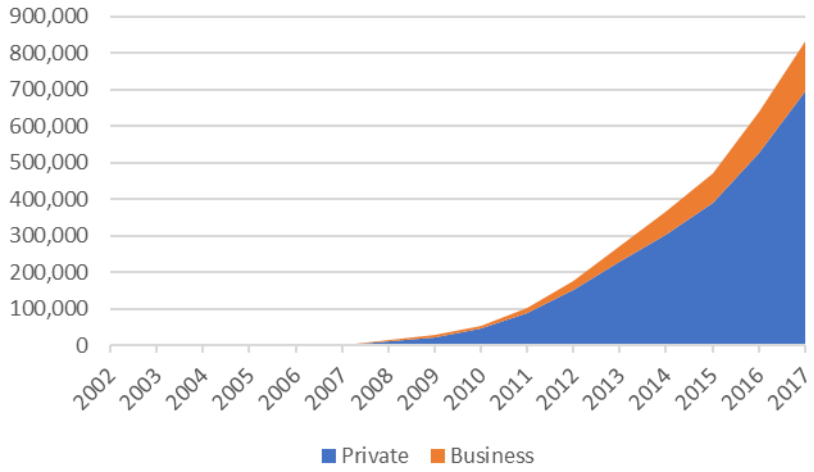
Source: WIK-Consult based on PTS market data H1 2018.

69 PTS market data.

PTS reports that as of H1 2018, there were 9.1 million subscriptions, which had used services in the 4G (LTE) network representing 64 per cent of all mobile subscriptions.[70]

Data traffic on mobile networks increased to 493 Pbytes in during the first six months 2018, an increase of 30% on the previous year. Private customer subscriptions for both voice and data generated on average 6.4 Gbyte per subscriptions and month, which was an increase by 52 per cent.

Figure 4-33: Mobile data traffic in Sweden: Terrabytes

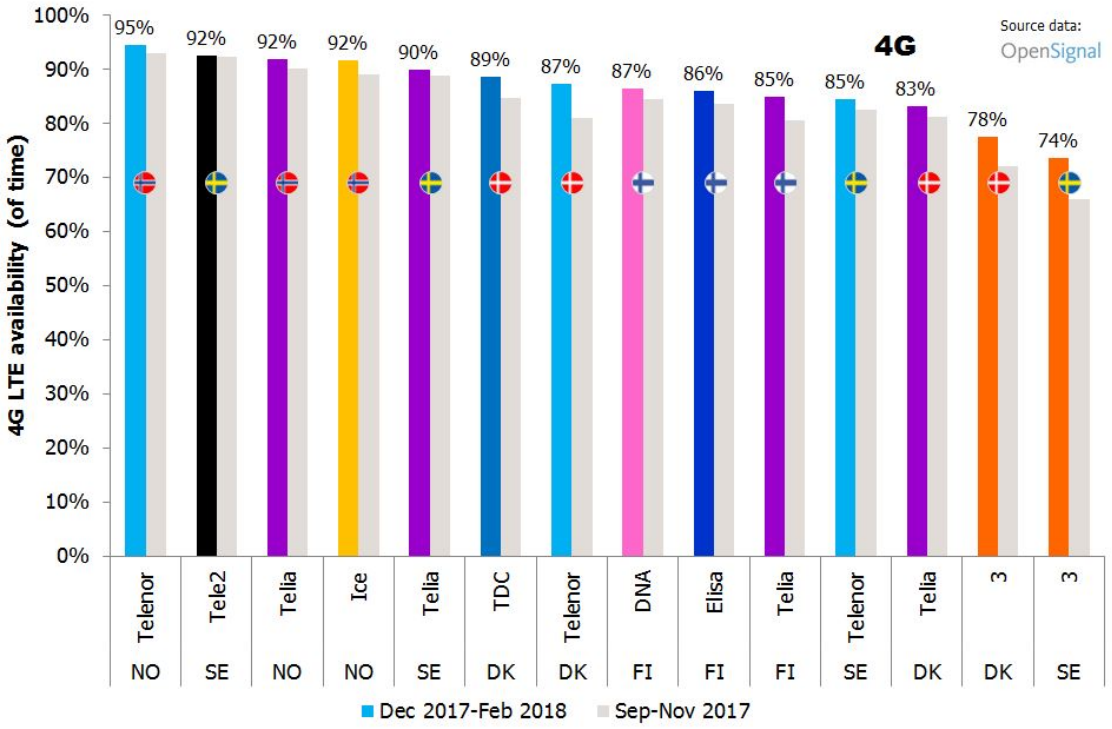


Source: WIK-Consult based on PTS market data H1 2018.

Data from Opensignal shows that users of Tele2 experienced the highest availability of 4G networks in Sweden, an indicator of good coverage. However, despite sharing the underlying network,Telenor Sweden's 4G "availability" is suggested to be significantly lower. The lowest availability shown amongst the Nordic countries is 3 Sweden, perhaps signalling the challenge in constructing a single operator network, without the benefit of complementary fixed infrastructure.

70 PTS market data H1 2018 https://www.pts.se/globalassets/startpage/dokument/icke-legala-dokument/rapporter/2018/telefoni/svt-halvar-2018-engelska/stm1h2018-eng.pdf.

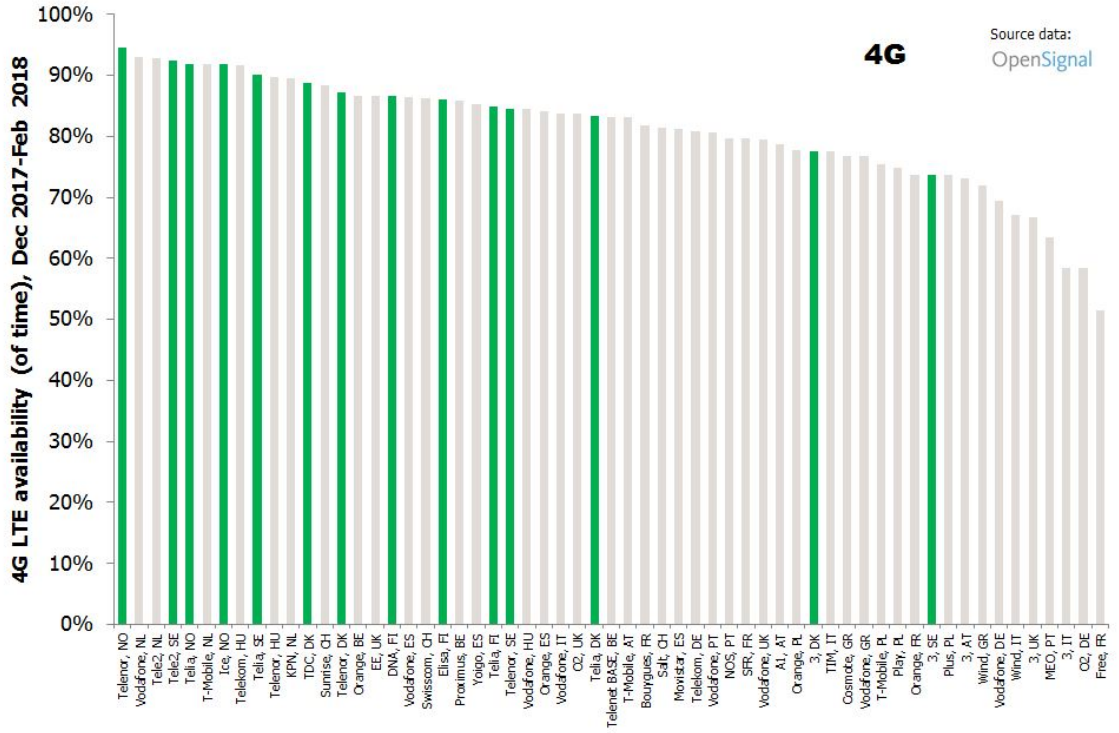
Figure 4-34: 4G LTE availability (% of time) – Nordic countries



Source: OpenSignal.

Looking more widely across Europe, 4G availability in Sweden as well as Denmark was reported to be higher than in the other countries studied.

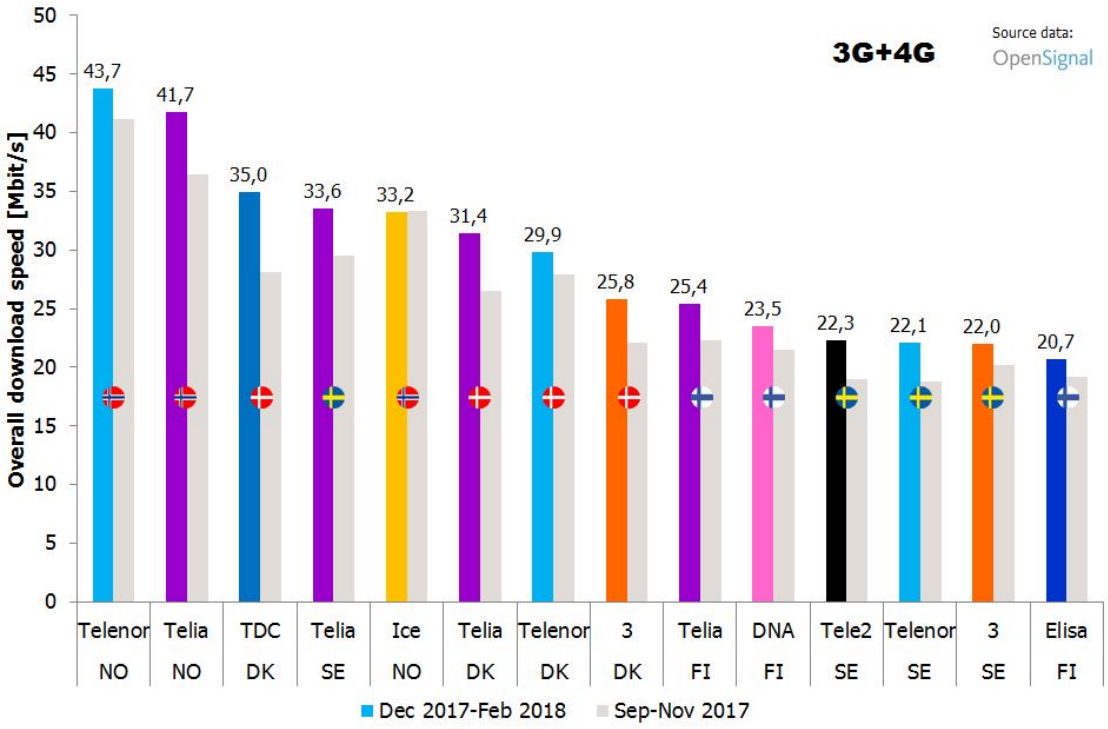
Figure 4-35: 4G LTE availability (% of time) – European comparisons



Source: OpenSignal.

Average download speed by operator in Sweden was very similar for Tele2 and Telenor, but also close to that of 3.

Figure 4-36: Average download speeds by operator – Nordic countries



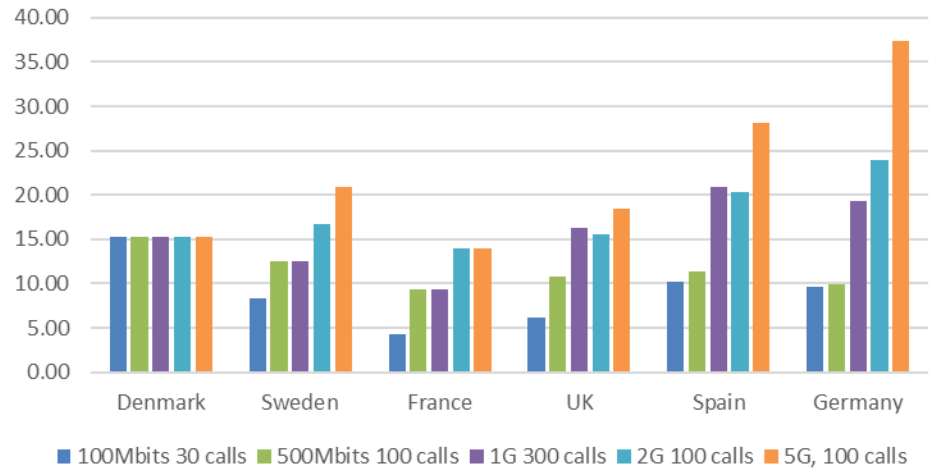
Source: OpenSignal.

More widely, 4G download speeds in Sweden were reported by Opensignal[71] at 27.6Mbit/s in 2018. This was below the speeds reported for Denmark (33Mbit/s) and Spain (31Mbit/s), but above France (25 Mbit/s) and the UK (23Mbit/s).

Data collected for the European Commission[72] shows that Swedish mobile prices were in the mid-range of the countries studied for this report, and follow a clear tiering structure, with the highest charges for packages include high data volumes.

71 https://www.opensignal.com/reports/2018/02/state-of-lte.
72 European Commission: Mobile broadband prices in Europe 2017 https://ec.europa.eu/digital-single-market/en/news/mobile-broadband-prices-europe-2017.

Figure 4-37: Mobile charges in euro per month 2017



Source: WIK-Consult based on European Commission Digital Agenda Scoreboard.

4.5 Lessons from case studies

The case studies analysed allow us to examine potential effects associated with four scenarios for mobile competition in the context of 4G deployment.

Sweden and Denmark have pursued an *extensive form of mobile network sharing*, *including spectrum sharing* alongside RAN sharing and sharing of passive infrastructure via a Joint Venture. In effect, three 4G networks have been deployed to support four mobile network operators in these countries.

In *France active (RAN) sharing* has occurred, but in a more limited geographic area (serving just under 60% of the population), without any spectrum sharing.

In Spain, Yoigo, reached a deal to provide Telefonica *access to its 4G network* in 2013, while benefiting from access to Telefonica's transport network.[73] However, this agreement was found in 2015 by the regulator to be anti-competitive, and network sharing has otherwise been limited in Spain.

Finally, network sharing beyond passive sharing has not been a feature of the German mobile market, despite guideilnes from the regulator opening the door to further network sharing opportunities. However, two of the four mobile network operators (E-Plus and Telefonica) merged in 2014, resulting in *consolidation in the market to 3 players*.

There are many factors which influence financial outcomes in the market as well as outcomes for consumers. It is therefore not possible to be definitive about the effects that specific types of mobile network sharing may have had on investment.

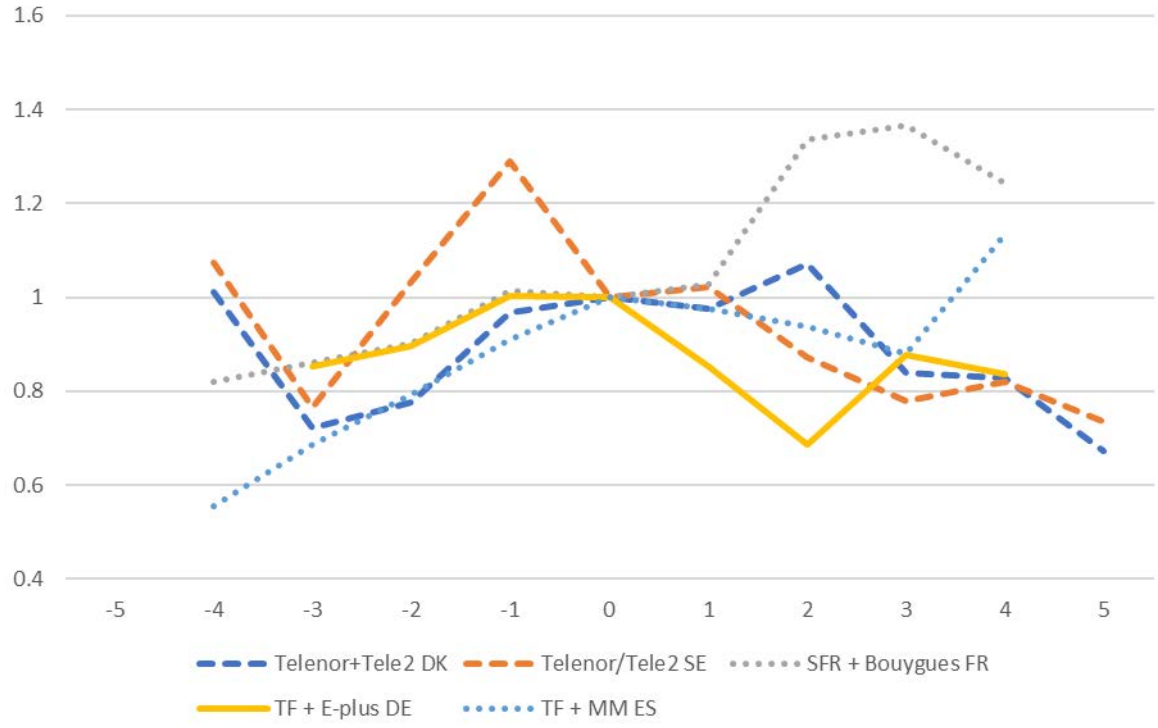
73 https://www.teliacompany.com/en/news/press-releases/2013/8/teliasoneras-subsidiary-yoigo-and-telefonicas-movistar-in-network-sharing-agreement-to-provide-better-services-to-more-customers/.

However, a comparison of the capital intensity (capex as a proportion of revenues) of the firms involved in sharing or consolidation before and after the agreements provides some interesting insights.

In the graph below – consolidation (to three players) is shown through a solid line, while the most extensive form of network sharing (joint venture involving spectrum sharing) is shown through a thick dotted line.The less extensive arrangement in France (rural RAN-sharing only) is shown in a thin dotted line.

It can be seen that the capital intensity of the firms engaged in more extensive collaboration or merger reduced following those collaborations, while investments by the French operators continued to increase. In Spain, a reduction in combined capex of Yoigo and Telefonica can be seen following the 4G access arrangement in 2013, while an increase followed the termination of the agreement in 2016.

Figure 4-38: Change in capex ratios for companies engaging in network sharing or mergers



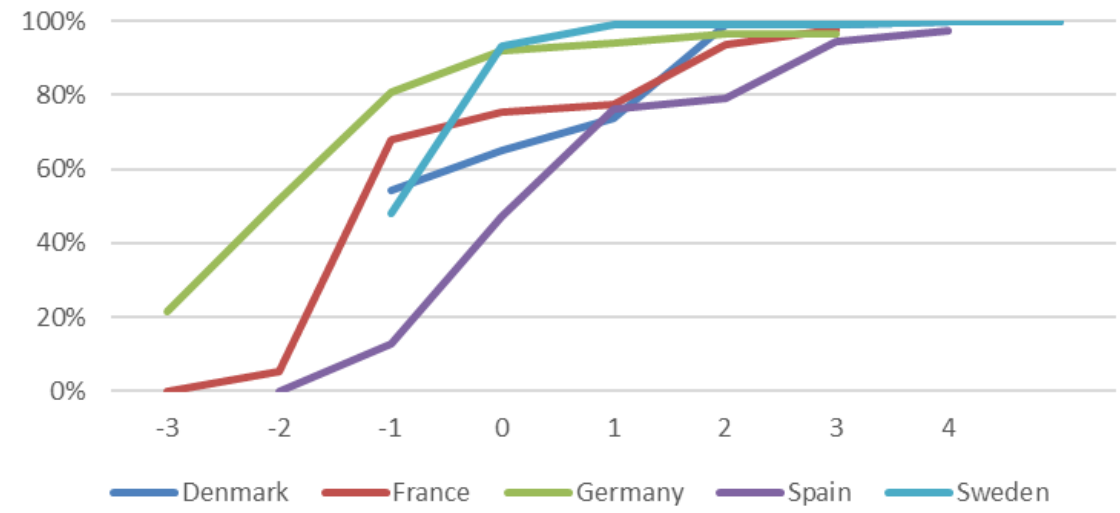
Source: WIK-Consult based on data from Newstreet.

Data within the Sweden and Spanish markets also suggests that the capital intensity of the collaborating partners reduced compared with those not engaged in collaboration. However, data from the other countries does not show clear patterns.

The following chart shows the evolution in 4G network coverage in the countries examined before and after the date when network sharing or consolidation occurred. It is

evident that 4G coverage in Sweden (a country featuring spectrum and RAN sharing through a JV) followed a rapid trajectory, increasing from 48% in 2011 to 93% in 2012. There was a significant increase in coverage in France prior to the network sharing agreement, followed by a stable period, followed by a further increase to cover rural areas, which may have been supported by the RAN sharing agreement between Bouygues and SFR, which specifically addressed less dense areas. Other trends are however difficult to detect, and progress in 4G deployment may have been influenced by a number of factors.

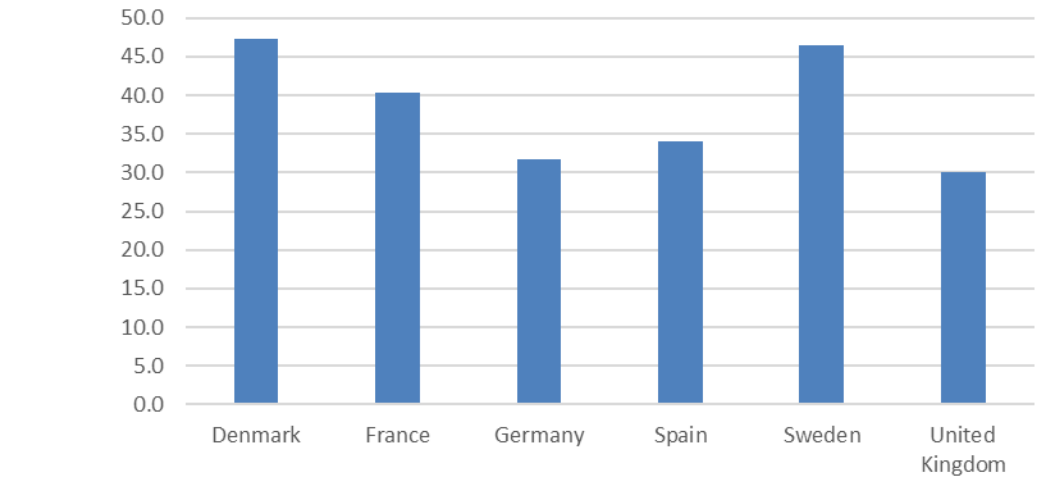
Figure 4-39: Evolution in 4G network coverage before and after network sharing or consolidation



Source: WIK-Consult based on data from the European Commission – digital agenda scoreboard.

Data on actual download speeds achieved via mobile networks shows strong performance amongst the countries which feature extensive network sharing arrangements – Denmark and Sweden.

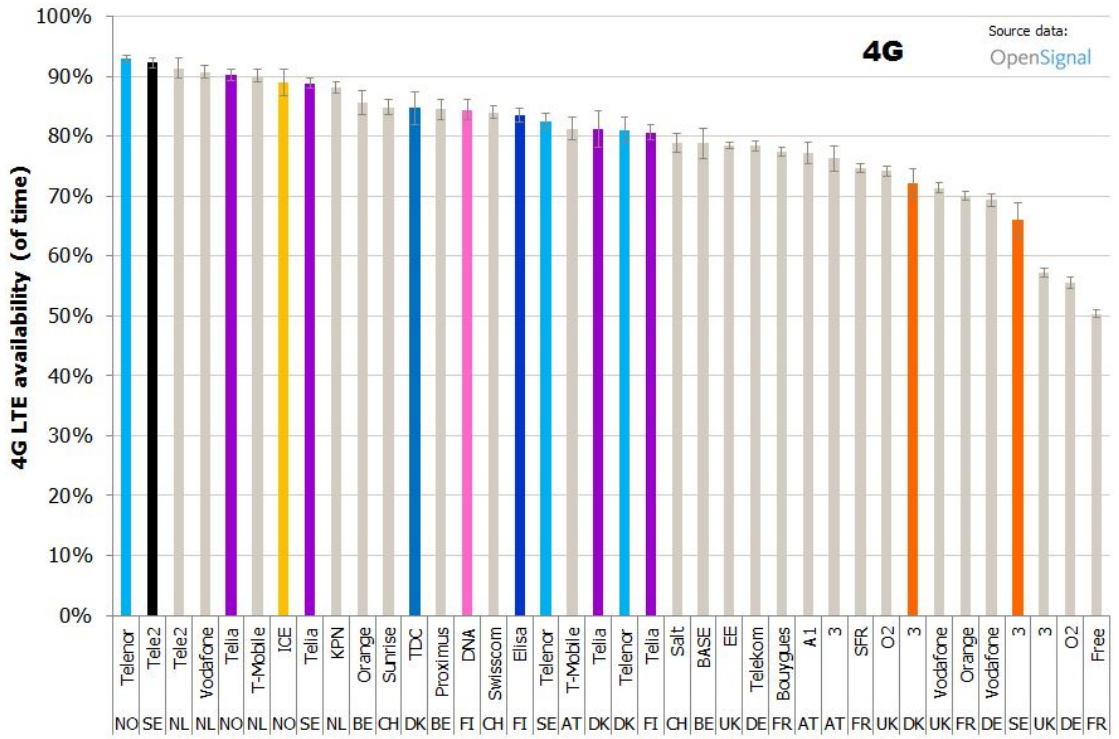
Figure 4-40: Mobile download speed (Mbps) 2018 selected countries



Source: WIK-Consult based on Ookla.

These countries (and specifically the operators engaged in network sharing) also perform relatively well for “network availability” (see below) compared with the smaller independent operators in Denmark and Sweden as well as operators in countries without extensive network sharing such as France and Germany.

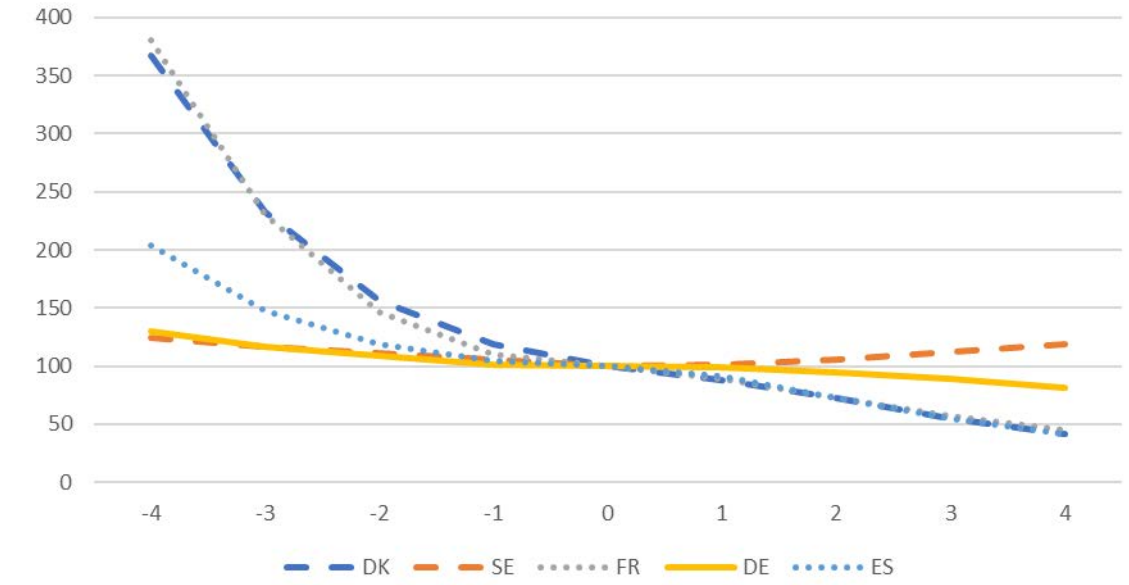
Figure 4-41: 4G availability in the EU



Source: tefficient

As regards potential pricing power, the following chart shows how mobile ARPU changed in the period before and after changes to the market structure or agreements on network sharing, with '0' representing the year in which these changes occurred. No patterns are visible which would indicate a difference in outcomes between countries featuring consolidation or strong forms of network sharing (Germany, Sweden and Denmark) vs those in which network sharing was more limited in nature or in time (France and Spain).

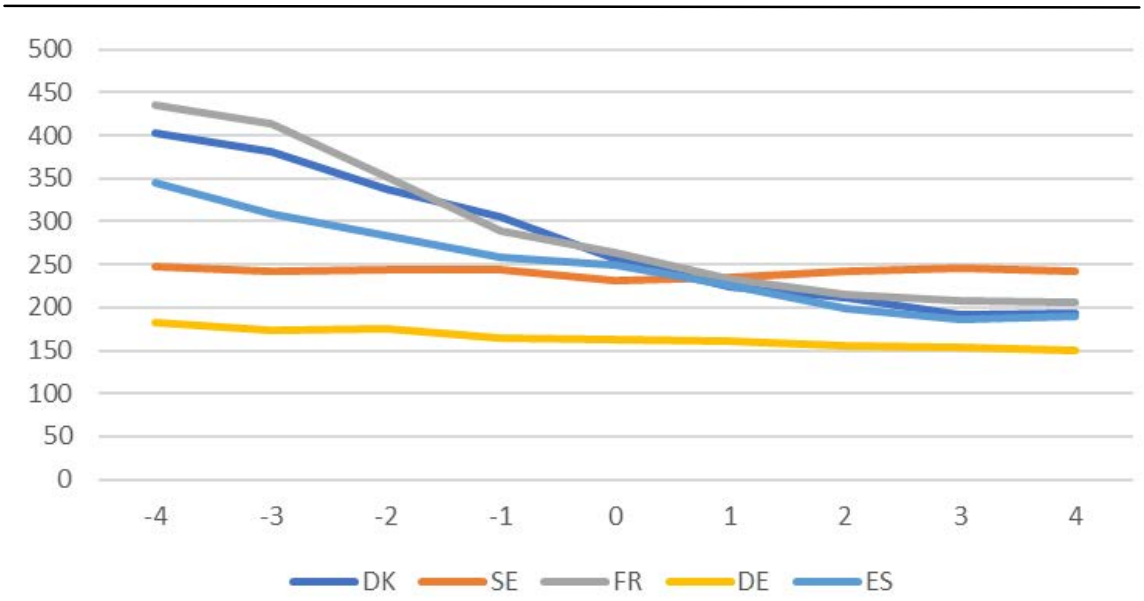
Figure 4-42: Change in ARPU before and after network sharing / consolidation



Source: WIK-Consult based on data from Newstreet.

A review of absolute ARPU levels in the countries examined confirms that ARPUs remained relatively stable in Sweden and declined slowly in Germany, following the 4 to 3 consolidation. Steeper declines can be seen prior to the 4G network sharing agreements that occurred in Denmark, France and Spain, with ARPUs stabilising shortly after the structural changes or agreements occurred.

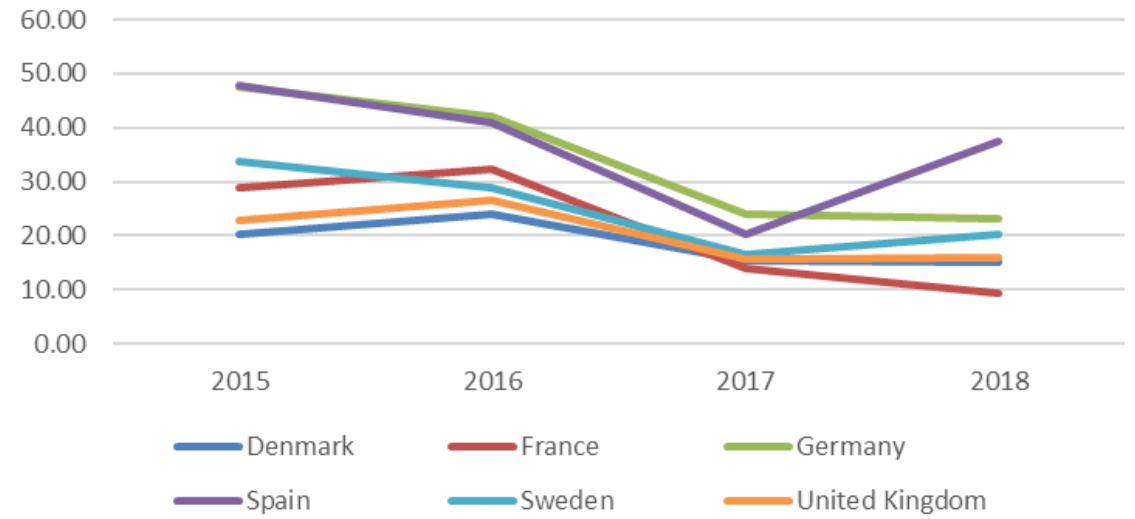
Figure 4-43: ARPU before and after network sharing / consolidation (absolute values)



Source: WIK-Consult based on data from Newstreet.

Comparative data on pricing for mobile bundles including 2GB data, also reveals no clear patterns that would indicate a positive or negative effect on pricing levels that could be directly associated with different degrees of network sharing.

Figure 4-44: Monthly price for mobile bundle including 2GB and 100 minutes (€ PPP VAT included)



Source: WIK-Consult based on data from the OECD.

The overall conclusion from examining data from the countries studied is that mobile network sharing in the context of 4G may have enabled capex reductions (with the strongest evidence of this in Sweden, and potential in Spain), and may have supported 4G deployment and availability in certain areas for the operators concerned, although this link cannot be proven. There is no evidence to suggest that stronger forms of network sharing have been associated with worse outcomes for consumers in terms of network quality or excessive pricing, although effects should be examined more closely in a national context.

One caveat is however that even where extensive network sharing or consolidation occurred, there were still three independent 4G networks present in the countries studied.

A 2018 analysis by WIK for the European Commission[74] suggests that more pronounced effects on competition and consumer outcomes might occur with consolidation to two networks, especially if the market is mature, and market shares are stable.

It is possible that this effect might also apply in the case of extensive network sharing, resulting in two networks, supporting three or more retail players. However, the lack of examples has meant that this hypothesis could not be tested.

A factor that may militate against this effect occurring in the context of 5G deployment is that this could potentially be a disruptive technology, providing an advantage to first

74 WIK (2018) Review of the Significant Market Power (SMP) Guidelines https://www.wik.org/index.php?id=1023.

movers, with potential rewards for those achieving full connectivity e.g. in terms of support for connected cars. As such, it is possible that even with two underlying networks (or one in rural areas), there might still be an incentive to invest.

5 Interviews with Danish stakeholders

In order to provide a perspective for the future, WIK conducted on-site interviews with all four MNOs in Denmark: TDC, Telenor, Telia and Hi3G, following the presentation of the interim report at the Danish Energy Agency. In this context, the interviewed operators provided their views regarding past and upcoming spectrum auctions for 5G frequency bands and their expectations concerning the need for network sharing. A summary of the main messages from stakeholders are summarized below.

- Danish mobile operators do not see a short term consumer demand for 5G specifically (although there is increasing demand for higher bandwidths for consumer applications). Rather, most operators agree that the service demand of residential customers can be met through existing LTE or LTE advanced networks, at least in the near future. However, as in many other countries, Danish operators see 5G as providing opportunities to target specific industry sectors and to support developments such as as self-driving cars, VR/AR applications and mass IoT adoption. Achieving ultra-reliable and low-latency communication through 5G networks is also considered a key trigger enabling a shift from wired to wireless applications.

- Following the recent auction results, it is commonly acknowledged that TDC is best placed to achieve a rapid deployment of 5G based on the spectrum acquired.

- More extensive sharing, potentially around two networks, is seen as desirable or necessary in the context of 5G deployment, at least in certain circumstances or areas.

- The role of intelligence in the core network, and the importance of low latency mean that operators consider that national roaming is unlikely to enable effective competition in a 5G context. MOCN models are considered more suitable, with consideration needed of sharing in the transmission network.

- There is widespread demand for guidance from the NRA and competition authorities on what might be considered as reasonable approaches to network sharing in the context of 5G.

- Mobile operators consider it unlikely that verticals will directly bid for spectrum in upcoming auctions.

More detailed feedback from stakeholders is provided in the confidential sections below.

5.1 Past and upcoming auctions

[confidential]

5.2 5G rollout, and prospects for network sharing and consolidation

[confidential]

6 Common themes and implications for 5G

This chapter explores the main 5G use cases, including residential and industrial applications, the implications of these use cases for spectrum usage in different bands, as well as network densification, and the consequent drivers for network sharing in a 5G context. It concludes by identifying potential scenarios for network sharing in a 5G environment, and considerations for authorities.

Key findings are that:

- 5G investment is likely to create a number of drivers for network sharing or consolidation. Drivers include the need for widespread coverage for automated driving, rural coverage needs and potential challenges in addressing urban areas with parallel networks.
- The degree and nature of network sharing may go beyond what was required in the context of 4G e.g. requiring an MOCN model (when previously this may have been efficient, but optional), or entailing spectrum pooling amongst a greater number of players than are currently engaged in sharing – especially in the context of rural coverage.
- Evidence from examples of extensive network sharing for 4G deployment in Denmark and Sweden suggest that such sharing could reduce capex requirements and can occur without apparent detriment to investment in 4G deployment or consumer outcomes. However, available evidence is associated with 4G and the operation of at least 3 mobile infrastructures. There is limited evidence of the effect of additional sharing (towards one or two networks in given areas). Moreover, 5G raises new issues in comparison with 4G, including the need for redundancy for critical applications, the potential role of new use cases in driving innovation, importance of large spectrum holding in enabling innovation and the role of network slicing in enabling differentiated services to co-exist on a single network.
- Broadly, evidence points to the potential for there to be fewer concerns over network sharing in a 5G context than may have applied in previous generations (subject to ensuring redundancy), but this depends on the terms and pricing arrangements associated with such sharing. Guidance from the authorities is recommended to provide certainty to market participants once more extensive 5G deployment gets underway.

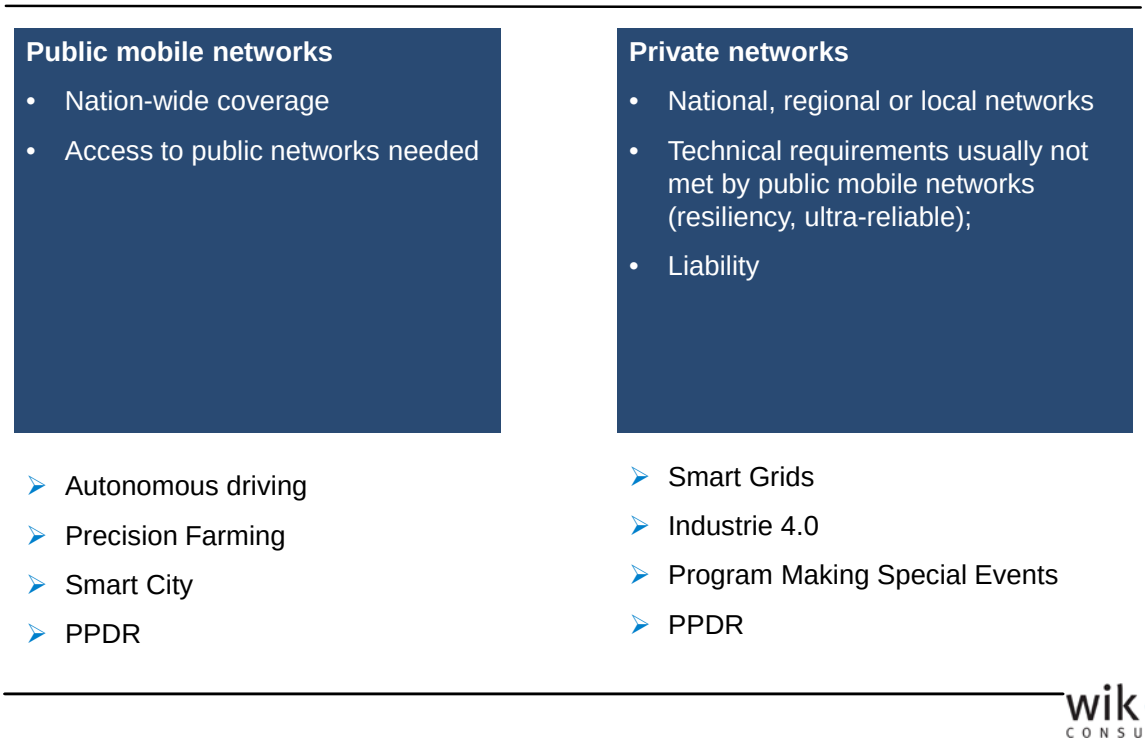
6.1 5G use cases

5G will support and facilitate very different use cases which involve different types of network configuration. The general use case of “Enhanced mobile broadband” (eMBB) might be the driver in the mass market segment (e.g. 4K video,, Augmented Reality). 5G might also be well placed to provide Gigabit speeds to households via fixed wireless access, although expanding FTTP coverage may make this less relevant in the Danish context.

However, as noted by Danish MNOs, demand for consumer 5G applications is seen as limited.Against this background, mobile operators have tended to focus on other segments of the potential 5G market. Considerable focus has been given to the role that 5G could play in supporting autonomous driving and IOT applications in various fields.[75] There is also demand for corporate networks (so called campus networks). In the context of "Industry 4.0" 5G is associated with the promise that current technologies used in production plants such as Wi-fi or 4G, can be substituted. 5G is the first cellular technology to combine the advantage of existing technologies by enabling higher data throughput, lower latency, mobility and security than Wi-Fi or 4G.

The following figure shows how 5G could lead to a more differentiated, structure of public and private networks supporting different use cases. Synergies between the two nonetheless exist, and it can be expected that MNOs will aim to play a significant role in both.

Figure 6-1: 5G, use cases and network deployment



Source: WIK-Consult.

6.2 Implications of 5G for network deployment

Investment requirements for 5G depend on the application and spectrum band used. Investments are also likely to evolve over time.

If mobile operators migrate from LTE to 5G in frequency bands below 1 GHz (e.g. 700 MHz or 800 MHz), as one can expect that the initial investment requirement will be

75 See for example the range of research and innovation projects supported by EU funding programmes https://ec.europa.eu/digital-single-market/en/news/europe-advancing-5g-new-wave-projects-launched-accelerate-5g-take-vertical-industries.

limited and migration to 5G will depend on demand. However, if demand for mass market applications increases at the same speed and degree as in previous years, the use of 5G for these purposes will require both a macro-network densification (more sites) and layer upgrades. Mobile operators are also likely over time to rely on 3.5 GHz frequencies which requires more cells due to its propagation characteristics.

Other use cases, such as automated driving, precision farming and certain IoT applications are also likely to increase investment needs in 5G.

Some of the applications may require significantly greater throughput than is currently offered by Narrowband-IoT for IoT services. . In addition, for the innovative use cases involving verticals, upload speed may become more important. For instance, in the context of autonomous driving it is necessary to upload data from the car to the backend server to provide security information to cars in the event that car-to-car communication is not possible due to distance – several Mbit/s per second may be needed for teleoperated driving. We expect that in future there will be hybrid networks combining public mobile networks and communication technologies such as ITS G5. Besides these applications, the download speed for entertainment service is of paramount importance as well. Low latency, beyond that available via LTE, is also critical for some automotive applications and applications for example in the field of healthcare.

Some of the new use cases may be best supported by spectrum in the 3GHz band. For example, in the context of Industrie 4.0, there is demand for different types of connectivity: 5G might substitute wireline connectivity for robots, enable human-robot interaction, enable Augmented Realty applications and provide connectivity to a great number of sensors etc. All these different applications need more bandwidth than it is available below 1 GHz. The provision of high bandwidths (with increased upload capabilities) and low latency, is further likely to require the operation of channel bandwidths, of at least 100MHz or even more.

Because backhaul to 5G antenna’s is likely in most cases to require fibre connectivity, this is also likely to increase cost, especially where fibre needs to be newly installed, or leased at higher cost than the provision of microwave links.

6.3 Implications for network sharing

Initially, the additional investments required for 5G might be limited because mobile operators will still be investing in LTE (deploying single RAN technology), with the intention to migrate towards 5G at a later stage. Vendors already offer 5G-ready equipment which is compatible with LTE architecture. Thus the implications of 5G on network sharing may be limited, at least at the outset.

However, as the next phase of 5G deployment proceeds, pressure may arise for further consolidation at the network level and/or deeper network sharing arrangements from the following sources:

1. **Autonomous driving and IOT:** As described above, certain applications such as autonomous driving will require comprehensive nationwide coverage (including along highways) with low latency and medium data rates in particular for the uplink. Even if there is current availability of LTE, 5G will likely be needed over and beyond LTE to provide the necessary quality of services with can be enabled with network slicing. Network slicing will be introduced with 5G and is an instrument to provide users with a specific quality of service. If the use case requires nation-wide coverage, operators are likely to make use of frequencies below 1 GHz for this purpose, because of their potential to achieve greater coverage at lower cost. Frequencies above 1 GHz usually deployed to increase capacity, can be used as well but at higher costs. For example, one can estimate that using 3,5 GHz might increase the required number of sites by a factor of 4. Due to these cost factors, for applications requiring high QoS nationwide, operators with limited spectrum in frequency bands below 1 GHz, may have an interest in network sharing by e.g. it is unlikely that an operator with only 2 x 5 MHz (as awarded to TTN) could realistically offer such services in 700 MHz. At least 2 x 10 MHz or even more bandwidth is needed. MOCN (Multiple Operator Core Network[76])may be essential in such cases. Roaming agreements would be insufficient to enable operators to offer such ultra reliable low latency services, as it entails communications passing between the host and roaming operator, which increases latency.

2. **Economics of deployment in rural areas:** 5G deployment in rural areas will likely require the upgrade of backhaul capacity to fibre and in time, the potential deployment of additional sites. This may further limit the economic viability of multiple parallel deployments in these areas.

3. **Constraints in city deployment:** Even though deployment in cities should in theory be more economically viable than 5G deployment in sparsely populated areas, there may still be constraints which limit the independent deployment of several parallel networks.

    a. there may be insufficient sites available, in light of urban planning,

76 RAN sharing in connection with frequency pooling is also called as Multi-Operator Core Network. MOCN is of particular interest for operators if there is not sufficient spectrum available or if services with a high bandwidth requirement are to be provided. The joint use of frequencies can be handled nationwide, or limited to a particular region or location.

b. EMF limits may constrain the potential for network duplication, if limits are stringent and/or if 5G is deployed in 3.5 GHz on existing sites in addition to LTE.

c. It is unlikely that operators will be able to support all technologies (2G, 3G, 4G and 5G) and the respective frequencies at the same site. However, this could be alleviated if there is a phasing out of technologies (most likely 3G) as this may increase the potential to deploy 5G on existing sites.

d. The business case for densification depends on willingness to pay of customers and the addressable market, which may in some cases, even in cities, be insufficient to support multiple networks. This may particularly be the case for the deployment of small cells and associated fibre connectivity.

We understand that measures have been put in place to address some of these issues. For example, urban planning issues are addressed in the context of the Danish 5G Action plan. However, if issues remain which affect the viability of multiple deployments in cities, network sharing options could be considered. Passive infrastructure sharing typically causes few concerns for competition authorities, but would not address challenges concerning the simultaneous operation of multiple mobile technologies on the same site. Active infrastructure sharing (with or without spectrum pooling) could on the other hand provide a solution to this problem.

4. **Competition from verticals:** One of the key elements supporting the business case for 5G deployment in Europe is the potential to gain revenues from new use cases, including corporate networks. If (as in Germany and Austria) some verticals can ask for spectrum and decide to deploy their own network infrastructure (campus or corporate networks) rather than cede this role to an MNO, this may limit a potentially valuable source of revenues for the MNOs. Although stakeholders consider that such developments are unlikely in Denmark, if they occurred, they could put pressure on the business case for 5G for traditional operators, creating greater pressure for cost efficiency and network sharing. Network sharing models could also emerge between MNOs and any verticals acquiring their own spectrum.

The challenges described above may result in demand for increased network sharing in particular in rural areas, where there could be demand amongst competitors to engage in MOCN with TDC, to benefit from the extensive coverage it plans, or for competitors to combine forces to compete with TDC in these areas. Thus, there could be demand for network sharing resulting in two or even one mobile network with pooled spectrum at least in certain regions. Pooled spectrum could in this context provide a mechanism to increase the efficiency of frequency use.

Pressure on resources could also lead to renewed demands for consolidation. An extreme version could be the existence of a pure wholesale only operator, providing access to the RAN, and utilising most of the spectrum, as 5G can support a 400 MHz

bandwidth channel (most likely only in millimetre frequencies[77]). There could in theory be an interest from TDC, through its netco, to support such a model, although the likelihood of approval may be limited. Alternatively, there could in theory (and especially if more extensive network sharing options are not permitted), be renewed calls for consolidation from four operators to three.

6.4 Potential impact of network sharing in a 5G context

Experience from the country studies shows that network sharing has been used in several cases to support the deployment of 4G networks by pooling resources amongst smaller operators, or enabling those without sufficient spectrum to compete in the market. Evidence from examples of extensive network sharing for 4G deployment in Denmark and Sweden suggest that such sharing can occur without apparent detriment to investment levels or consumer outcomes – at least for traditional mobile broadband services.

However, the case studies do not provide concrete answers on what the implications might be for network sharing in a 5G context. Firstly, the case studies typically involve the sharing of three mobile networks between four mobile operators. There is limited empirical evidence of the effect on investment and competition of additional sharing (towards one or two networks), as may be sought in the context of 5G deployment in some areas.

There are also differences between 4G and 5G, which could affect the outcomes in each case.

1. 4G has mainly been focused on supplying mass-market mobile broadband, but 5G is likely to be focused additionally on specific use cases which require significant spectrum holdings. Thus additional spectrum sharing in a 5G context may deliver additional innovation benefits which would not apply to 4G

2. The fact that the 5G business case (and particularly revenues) are likely to rely on new use cases may increase the incentives for investment to offer new services, even in the absence of parallel competing networks.

3. Competition and investment may not be the only factors that need to be considered in a 5G network sharing (or consolidation) scenario. Some of the critical use cases for 5G also require redundancy and resilience. In particular redundancy implies that there should, if possible, be at least two nationwide networks available

4. One of the innovations inherent in 5G is the capability for network slicing. Network slicing could be seen as a new mechanism to support infrastructure sharing, while maintaining the independence of each operator to differentiate on quality and price. This is however, dependent on the standards and specifications established for network slicing and the pricing mechanisms established.

77 See ETSI TS 138 101-2 V15.2.0 (2018-07).

Broadly speaking, these factors tend to support the potential for 5G to support a greater degree of network sharing without detriment to investment or competition than in the 4G context. However, the impact is likely to depend on the precise conditions in which sharing takes place.

6.5 Conclusions

In conclusion, 5G investment is likely to create a number of drivers for consolidation in the number of networks for specific purposes or in certain areas. For example, in order to offer 5G services in the context of autonomous driving or with regard to precision farming a certain level of bandwidth and capacity is needed below 1 GHz, for efficient operation.

The pressure for consolidation could be directly influenced by the manner in which spectrum is assigned in 3.5 GHz and 700 MHz – i.e. by permitting the acquisition by a single player of large spectrum bands. However, such a strategy might result in excessive control over investments and a limitation on the incentives for competition and innovation. Thus, there are valid reasons to design auction processes to avoid individual operators having control over significant portions of frequency.

An alternative would be to design auctions so as to enable a more even distribution of frequencies according to need, but to open the door towards further network sharing.

For 5G, our analysis suggests that the degree and nature of network sharing may go beyond what was required in the context of 4G e.g. requiring an MOCN model (when previously this may have been efficient, but optional), or entailing spectrum pooling amongst a greater number of players than are currently engaged in sharing – especially in the context of rural coverage. National roaming solutions may be less suited to supporting certain applications.

In this context, it worth recalling that LTE is and will be in the medium term, the backbone of competition. 5G deployment might, in the initial phase, be constrained to hot spots and corporate networks. As long as there is effective competition based on LTE, some freedom could be given to operators to develop business models and exploit the opportunities of 5G. At the point where a nationwide deployment of 5G becomes economically feasible, the amount of spectrum assigned to mobile operators will become more crucial and the duplication of infrastructure constrained. In this event, regulatory guidance on infrastructure sharing could be a vital tool to provide certainty and safeguard competition.

Such guidance could inter alia address questions on how further consolidation in networks (from 3 to 2) through network sharing might be viewed by the authorities, respectively in rural and urban areas, attitudes towards MOCN and the degree to which sharing could be envisaged beyond the RAN and into the transmission network. The role of network slicing in 5G network sharing, as well as associated pricing and terms to ensure independent operation, could also be considered.

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