THE IMPACT OF MOBILE MARKET CONSOLIDATION ON QUALITY

A report prepared for Three UK

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EXECUTIVE SUMMARY

The impact of consolidation on consumer outcomes has attracted a lot of interest in recent years, in light of a number of mostly 4-to-3 mergers in Europe. This has included an assessment of the impact of consolidation on non-price consumer outcomes, and in particular data consumption and speeds, as demand for mobile data has increased. In this context, and also in relation to the strategic review of the mobile market that is being undertaken by Ofcom, Three has asked Frontier to explore further the relationship between 4-to-3 mergers and investment and non-price consumer outcomes. We have considered this question by drawing on more recent data (in particular on average download speeds) which has allowed us to expand the previous analyses. We have also been able to examine in much more detail evidence on Three's experience in two countries which experienced such consolidation.

The effects of mergers on investment and quality

In principle, 4-to-3 mobile mergers can have a positive impact on the quality of the merging parties' services. As merging parties combine their existing networks and spectrum holdings, the merged entity will be able to deploy more spectrum on each site, and may be able to combine different spectrum frequency holdings in a more efficient manner to improve the quality of service offered to its subscribers. The merged entity will typically have a denser network after the merger, even after removal of duplicate sites. Therefore, the merged entity would be expected to have higher capacity (per subscriber) than each of the two standalone networks. Higher capacity, in turn, implies better quality and higher speeds. In addition, the merged entity's geographic coverage will be superior if there are localities where one, but not both, of the standalone networks is present.

Furthermore, mergers are expected to lead to cost synergies, e.g. merging parties should be able to remove duplicate sites and non-network duplication (e.g. in IT, marketing, retail outlets, etc.). These expected cost synergies[1] imply that the merged entity should be able to deliver the same (or better) consumer outcomes with lower investment per subscriber and lower opex per subscriber, other things being equal.

Furthermore, the merged entity has stronger incentives to invest in expanding its network as it is able to monetise its investment over a larger customer base.

However, consolidation might also alter the market's competitive dynamics. This change in competitive dynamics may have a positive or negative impact on investment. Indeed, the new competitive dynamic may positively impact investment incentives as mobile operators are less likely to see the return to investment competed away. On the other hand, the impact on investment incentives may be negative as mobile operators have less incentive to 'escape the

[1] While some cost synergies may be achieved with network sharing, these are typically lower than what could be achieved with full network integration.

competition'.[2] Taken in the round, mergers can in principle lead to improved consumer outcomes and the question of whether they do is an empirical one.

Our overall approach

There have been a number of studies that have examined the relationship between mergers and consumer outcomes. These have in general used statistical methods to estimate a hypothesized relationship, informed by data availability. There are two issues with this approach: first, data on consumer outcomes or proxies has tended to be either unavailable (e.g. coverage) or 'noisy' (e.g. capex); second, the statistical methods effectively rely on a comparison of the impact of mergers/entries on consumer outcomes in countries where there have been such events, relative to countries where there have not been any. In practice, there has been a relatively limited number of 4-to-3/3-to-4 mergers/entries, and the speed and nature of the impact of mergers/entries is market specific. Hence it is more difficult for a statistical approach to identify the impacts.

In our approach to the study, we therefore used mixed methods research that combines elements of quantitative and qualitative analysis in order to deepen our understanding of the impacts of mobile mergers on quality. More specifically, we combine econometrics analysis and evidence-based case studies, which consider, in more depth, developments in markets that have experienced consolidation and provide a comparison with markets where there has not been any. We consider this approach to be preferable to one which is based purely on econometrics, given the data limitations mentioned above.

Our econometric analysis

We have used econometric techniques to estimate two relationships: one models the relationship between market structure and investment per mobile connection, and the second models the relationship between market structure and average download speeds.[3]

Both models are estimated using operator level quarterly data based on the GSMA Intelligence (GSMAi) data for capex, and other market characteristics, and Ookla data for speeds in 30 European countries between 2011 and 2019 (for average download speeds) and 2009 and 2020 (for other variables). The analysis controls for the influence of factors other than market structure, such as the rollout of 4G and dynamics of investment.

Based on our econometric analysis, we do **not** find a statistically significant relationship (either positive or negative) between mergers and investment per mobile connection, or between mergers and download speeds. These results are not surprising given that:

- The absence of a positive or negative effect is consistent with the theory, especially for the type of mergers/entries in our sample (4-to-3 and 3-to-4);

[2] See Aghion, Bloom, Blundell, Griffith, Howitt (2005) "Competition and Innovation: an Inverted-U Relationship" for more details

[3] The statistical analysis effectively compares the outcomes in markets where there have been mergers and in markets where the number of operators has not changed.

- In relation to the impact of consolidation on investment and speeds, out of the 30 countries considered, there are effectively three countries in the sample which can provide insights into the impacts of mergers on investment and speeds;
- While we control for a number of market characteristics, there appear to be other factors which are harder to control for in a systematic way, e.g. the degree of network sharing (no/limited network sharing vs. passive vs. active), how many players are involved in network sharing and coverage obligations which could also be expected to impact investment. The presence of these unobservable factors makes it more difficult to identify the impact of mergers on investment per connection and average download speeds accurately.
- If quality is impacted over varying timeframes in different markets that have undergone consolidation, it may be challenging to identify a universal relationship between mergers and quality, especially if the data only covers a relatively short period of time after the mergers took place.

If anything, the econometric analysis would suggest that mergers do not have a material impact on capex per connection. In practice, as mergers are in general expected to lead to some capex cost savings between the merging parties, the analysis would be consistent with the merging parties re-investing at least some of the expected merger capex savings. All else the same, the evidence would therefore suggest that the subscribers of the merging parties could expect to see an improvement in the quality of service, with the impact on other mobile subscribers depending on the reaction of the non-merging parties.

Case studies of mergers in Ireland and in Austria suggest that there were significant improvements in quality, with benefits taking significantly different periods to materialise

As mentioned above, we have complemented our econometric analysis with case studies. We focus on two mergers – in Ireland and Austria, as these are the countries where Three was one of the merging parties and therefore has direct insights into the merger process and outcomes. We also contrast consumer outcomes in Ireland and Austria with consumer outcomes in 4-player markets (i.e. in markets where there have been no consolidation).

Three was involved in mergers both in Ireland and in Austria. In both countries, Three was the smallest player (with c. 12% market share), no 2G network and no sub-1GHz spectrum. In Ireland, Three merged with O2, which was the second largest operator in the market. At the time of the merger, O2 had good 2G coverage, but relatively limited 3G coverage and had not meaningfully invested in 4G. In Austria, Three merged with Orange, which was the third largest operator in the market and, as O2 in Ireland, had not started rolling out 4G.

In Austria, the network integration process was comparatively smooth, and within 18 months, Three was able to increase its average download speeds from 4 Mbps to 21 Mbps and became the market leader in terms of average download speeds. In the following years, all three operators (Three, A1 and Magenta) continued to increase their average download speeds, reaching 40-50Mbps by 2020. In the same period, Three also increased its 4G coverage from 25% to 98%, and it has

been recognised as having the fastest 5G network in Austria. Customer satisfaction has also improved dramatically, with customer satisfaction levels exceeding those for both A1 Telekom and Magenta Telekom.

Figure 1 Average download speeds (Mbps) for each Austrian MNO, 2011 – 2019

Source: Frontier Economics analysis of Ookla data
Note: Data for 2011 to 2019 has been provided directly to Frontier Economics by Ookla,

By comparison, network consolidation proceeded more slowly in Ireland. Three first needed to unwind the existing network sharing agreement between O2 and Eir, which took 18-24 months. Afterwards, Three had to combine the two networks, while also replacing all equipment to ensure vendor consistency across both networks and removing 400 duplicate sites. The whole process took a materially longer period to complete (around five years).

As a result, Three's average download speeds increased gradually in Ireland, from 7.2 Mbps in 2014 to 21.8 Mbps in 2019. However, after the network consolidation was completed in 2019-20, Three's speeds have increased dramatically. According to Ookla, Three is now the market leader in Ireland with 69.7 Mbps average download speeds, ahead of the previous market leader Vodafone. [4]

[4] Note that 2020/21 data is not included in the econometric analysis.

Figure 2 – 2021 Average download speeds (Mbps) for each Irish MNO, 2011

[✂]

Source: *Frontier Economics analysis of Ookla data.*

Note: *Data for 2011 to 2019 has been provided directly to Frontier Economics by Ookla, while data for 2020 and 2021 has been provided indirectly via Three Ireland.*

In order to assess the merger impact, we have also examined improvements in average download speeds in 4 player markets (illustrated in Figure 3 below). The figure shows the average download speed improvement achieved by Three in Austria (the light blue line) and in Ireland (the grey line). These average download speed improvements are compared against the improvement for the "typical 4th operator" and the "typical 3rd operator" in four-player markets.[5]

Figure 3 shows that Three Austria improved its average download speeds faster than the typical 3rd or 4th operator in four-player markets. Three Ireland's average download speed improvements kept pace with the typical 4th operator over the integration period (2014 to 2019). Now that the integration process is complete, Three Ireland's average download speeds are faster than the average download speeds for the typical 3rd or 4th operator in four-player markets.

Figure 3 Three's average download speeds in Austria and Ireland vs average download speeds for the typical 3rd operator and typical 4th operator in four-player markets.

[✂]

Source: *Frontier Economics based on Ookla data*

Note: *Dashed lines denote projections based on 2018 to 2019 growth rates. The typical fourth operator and typical third operator is calculated using data on the third and fourth largest MNO (based on current market share) in Denmark, Poland, Romania, Slovenia, Spain, Sweden and the United Kingdom. Data on the relevant MNO from each country is weighted according to the number of speed tests recorded for that operator.*

The evidence from these case studies indicates that the benefits of mergers can take varying amounts of time to materialise, reflecting country specific and operator specific conditions. They are also consistent with economic theory, in the sense that they indicate an improvement in the quality of the service of the merging parties, absolutely and when compared to the quality of service of 3rd/4th operators in 4-player markets.

Consistency of our analysis with Ofcom's discussion paper

In December 2020 Ofcom published a discussion paper which explored the relationship between the structure of the mobile market, investment and quality[6] (below referred to as "the discussion paper"). The discussion paper's finding of a negative relationship between the number of MNOs and investment per capita/

[5] The download speed improvements for the "typical" operators are calculated using weighted data for operators in the seven four-player European markets.

[6] Ofcom (2020a) Market structure, investment and quality in the mobile industry

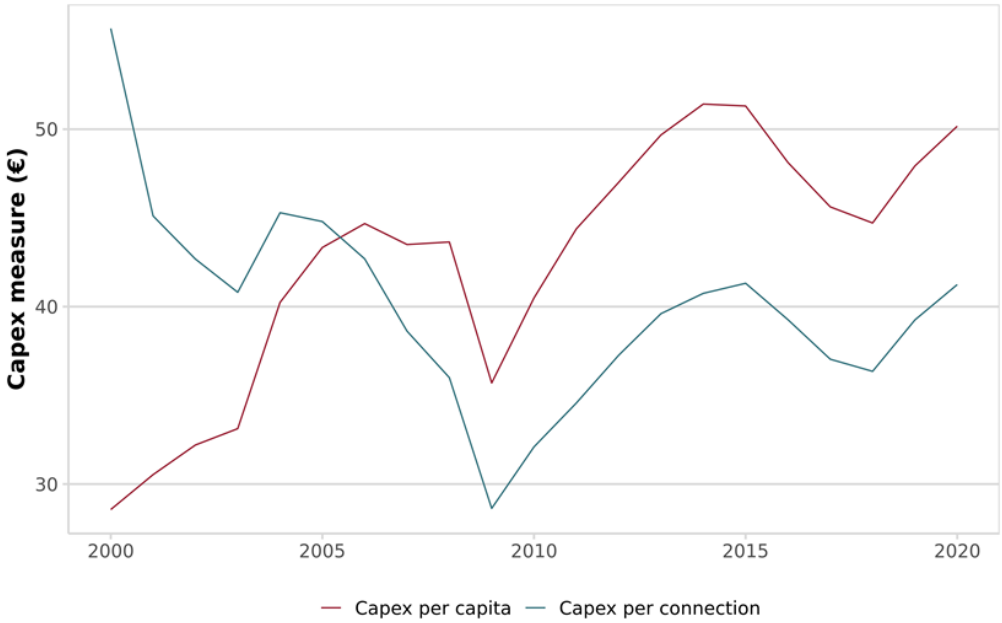
average download speeds contrasts with the findings of a number of previous studies, and our own findings. Previous work has either found evidence of a positive relationship or no statistically significant relationship between consolidation and investment.

We have therefore reviewed this analysis and identified a number of issues which seem to explain the difference between our findings (and those of the literature more generally) and those of the discussion paper[7].

The first issue is that the discussion paper assumes the average impact of entry on investment is symmetrical to the average impact of a merger (i.e. a merger in one country and an entry in another will have the same sized impact but in opposite directions). This assumption is not justified in principle, and, as we demonstrate in our report below, the evidence also does not support it. This assumption implies that the estimated effect of a merger will be influenced by the strength of any effect of entry.

The second issue is the measure of investment. The discussion paper uses investment per capita, rather than investment per connection. As the sample used in the discussion paper covers the early 2000s (when mobile adoption was growing rapidly), the difference between the two measures is significant (see Figure 4 below). Investment per connection reflects more accurately the investment that can be expected to have an impact on mobile subscribers, especially during the period when the market was growing (i.e. when the number of subscribers was different from the size of the population).

Figure 4 Trend in investment per capita and investment per connection (across the 30 European countries in Ofcom's sample, 2000 to 2020)



Source: Frontier Economics analysis of GSMAi data.

[7] We note also that the improvements in speeds in Ireland in 2020/21 are not taken into account in the analysis of the discussion paper, as the speed data used in that paper only covers 2011-2019.

Note: Graphs are weighted averages of investment per capita and investment per connection for the 30 countries in the GSMAi dataset. Countries are weighted according to the number of connections in each country.

As a consequence of these two assumptions, the discussion paper's finding of a positive relationship between the number of mobile operators and investment per capita reflects the fact that, during the early 2000s, investment per capita was rapidly rising due to increased mobile adoption, and there was also a wave of entry. We have used largely the same dataset as the discussion paper, and were able to replicate the paper's findings when measuring investment on a per capita basis, and then found no impact of consolidation on investment, when measuring investment as capex per connection.

In relation to speeds, the discussion paper finds a positive relationship between investment and speeds, but no direct relationship between market structure and speeds. It follows, based on the above analysis, that consolidation should not be expected to have a negative impact on speeds.

1 BACKGROUND ON ASSESSING THE IMPACT OF CONSOLIDATION ON QUALITY/CONSUMER OUTCOMES

Ofcom's discussion paper "Market structure, investment and quality in the mobile industry" considers the relationship between market structure, investment and average download speeds in mobile markets.

During merger investigations, merging parties have argued that concentration leads to efficiencies and increased margins; the latter effect raises the incentive and ability to invest.[8] Both effects benefit consumers and could outweigh any potential price increases associated with a lessening of competitive pressure. However, competition authorities have tended to disregard these claims due to an absence of evidence that meets the required standard of proof.[9]

The existing evidence on this topic, which includes peer-reviewed academic research, is considered by Ofcom to have "significant limitations"[10] and is "inconclusive or does not support the inferences being made".[11] As Ofcom expects to provide advice to the CMA during any future telecommunications merger investigations, Ofcom has decided to conduct its own empirical research. This section recaps Ofcom's analysis and compares its contribution to the existing literature.

1.1 A summary of Ofcom's findings

In the first of two empirical exercises, Ofcom's discussion paper analyses the relationship between mobile market structure and investment and average download speeds across 30 European countries over a period spanning 8 to 19 years. This analysis suggests that:

- industry-level investment is lower in more concentrated markets; and
- average download speeds are lower in more concentrated markets.

In particular, Ofcom's results suggest that investment per capita decreases by between 13.2% and 18.5% in the long run when the number of MNOs decreases by one (from any level). Average download speeds fall by between 5.3% and 7.4% when the number of MNOs decreases by one. The impact on average download speeds is, however, entirely driven by the impact that consolidation has on investment. Ofcom finds no evidence of a "direct" impact of consolidation on average download speeds separate and independent from any impact via investment.

In the second empirical exercise, Ofcom uses synthetic control methods to compare industry-level investment and average download speeds in three countries which experienced consolidation against investment and speeds in a

8 Ofcom (2020a) paragraph 2.1.
9 Ofcom (2020a) paragraph 2.2.
10 Ofcom (2020a) paragraph 1.6.
11 Ofcom (2020a) paragraph 1.6.

counterfactual world in which the countries did not experience consolidation. The results of this exercise are mixed and depend on the country in question.

Ofcom carefully contextualises its interpretation of the analysis. Ofcom clearly sets out the role of its discussion paper in informing Ofcom's policy: the discussion paper may be used "to inform its views", but does "not represent the concluded position of Ofcom on particular matters".[12]

Furthermore, Ofcom concludes that its analysis "finds no evidence that increases in market concentration are associated with increases in investment or average download speeds".[13] This is distinct from taking the analytical results at face value and concluding that concentration reduces investment and average download speeds.

Ofcom also recognises that its results "do not imply that the impact of any potential future consolidation from four to three MNOs will never result in better consumer outcomes",[14] and that historic relationships "may not be the best guide to any future impact".[15]

1.2 Previous studies have concluded that consolidation is beneficial for investment

Ofcom's findings are not consistent with those in the existing literature. Ofcom has identified six existing empirical studies. These studies find:

- either a positive effect on operator-level investment from increased concentration, or no evidence of any effect;[16]
- generally no evidence of an effect on industry-level investment, although one study finds a negative impact on industry-level investment in the short-run and a positive impact in the long-run;[17] and
- a positive effect on average download speeds from consolidations.[18]

We first discuss the previous studies that investigate the link between market structure and investment, before considering previous studies of the relationship between market structure and average download speeds.

1.2.1 Market structure and investment

Five of the studies referenced by Ofcom investigate the relationship between market structure and operator- or industry-level investment. Similar to Ofcom's discussion paper, these studies use panel data (i.e. data on multiple countries or

12 Ofcom (2020a) page 1
13 Ofcom (2020a) paragraph 10.1
14 Ofcom (2020a) paragraph 10.2
15 Ofcom (2020a) paragraph 10.3
16 Ofcom (2020b) Technical Annexes: Market structure, Investment and Quality in the Mobile Industry, Table A1.1.
17 Ofcom (2020b) Table A1.1.
18 Ofcom (2020b) paragraphs A1.10 – A1.12.

MNOs across numerous years). The studies use data over different time horizons at different frequencies.[19]

Aside from differences in the length and frequency of the time series data used, the main differences between the existing studies and Ofcom's discussion paper are:

- Each of the five existing studies considers investment at the operator-level, whereas Ofcom only investigates investment at the industry-level.
- Ofcom studies the relationship between market structure and investment *per capita*. The existing literature either studies investment *per connection/subscription* (Frontier Economics, 2015; WIK Consult, 2015; Genakos et. al., 2018[20]), or total investment at the country or operator level (Jeanjean and Houngbonon, 2017[21]; GSMA, 2020). As we discuss in Section 4, this is a crucial difference between Ofcom's discussion paper and the existing literature.
- Ofcom uses investment data provided by GSMAi (as does Frontier Economics (2015) and GSMA (2020)), whereas other studies use a diverse range of investment data sources.[22] It is important to note that industry-level investment is not reported, it is estimated. GSMAi's estimate of industry-level investment is likely to differ from the estimates of other data providers. The accuracy of any of the sets of estimates is ultimately difficult to verify.

Ofcom does not attempt to reconcile the differences between its findings and those of the existing literature. Rather, Ofcom states that analysis of investment at the operator-level is not insightful, and that it is "not possible to draw inference from existing industry-level investment studies."[23] The main criticisms that Ofcom levels at the existing literature are discussed below:

- Ofcom criticises existing studies for studying operator-level investment. The issue identified by Ofcom is that operator-level investment will necessarily increase following consolidation as consolidation increases the size of the average operator.[24] This is a valid concern, but it does not apply to studies which control for this effect by studying investment per connection (rather than each operator's total investment). Most of the existing studies use investment per connection. As will be later discussed at length in Subsection 4.1, investment per connection (at the operator level) translates more directly into quality of service than Ofcom's measure of investment (industry-level investment per capita).
- Ofcom states that previous studies "have not accounted for the dynamics of multi-year investment plans and technology cycles".[25] These dynamics can be

[19] For example, Frontier Economics (2015) uses quarterly data between 2000 and 2014, WIK Consult (2015) uses annual data between 2005 and 2013, and GSMA (2020) uses quarterly data between 2011 and 2018.

[20] Genakos, Valletti and Verboven (2018) Evaluating market consolidation in mobile communications, 33(93), pp. 45 – 100

[21] Jeanjean and Houngbonon (2017) Market structure and investment in the mobile industry, Information Economics and Policy, 38(C), pp. 12 – 22

[22] WIK Consult (2015) use data provided by New Street, Jeanjean and Houngbonon (2017) use data provided by Yankee Group, and Genakos et. al. (2018) use data provided by Bank of America.

[23] Ofcom (2020a) paragraph 2.5

[24] Ofcom (2020b) paragraph A1.3

[25] Ofcom (2020a) paragraph 3.24

modelled by an equation in which investment today is a function of past levels of investment (and other variables). Ofcom's models follow such an approach. However, so do most of the existing studies. Frontier Economics (2015), WIK Consult (2015), and Jeanjean and Houngbonon (2017) present models which reflect the dynamic nature of investment plans, while Genakos et. al. (2018) report that their results do not depend on whether the dynamics are modelled.

1.2.2 Market structure and average download speeds

Two of the studies referenced by Ofcom investigate the relationship between market structure and average download speeds.[26] The first of these studies, GSMA (2017) is a case study of the 2012 Three–Orange merger in Austria, while the second, GSMA (2020) is a panel data model of the relationship between market structure and average download speeds. GSMA (2017) concludes that the Austrian merger resulted in a positive and statistically significant effect on the 4G coverage and average download speeds of Three and its competitors. GSMA (2020) similarly concludes that 4G coverage and average download speeds are greater in more concentrated markets.

Ofcom offers a discussion of the "significant limitations" of both studies.[27] Ofcom criticises both the methodology and data sources used by GSMA (2017). We are unable to fully assess these criticisms as much of the relevant detail is discussed in the annex to GSMA (2017), which is not available to us. The data limitations of GSMA (2017), as described by Ofcom, appear to be significant. However, this does not necessarily mean that the conclusions of GSMA (2017) are false.

In respect of the GSMA (2020) study, we note that we do not agree with several of Ofcom's criticisms.[28] In addition, Ofcom's description of the GSMA (2020) study's methodology is also, in some places, inaccurate.[29] Furthermore, most of Ofcom's criticisms relate to the study's analysis of the link between average download speeds (and coverage) and concentration (as measured by HHI). This is a related, but ultimately distinct, issue to the impact of consolidation on average download speeds.

[26] GSMA (2020) and GSMA (2017) Assessing the impact of mobile consolidation on innovation and quality: An evaluation of the Hutchison/Orange merger in Austria

[27] Ofcom (2020b), paragraph A1.13

[28] For example, Ofcom's lead criticism of the GSMA (2020) study is that it uses the within estimator instead of the LSDV estimator. The criticism is not valid as both estimators produce identical coefficient estimates (see Verbeek, M. (2012) A Guide to Modern Econometrics (Fourth Edition), pp. 377).

[29] For example, Ofcom state that GSMA (2020) study use pooled OLS models. This is not correct, the study uses fixed effects models, which are better suited to the research question at hand.

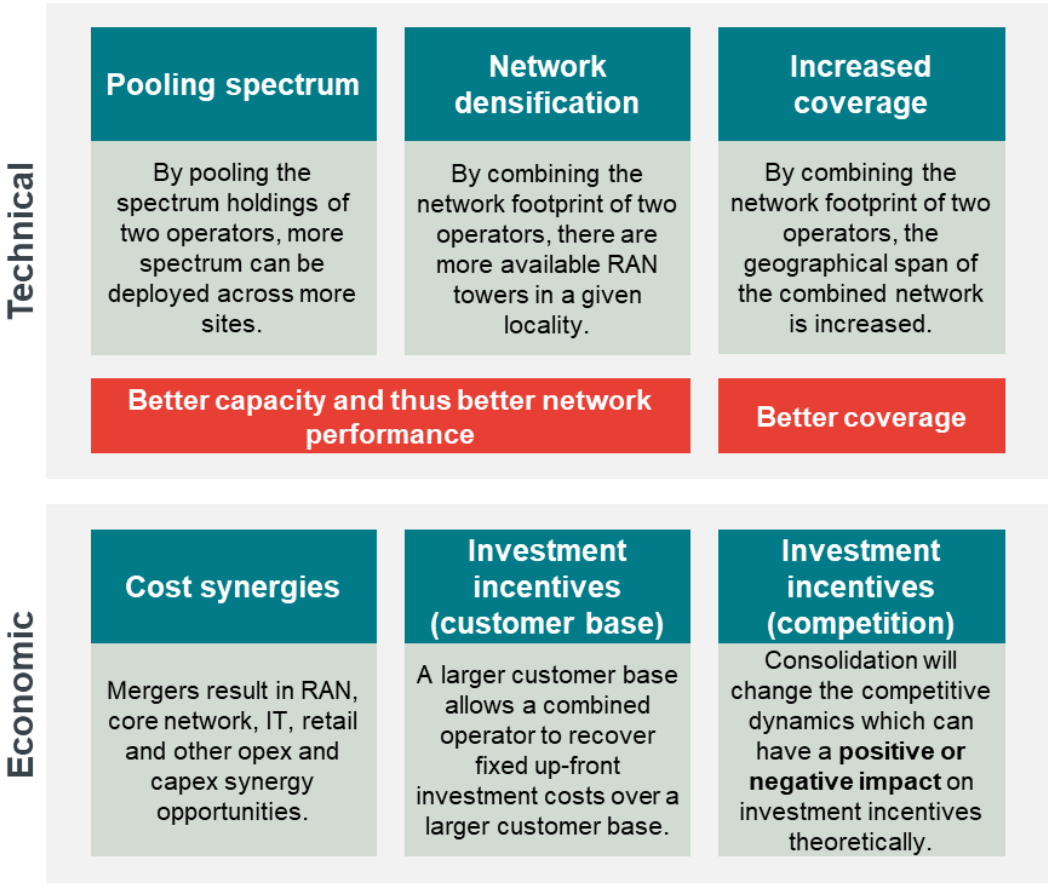
2 CONSOLIDATION CAN IMPROVE CONSUMER OUTCOMES

We begin our study of the impact of consolidation on consumer outcomes by considering the mechanisms by which consolidation may result in improved network performance and coverage. Having considered the theoretical impact, we then discuss the empirical challenge of quantifying consolidation's effect on consumer outcomes and present the results of our econometric analysis.

2.1 Consolidation can improve network outcomes for technical and economic reasons

Consolidation among MNOs can improve network performance and network coverage for technical and economic reasons. Figure 5 summarises the technical and economic processes at work, each of which is discussed in further detail below.

Figure 5 Summary of the possible mechanisms linking consolidation to improved quality



Source: Frontier Economics illustration.

2.1.1 Consolidation can improve capacity and coverage

Network capacity is an important determinant of network quality. Holding everything else fixed, an increase in capacity will improve network performance (download and upload speeds, latency and network reliability). Consolidation can generally improve capacity through two mechanisms: spectrum and network densification.

When two MNOs merge, the opportunity exists for the merged entity to pool the merging parties' spectrum holdings together. This means that more spectrum is deployed at each site in the combined network. The more spectrum that is deployed, the greater the network's capacity (holding everything else constant).[30]

In addition to increasing the amount of deployed spectrum, consolidation may also allow operators to make more efficient use of spectrum for the following reasons:

- A merged entity should have a more diverse spectrum portfolio. As such a merged entity may be able to deploy a more efficient "mix" of spectrum than would have been possible for the two smaller independent networks to achieve. Spectrum "mix" refers to the blended use of low frequency spectrum (which is important for coverage) and high frequency spectrum (which has greater capacity but poorer propagation characteristics).
- Pooling spectrum resources together also presents better opportunities for spectrum re-farming. While operators need to continue to provide 2G services for some time, the merged entity will be able to reduce the aggregate amount of spectrum dedicated to 2G, while re-farming more spectrum for 4G and ultimately for 5G.

In addition to greater, and more efficient, deployment of spectrum, consolidation can also improve network capacity through network densification. When two network operators merge, the merged entity will evaluate its sites estate. In areas where both the standalone networks have coverage, the merged entity might remove some duplicate sites (discussed below), but would generally continue to operate more sites than either of the standalone networks. This would result in a denser network "grid" of sites.

Another important dimension of quality is network coverage. When two independent networks merge, sites will be retained in localities where one of the standalone networks is present, but the other is not. This increases the geographic spread of the merged entity compared to either of the standalone networks.

2.1.2 Consolidation can lead to synergies and may improve investment incentives

In addition to the technical reasons why consolidation can improve consumer outcomes, there are also economic reasons which could result in an improvement in consumer outcomes.

[30] For example, suppose Operator A and Operator B merge. Pre-merger, Operator A's spectrum holdings are only deployed at Operator A's sites (likewise for Operator B). Post-merger, Operator A's spectrum is deployed at its sites and those previously belonging to Operator B (and likewise for Operator B). This increases the amount of spectrum deployed at each site.

Consolidation may allow the merged entity to achieve cost synergies. Cost synergies arise because the merged entity can eliminate duplication which occurs across the standalone networks. The synergies are particularly significant in network costs, as consolidation allows operators to remove duplicate sites. But they also arise across other parts of business, such as IT systems, retail and back-office functions. Synergies are possible in terms of both investment expenses and operating expenses. Cost synergies imply that a specific level of network quality is achievable at lower total cost for a consolidated network than for the sum of two standalone networks.

Consolidation may also impact investment incentives through two channels:

- through a change in the size of the customer base; and
- through a change in the competitive dynamic of the market.

If two networks merge, the merged entity will have more customers than either of the two standalone networks. Scale matters in the mobile market as a significant portion of investment and operating costs are fixed. The merged entity can spread fixed costs over a larger customer base, and thus can achieve a smaller unit investment cost (for any given investment project). Smaller unit investment costs mean that investments that were not profitable for the two standalone networks may become profitable for the merged entity. Therefore, investment incentives in the mobile market are stronger for larger networks than smaller networks (holding everything else constant).

However, when a network becomes larger due to consolidation, it is not the case that "everything else is held constant". Consolidation will alter the competitive dynamic between operators, which has its own impact on investment incentives.

The impact of consolidation on investment incentives, via the competitive dynamic mechanism, may either be positive or negative in theory. There are two opposing effects at work:

- The **Schumpeterian effect**. Classic microeconomic theory dictates that firms with a larger market share are more likely to have market power. If an investment allows a firm to make greater profits (because the benefits of the investment are valued by consumers), then a firm with a greater market share is more likely to make the investment since there is a reduced prospect of the greater profits being competed away.
- The **escape competition effect**. According to this dynamic, firms with a larger market share are less likely to investment. The rationale is that there is a reduced incentive to invest in a "technological breakthrough" which allows a firm to "leapfrog" its rivals. This is because a firm with a larger market share will in theory be more profitable than a firm with a smaller market share – this reduces the size of the "prize" from leapfrogging rivals.[31]

It is ultimately an empirical question at what level of concentration investment is maximised. To summarise, investment incentives are greater when a mobile operator has a larger customer base (holding competitive dynamics constant). However, consolidation's impact on the competitive dynamics may accentuate or

[31] See Aghion, Bloom, Blundell, Griffith, Howitt (2005) "Competition and Innovation: an Inverted-U Relationship" for more details

reduce the positive impact of consolidation on investment incentives via the scale effect.

2.2 But as each consolidation is unique, modelling "the impact" of consolidation is challenging

As discussed above, the theoretical relationship between consolidation and investment is ambiguous and depends on the relative strength of the two effects set out above. Therefore, the impact of consolidation on investment is an empirical one.

However, estimating this effect empirically is challenging for a number of reasons[32].

First, there are few cases of consolidation to use in the analysis. There have been relatively few cases of consolidation in European mobile markets. The fewer incidences of a type of "event", the harder it is to estimate the average effect of that type of event (holding everything else constant).

Figure 6 lists the five recent European MNO mergers. These are the only MNO mergers in the last 10 years[33]. Although there is no fixed rule as to how many mergers is "enough", it is uncontroversial to conclude that having just five mergers in the sample is a significant empirical challenge.

Figure 6 Recent European MNO mergers

Country	Merger completion	Merging parties
Austria	2013 Q1	Orange and Three
Germany	2014 Q4	E-Plus and O2
Ireland	2014 Q3	O2 and Three
Italy*	2016 Q4	Three and Wind
Netherlands	2019 Q1	Tele2 and T-Mobile

Source: *Frontier Economics based when the GSMAi recognises when the merging parties become a single entity*

Note: ** The Three and Wind merger coincided with entry from a new player*

The merger in the Netherlands took place in 2019 – the last year of the period covered by the Ookla data, which makes it practically impossible to assess the impact of the merger. In Italy the merger was immediately followed by an entry, conflating the two impacts. Hence, there are effectively only three countries in the sample which can provide useful insights into the impacts of consolidation on quality.

Second, there may be 'omitted' variables, i.e. variables which are difficult to control for in a systematic way[34] (such as network sharing, planning restrictions, etc), which affect investment and average download speeds. The exclusion of these variables means that we cannot fully account for every process which affects investment or average download speeds in our statistical analysis. This, in turn,

[32] Each of these challenges apply to Ofcom's analysis as much as they do to any other analysis of consolidation among European MNOs.

[33] This is the time period that coincides with the time period covered by the available data on download speeds. The data was provided to Ofcom by Ookla.

[34] We cannot control for these omitted variables because the data is not available for us, or because variable does not lend itself to measurement/ quantification.

makes it harder to identify the impact of the variables we do observe, as they will be affected by the omitted variables. As a result, econometric modelling may find no evidence of a (statistically significant) relationship between consolidation and investment/average download speeds, even in the presence of an actual relationship between the two.

Finally, there are multiple channels through which consolidation could potentially impact consumer outcomes. It is likely that the effect of each consolidation will be unique. Indeed, this is precisely what is indicated by the case studies which we present in Section 3. This, however, is problematic for econometric modelling, as an implicit assumption of estimating a "consolidation impact" is that there is a consistent effect of consolidation on the outcome being modelled. The greater the variability (i.e. individuality) of the impact of each consolidation, the harder it is to detect the *average* effect of consolidation on consumer outcomes.

2.3 Our econometric results find no relationship between consolidation and quality

The small number of cases of mobile market consolidation and the idiosyncratic nature of the integration process that follows means that quantifying the impact of consolidation on quality is challenging. Notwithstanding this challenge, we set out what we consider to be the most appropriate approach to assessing the impact of consolidation on quality using econometrics.

Specifically, we estimate the effect of consolidation on investment per connection and average download speeds. We find neither a positive nor negative statistically significant effect of consolidation on both outcomes. The following sections describe the essential features of the econometric analysis, further details are available in Annex A.

2.3.1 No evidence of a relationship between investment per connection and consolidation

We study the impact of consolidation on the investment per connection of MNOs. We use a panel dataset of quarterly data on MNOs from 30 European countries spanning 2009 to 2020. The dataset includes MNO and mobile market data provided by GSMAi as well as non-mobile market data (e.g. demographic and macroeconomic data) from various sources.

The key aspects of our modelling approach are as follows:

- **We use operator level data as opposed to country level data.** GSMAi estimate quarterly industry level (i.e. country level) investment. We cannot be certain of the accuracy of these estimates, which is one reason why we prefer to work with operator level data. This data is reported by the operators themselves, meaning we can be assured of the accuracy of the investment measure we are using. Furthermore, operator-level investment is the more relevant outcome since the quality of service received by a consumer is determined by their operator's investment decisions, not the aggregate investment decision of MNOs in the market.

- **Our sample covers the "mature" (or "data-focused") phase of mobile markets only.** Industry level investment estimates are available from 2000 onwards, whereas operator level investment data are widely available from only 2009 onwards. As such, we work with a shorter time horizon. However, an advantage of working on the shorter time horizon is that we focus on the "mature" phase of mobile markets (i.e. the period when mobile market penetration had plateaued). This period is more representative of the future of mobile markets, than 2000 – 2009 when mobile markets were in an active growth phase.
- **We measure investment as "investment per connection".** We note that Ofcom's discussion paper uses "investment per capita" rather than "investment per connection". We consider investment per connection to be the more relevant determinant of network quality than investment per capita. This issue is discussed in more detail in Section 4 below.

We estimate panel regression models using the quarterly data on MNOs described above. By using a particular type of panel model, known as a fixed effects model, we control for all time-invariant differences between each MNO. For example, we can control for the fact that investment decisions might be different for MNOs located in a particular country or for MNOs which belong to a particular MNO group. In fixed effects models, the impact of consolidation is detected by comparing changes in investment for MNOs in countries which experienced consolidation before and after the consolidation.

We estimate two types of models. In each model we account for seasonality in investment (the pattern of investment is being higher in certain quarters of the year), dynamics in investments (the dependency of investment today on investment in previous quarters)[35], the long-run trend in investment over time[36], and factors that influence investment over than market structure[37].

The difference between our two model is as follows:

- **Specification 1** estimates separate impacts on investment per connection between entries and mergers. These impacts are assumed to be constant over time.
- **Specification 2** is more flexible. Whereas Specification 1 assumes that there is a constant impact of mergers on investment per connection, Specification 2 allows the effect of mergers (and entries) to vary over time. However, this specification is more "demanding" on the data, therefore it is not unambiguously superior to Specification 1.

Figure 7 contains the results of assessing the impact of entries and mergers on investment per connection. We find that both coefficients are not statistically

[35] In our preferred specification, we include five lags of investment per connection, as these lags are statistically significant in their own right, whereas the sixth lag is not. However, our findings do not depend on whether lags are included or the number of lags if they are included.

[36] We experiment with a linear time trend and time (quarter) fixed effects. Our results do not depend on which approach is adopted.

[37] We include the following control variables: population density; percentage of the population that is rural; unemployment rate; logarithm of GDP per capita; nationwide 4G population coverage; an indicator of whether nationwide 4G population coverage is greater than 90%; percentage of the country's mobile connections that are prepaid, and the smartphone adaptation rate (%) for the country.

different form zero. Therefore, in our econometric analysis, we find no evidence of a positive or negative impact of consolidation on investment per connection.

Figure 7 Econometric analysis of consolidation's impact on investment per connection (Specification 1)

	Impact of entry	Impact of merger
Coefficient estimate	0.034	-0.021
Standard error	0.072	0.101

Source: Frontier Economics analysis.

*Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% significance levels respectively.*

For the sake of brevity, we only report the results of Specification 2 in Annex A. This is because the results of the specification are consistent with Specification 1. That is, there is no statistically significant relationship (positive or negative) between investment per connection and consolidation in all but one of the specific quarters following a merger.

It appears that, if anything, the econometric analysis would suggest that mergers do not have a material impact on capex per connection. In practice, as mergers are in general expected to lead to some capex cost savings between the merging parties, the analysis would be consistent with the merging parties re-investing at least some of the expected merger capex savings. All else the same, the evidence would therefore suggest that the subscribers of the merging parties could expect to see an improvement in the quality of service, with the impact on other mobile subscribers depending on the reaction of the non-merging parties.

2.3.2 No evidence of a relationship between average download speeds and consolidation

To study the impact of consolidation on the average download speeds of European MNOs, we again use a panel dataset of quarterly data on MNOs from the same 30 European countries. Average download speed data is provided by Ookla, who collects data from user-initiated on-device speed tests. This data is only available across all 30 countries for the period 2011 to 2019. This means our average download speeds analysis is based on a slightly smaller sample than our investment per connection analysis.

We estimate the same two specifications that we applied to investment per connection. The only differences in methodology between our analyses of the two outcomes are: the outcome variable is (necessarily) different, and we use a different set of control variables.[38]

Figure 8 reports the results of using specification 1. As with investment per connection, we find no evidence of a positive or negative impact of entries or mergers on average download speeds.

[38] We use a different set of controls as some of the data sources used by Ofcom for control variables are not available to us. We include the following control variables: population density; percentage of the population that is rural; nationwide 4G population coverage; an indicator of whether nationwide 4G population coverage is greater than 90%, and the smartphone adoption rate (%) for the country.

Figure 8 Econometric analysis of consolidation's impact on average download speeds – specification 1

	Impact of entry	Impact of merger
Coefficient estimate	-0.010	0.019
Standard error	0.016	0.033

Source: Frontier Economics analysis.

*Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% significance levels respectively.*

Again, for the sake of conciseness, the results of Specification 2 are reported in Annex A. However, the results of that specification are consistent with Specification 1. That is, there is no evidence of a statistically significant relationship between average download speeds and consolidation in any post-merger periods.

In summary, we do not find any statistical relationship between mergers and investment per connection, or average download speeds. However, our inability to detect and quantify these relationships does not mean that such relationships do not exist. As set out earlier, it is challenging to assess the impact of consolidation using econometrics because: the impact of different consolidations are likely to differ from one another, and there are only a few countries which have experienced mergers. Therefore, in the next section, we continue to assess the relationships of interest by adopting a mixed methods approach.

3 AUSTRIA'S AND IRELAND'S MERGERS SHOW THAT CONSOLIDATION IMPROVES QUALITY

The previous section sets out the theoretical mechanisms by which consolidation could impact quality, and explained that empirically identifying the relationship between consolidation and quality using econometrics is challenging. This section adopts a mixed methods approach to evidencing this relationship. Specifically, data and the underlying context is brought together to describe the impact of MNO mergers in Ireland and Austria. We focus on these countries as Three was one of the parties involved in both mergers and therefore was able to provide additional information on the merger process in each case.

3.1 A mixed methods approach, which combines quantitative and qualitative analyses, is a well-established tool to conduct evaluations

A mixed-method approach combines both qualitative and quantitative methods. The HM Treasury Magenta Book, which sets out the UK government's view on best practice in policy evaluations, states:

> *"No one evaluation approach can appropriately evaluate all types of intervention… and often approaches may need to be combined".*[39]

The guidance states that using several approaches results in a more complete evaluation given each approach has its advantages and disadvantages. Moreover, the guidance specifies that a purely quantitative approach may not be appropriate in situations where impact is highly context-dependent or where there are data limitations. This is especially important when considering the impact of mergers since these impacts are likely to be influenced by market characteristics, some of which are unobservable/ difficult to measure. The case studies may be used as a deep dive into specific cases in order to better understand the context and the drivers of specific outcomes.

Following established practice set out in the Magenta Book, we combine quantitative and qualitative approaches in order to produce a more complete assessment of the impact of mergers in the mobile market.

[39] HM Treasury (2020) Magenta Book: Central Government guidance on evaluation. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf

3.2 Three Ireland's consumer outcomes have improved after the merger

The previous subsection explained the need to follow a mixed methods approach to studying the impact of consolidation on consumer outcomes. This subsection uses such an approach to investigate how the merger between Three and O2 in Ireland led to an improvement in consumer outcomes.

The context to the merger is discussed first, followed by details of the integration process between the two networks. The subsection finishes by showing that consolidation is linked to greater investment per connection, faster average download speeds and wider coverage.

3.2.1 Before the merger Three was constrained by a lack of spectrum and its small scale

A merger between Three and O2 was announced in June 2013. Before the merger, there were four MNOs in Ireland: Vodafone (with a 42% market share), O2 (26%), Eir (21%), and Three (12%).[40]

The last entrant to the market, Three won a 3G licence in 2002 and launched commercially in 2005. As the most recent entrant, Three had a scale disadvantage compared to each of its rivals, and it also relied on a roaming agreement with Vodafone for 2G coverage.

By the time of the merger, Three had extensive 3G coverage, but its 4G rollout was limited (30% population coverage) compared to market leaders Vodafone and Eir (57% and 58% respectively). Meanwhile, O2 had invested in 4G spectrum but it had not invested significantly in rolling out a 4G network.

Furthermore, Three was also disadvantaged, relative to competitors, due to its limited sub-1 GHz spectrum holdings. After the 4G spectrum auction, Three held only 2x5 MHz of 900 GHz spectrum (and no 800 MHz spectrum). In contrast, O2 , Eir, and Vodafone each had 2x20 MHz of Sub-1 GHz spectrum (2x10 MHz of 800 MHz and 2x10 MHz of 900 MHz).

Three expected, that by combining its spectrum holdings with O2's holdings, network coverage would improve faster than would be the case had the two networks operated independently.[41] Three also anticipated that investment would increase as a result of the merger due to an improvement in cash flow.[42] Furthermore, Three's business case foresaw synergies in opex, capex (i.e. investment expenses), and tax liabilities.[43] Synergies were expected across the business, with 60% to 70% of the synergies being unrelated to the network.

The European Commission approved the merger in 2014, conditional on Three complying with three remedies. Three was required to:

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40 GSMAi estimates of market shares based on number of mobile connections, 2014 Q2.

41 European Commission, DG Competition (2014) Hutchison 3G UK – Telefonica Ireland (Case M.6992) Decision, paragraph 746 (b).

42 *Ibid*, paragraph 764 (a).

43 *Ibid*, paragraph 751.

- commit up to 30% of its capacity to two MVNOs;
- offer to divest spectrum to one of the same two MVNOs (until 2026); and
- conclude a network sharing agreement with Eir.

The merger reduced the number of MNOs from four to three. Immediately after the merger, Vodafone remained the largest network (42% market share), while Three became the second-largest network (37%) with Eir in third place (21%).

3.2.2 Integrating Three's and O2's networks was challenging

As a comparison between the Irish and Austrian case studies will show, integration processes take different amounts of time to complete. The integration process between Three and O2 in Ireland is an example of a more complex process.

Before the merger, O2 was party to a passive network sharing agreement with Eir. Meanwhile, as a result of a merger clearance remedy, Three was required to sign a new network sharing agreement with Eir. The implication of these agreements was that there was comparatively little progress on integrating the two networks during the two years following the merger. Instead, managerial and technical effort was expended on unwinding the Eir – O2 agreement and planning the deployment of sites under the Three – Eir agreement.

Another complication in Ireland was inconsistencies in the RAN equipment used by Three and O2. O2 used Ericsson equipment for its sites, while Three used a different vendor for its 3G and 4G sites. This posed a problem as, in order to make the most efficient use of the spectrum available, an operator needs to use equipment from the same vendor across its sites. As a result, as part of the integration process, O2's non-2G equipment was swapped out to be consistent with Three's.

Three was only able to achieve a single, unified voice network in 2018 – four years after the merger. While the integration was substantially completed in 2019, Three is still in the process of decommissioning some duplicate sites[44]. That is, there remain some merger synergies which are yet to accrue.

3.2.3 Consolidation preceded greater investment, faster speeds and wider coverage for Three customers

Figure 9 plots investment per connection for Three, O2 and Eir over the period between 2010 and 2020 (data is not available for Vodafone). The vertical grey dashed line indicates when Three and O2 merged. Before the merger, Three's investment per connection was approximately double the level of O2's investment per connection. This reflects the scale disadvantage of Three (as the smallest of four operators) compared to O2. The teal line represents the investment per connection for the sum of Three and O2 (before the merger) and the merged entity (post-merger).

There is a discontinuity in the level of investment per connection immediately before and after the merger. The discrete jump in investment per connection likely

[44] This timeframe is due to lengthy rental agreements, i.e. Three is only able to decommission sites after the rental agreements have expired

represents the combined effects of investments in the rollout of 4G and investments necessary to integrate the standalone networks. Investment per connection subsides after this jump. However, in the long-run, there is an upward trend in the combined investment per connection of Three and O2. For example, average investment per connection for Three and O2 was €48 in 2010, rising to €59 in 2016 and €80 in 2020. Investment per connection for Eir rose from €60 in 2010 to a peak of €113 in 2013, but fell sharply to €52 in 2014, and subsequently further gradually declined to €19 in 2020.

Figure 9 Investment per connection for Three, O_2 and Eir, 2010 - 2020

[✂]

Source: *Frontier Economics analysis of GSMAi data and Three Ireland internal data.*

Note: *Eir investment data, and mobile connection data for all operators, provided by GSMAi. Three and O_2 investment data provided by Three Ireland. Investment data for Vodafone Ireland is not available.*

Impact on average download speeds

Figure 10 shows the average download speeds achieved by each Irish MNO over the period 2011 to 2021.[45] Before the merger, O2 had the slowest average download speeds of any of the Irish networks, and Three was the second slowest. In the post-merger period until 2019, Three's average download speeds improved relative to Eir, allowing Three to become the second fastest network in Ireland. This is even though the integration of the standalone Three and O2 networks was still underway during this period. Once the integration of these networks was completed, there was a clear improvement in Three's average download speeds relative to both Vodafone and Eir. Since 2020 Q4, Three has had market leading average download speeds.

Figure 10 Average download speeds (Mbps) for each Irish MNO, 2011 – 2021

[✂]

Source: *Frontier Economics analysis of Ookla data.*

Note: *Data for 2011 to 2019 has been provided directly to Frontier Economics by Ookla, while data for 2020 and 2021 has been provided indirectly via Three Ireland.*

There are several merger-related impacts that potentially explain why Three's average download speeds have improved.

The first reason is the number of sites available to customers increased – which impacts both coverage and network performance. Before the merger, O2 had 1,850 sites and Three had 1,200 sites. The merged entity today has 2,350 sites. As a result of the merger, Three customers are served by 96% more sites than they were before the merger, while O2 customers are served by 27% more sites than they were pre-merger. At the same time, the merged entity has so far decommissioned 400 duplicate sites, resulting in opex and capex savings. The increase in the number of sites not only improves coverage (as is shown below) but also performance, as the network becomes "denser". A denser network has

[45] The vertical grey dashed line indicates when the merger between Three and O2 took place.

more capacity, which holding everything else constant, implies greater performance.

The second relates to the RAN equipment deployed at the sites. As discussed above, Three refreshed the equipment deployed at former O2 sites as the standalone networks used RAN equipment from different suppliers. As the performance of RAN equipment improves over time in line with innovations in the industry, the result of refreshing the RAN equipment was that more technologically-advanced equipment was deployed across all sites. Arguably, this upgrade to more advanced technologies was carried out faster than it would have been done otherwise, i.e. in the counterfactual in which Three did not need to merge the two networks.

The third relates to spectrum availability: both in terms of total spectrum holdings, but especially in relation to sub-1 GHz spectrum. Pre-merger Three customers had no access to 800MHz spectrum, which is critical for 4G coverage, while O2 had 2x10 MHz of 800 MHz 4G spectrum. After the merger, this spectrum could be utilised across both Three and O2 customers. Furthermore, Three and O2 each had 2x5 MHz and 2x10 MHz of 900 MHz spectrum respectively. Following the merger this spectrum could be pooled across both customer bases and also re-farmed more efficiently for 3G and 4G.

Impact on coverage

Figure 11 shows the improvement in coverage achieved by the integration of Three and O2. Before the merger, O2 had a 2G network whereas Three did not (therefore, Three was unable to serve 2G customers). O2's 2G network covered 86.3% of the population (indoors) at the time of the merger. As of 2021, this had increased to 99.7%.

On the other hand, before the merger Three had a 4G network (covering 43.1% of the population indoors) whereas O2 had not yet rolled out 4G. By 2021, Three's 4G network covered 97.6% of the population. As a result of the merger, Three customers gained access to O2's 2G network (directly, without national roaming) while O2's customer gained access to (what has become) a nationwide 4G network.

Pre-merger, both O2 and Three had 3G networks which covered c. 2 in 3 members of the population indoors, the combined 3G network now covers 99% of the population indoors.

It is likely that absent the merger Three and O2 would have had lower coverage, as they both had fewer coverage sites and less sub-1 GHz spectrum. This is particularly the case for Three, given it only had 2x5 MHz of 900 MHz spectrum before the merger. Moreover, Three's and O2's incentives to increase coverage would have been limited due to their smaller scale.

Figure 11 Three and O2 coverage (pre-merger) and Three coverage (post-merger)

Indoor population coverage	Three (2014)	O_2 (2014)	Three and O_2 (2021)
2G	0%	86.3%	99.7%
3G	66.3%	60.9%	99.0%
4G	43.1%	0%	97.6%

Source: Frontier Economics analysis of Three Ireland internal documents.

3.3 Consumer outcomes have improved in less than two years after the Three-Orange merger

The previous section provided an example of an improvement in quality post-merger, once the networks of the merging parties have been integrated. As already discussed, integration was a protracted process in Ireland. However, this section demonstrates that each integration process is unique. This section shows that the merger between Orange and Three in Austria led to prompt improvements in consumer outcomes due to the relative speed of the network integration there.

3.3.1 Three and Orange lagged A1 Telekom and Magenta Telekom before merging

Before the merger, there were four MNOs in Austria: A1 Telekom (40% market share), Magenta Telekom (30%), Orange (17%) and Three (13%).[46] A merger between the two smallest operators, Orange and Three was agreed in February 2012.

Three was granted a 3G licence in 2000, and launched their network in 2003. As the joint-newest entrant in the Austrian market (alongside tele.ring – now a Magenta Telekom subsidiary), Three was disadvantaged due to its limited spectrum holdings which were 3G-only. Orange's proposition was also weaker in certain areas compared to A1 Telekom and Magenta Telekom. While Three had extensive 3G coverage, Orange had a limited 3G network footprint compared to competitors. For example, at the end of 2012, Orange's 3G network covered 35% of the population while its competitors had at least 81% 3G coverage. In terms of 4G, at the time of the merger, Three's coverage was similar to A1 Telekom's coverage (32% and 30% respectively), whereas Orange had an extremely limited 4G footprint.

As in Ireland, Three predicted that by combining its spectrum holdings with Orange's holdings, and by deployed the combined spectrum across their combined estate of sites, network capacity and coverage would improve.[47] Three also expected that the merger would allow it to make efficiency gains through economies of scale, and reduce its scale disadvantage compared to the leading networks.[48] Three also expected the merger to result in a faster rollout of 4G, given

[46] GSMAi estimates of market shares based on number of mobile connections, 2012 Q4.

[47] European Commission, DG Competition (2013) Hutchison 3G Austria – Orange Austria (Case M.6497) Decision, paragraph 409.

[48] *Ibid*, paragraph 440 – 441.

that, absent the change in ownership, Orange would have been subject to financial constraints.[49]

The European Commission cleared the transaction in December 2012, conditional on three remedies. These remedies required Three to:

- divest spectrum to a potential new MNO, and to offer certain forms of support to that entrant (however, no new entrant was forthcoming);
- host up to 16 pay-as-you-go MVNOs; and
- complete one wholesale access agreement with an MVNO before completing the agreement.

The merger was completed in early 2013, reducing the number of operators from four to three. While the merger meant that Three's active subscriber base more than doubled from 1.3 million to 2.8 million, Three remained the smallest of the MNOs. The following section discusses how Three's average download speeds, coverage and customer satisfaction improved following the merger.

3.3.2 Consumer outcomes have improved rapidly post-merger

Unlike the integration between the standalone Three and O2 networks in Ireland, the integration between the Three and Orange networks in Austria was relatively straightforward. The integration of the two networks was completed in February 2014[50], fourteen months after the merger took place.

Impact on average download speeds

Figure 12 shows average download speeds for each Austrian MNO between 2011 and 2019. The vertical dashed line coincides with the merger between Three and Orange. Before the merger, Three (and Orange) had the slowest average download speeds among all operators. However, in mid-2014 around 18 months following the merger and shortly after network integration was completed, Three's average download speeds jumped from 4 Mbps to 21 Mbps (an increase of 425 percent). This was a result of Three's 4G rollout, which it completed ahead of the competition. After Three became the market leader in average download speeds, there appears to have been a competitive response from both A1 Telekom and Magenta Telekom who both improved their average download speeds to keep up with Three.

Figure 12 Average download speeds (Mbps) for each Austrian MNO, 2011 – 2019

[✂]

Source: Frontier Economics analysis of Ookla data.

Figure 12 only covers the period until 2019. However, more recent Ookla data indicates that Three is now the market leader in Austria in terms of average download speeds. Three won Ookla's 2021 Speedtest award for having the fastest

[49] *Ibid*, paragraph 429.

[50] https://www.telegeography.com/products/globalcomms/data/country-profiles/eu/austria/mobile.html

5G mobile network in Austria: Three's median 5G download speed was 183 Mbps compared to 145 Mbps and 111 Mbps for Magenta Telekom and A1 respectively.[51]

One implication of the merger was that the merged entity was able to make more efficient use of its spectrum holdings. Before the merger, Orange used its 1800 MHz spectrum to provide 2G connectivity. Following the merger, Three refarmed some of this spectrum for 4G. Three also combined the 1800 MHz spectrum dedicated to 4G with its 2600 MHz 4G spectrum using carrier aggregation.[52] The increased availability of spectrum for 4G plus the aggregation of that spectrum improves the capacity and efficiency, and thus performance of the merged entity's network that would not have been possible for either of the networks on a standalone basis.

Impact on coverage

Another implication of the merger is that the scale of the network grew, which has implications for both coverage and network performance. In terms of 4G, in August 2015, Three became the first MNO in Austria to upgrade all its sites to 4G. As such, Three covered 98% percent of the Austrian population, but Three also developed "one of the world's densest LTE networks."[53] Network density is an important determinant of network quality and will have been improved by retaining the optimal set of sites from each of the standalone networks.

The improvement in Three's coverage is visualised in Figure 13. It shows which parts of Austria were covered by Three's 4G network before the merger, and which parts are now covered by Three's 4G network. In 2012 Q4, Three's 4G network covered 31% of the Austrian population (outdoors). In around three years, the coverage of the network had expanded to 98% of the population (outdoors). Three's 3G coverage also improved. By the end of 2013, Three's 3G network had grown to 6,000 sites – 50% more than its standalone network.[54]

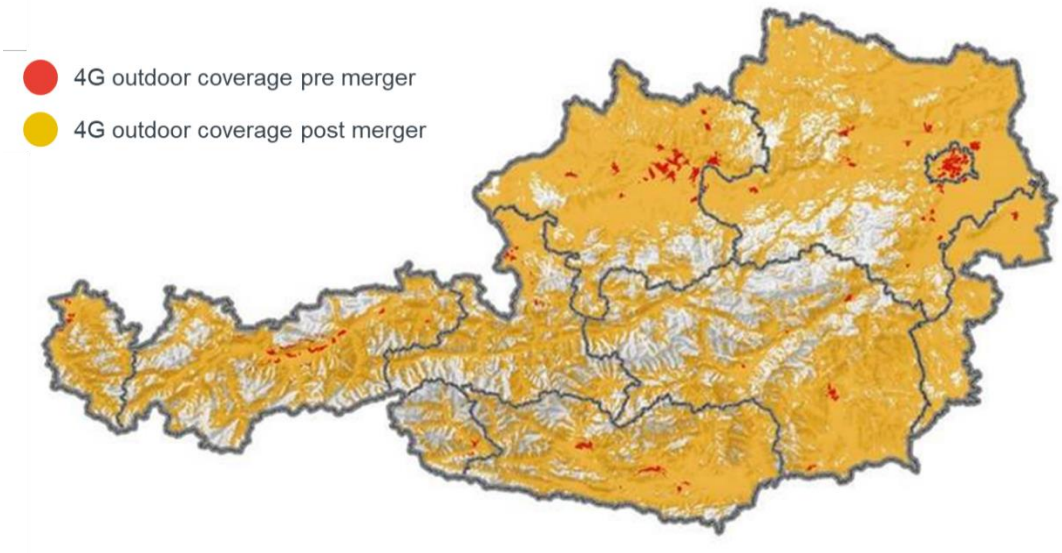
[51] https://www.speedtest.net/awards/austria/2021/?award_type=5g&time_period=q1-q2

[52] https://www.telegeography.com/products/globalcomms/data/country-profiles/eu/austria/mobile.html

[53] https://www.drei.at/de/ueber-uns/presse/presseaussendungen/detail_1241537.html

[54] https://www.telegeography.com/products/globalcomms/data/country-profiles/eu/austria/mobile.html

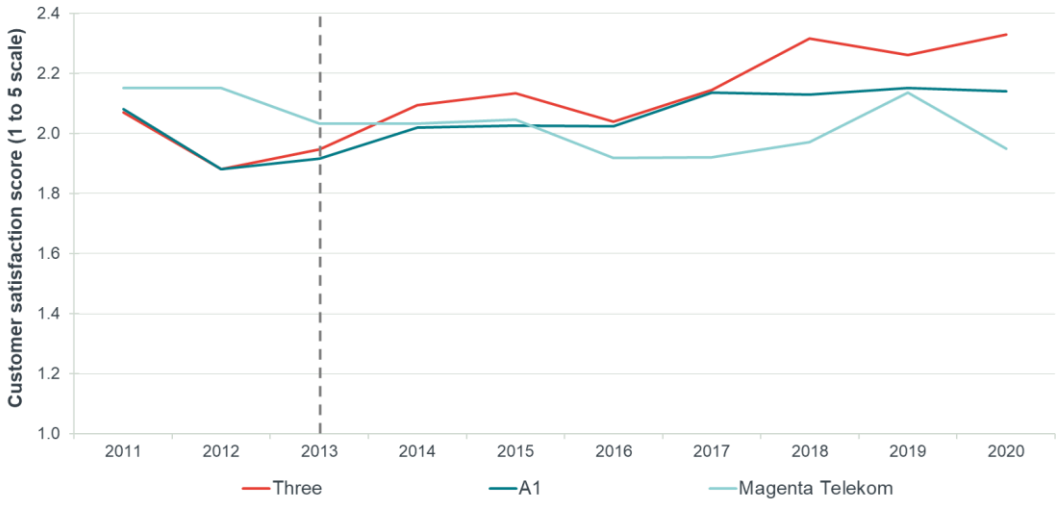
Figure 13 Three 4G outdoor coverage, pre- and post-merger



Source: Three Austria internal visualisation.

The improvements in Three's network quality (as measured by both average download speeds and coverage) has also translated into higher levels of consumer satisfaction. Figure 14 plots trends in consumer satisfaction survey results for Three, A1 and Magenta Telekom for 2011 to 2019. The vertical grey dashed line again represents when Orange and Three merged. The figure shows an absolute improvement in the satisfaction of Three customers (as reported by survey respondents) as well as a relative improvement in the satisfaction of Three customers (compared to A1 and Magenta Telekom customers). Before the merger, Magenta Telekom customers were more satisfied than Three customers, however, Three's customers have consistently been the most satisfied since the merger.

Figure 14 Consumer satisfaction survey results for each Austrian MNO, 2011 – 2019



Source: Frontier Economics analysis of data provided by Three Austria.

3.4 Consolidation benefits took different amounts of time to materialise

The previous two subsections have shown how Three's network performance and coverage improved in both Ireland and Austria following the mergers in those countries. In the case of Ireland, the improvements (particularly in relation to average download speeds) took several years to materialise, whereas in the case of Austria, the improvements were realised relatively quickly. This is symptomatic of the idiosyncratic nature of network integrations: some integration processes are smoother and faster than others.

A relevant question is: to what extent would the improvements in Three's quality have materialised had Three not merged with a competing operator? The preceding sections link the observed improvements in Three's quality to specific consequences of the consolidations in Ireland and Austria. This section provides a quantitative answer to the same question.

Figure 15 shows the average download speeds of Three Austria (between 2011 and 2019; the light blue line) and the same for Three Ireland (between 2011 and 2021; the grey line). The figure also shows the average download speeds of the "typical 3rd operator" and "typical 4th operator" in European four-player markets. We calculate the average download speeds of these typical operators by aggregating data on the 3rd and 4th operators (according to market share) in the seven European markets served by four MNOs.[55]

There are three important conclusions from Figure 15:

- Average download speeds of the typical 3rd operator in four-player markets grow faster than the average download speeds of the typical 4th operator in the same markets. This implies a positive link between scale (relative to the size of the market) and average download speeds growth.
- Shortly after the merger in Austria, Three Austria's average download speeds improved much more quickly than the average download speeds of the typical 4th and 3rd operator. It is possible that had Three not merged with Orange in Austria, Three Austria's average download speed improvement would be closer to the improvement of the typical 4th operator.
- After the Irish merger, Three Ireland's average download speeds broadly tracked those of the typical 4th operator until 2019. This may not be a surprise given that the integration of the standalone Three and O2 networks was an ongoing process throughout this period. However, in 2020 and 2021, once the network integration was substantially completed, the speed improvement achieved by Three Ireland is far in excess of (our estimate of) the speed improvement of the typical 4th operator. Had the merger not gone ahead in Ireland, the Three Ireland's speed improvement may have been lower (and more representative of the typical 4th operator).

[55] We use the most recent market share data for the relevant markets as per Telegeography. The seven European markets with 4 MNOs are: Denmark, Poland, Romania, Slovenia, Spain, Sweden and the United Kingdom. We weight the data on the 3rd or 4th largest operator in each of these countries based on the number of tests carried out for each operator.

Figure 15 Three's average download speeds in Austria and Ireland vs average download speeds for the typical 3rd operator and typical 4th operator in four-player markets.

[✂]

Source: Frontier Economics based on Ookla data

Note: Dashed lines denote projections based on 2018 to 2019 growth rates. The typical fourth operator and typical third operator is calculated using data on the third and fourth largest MNO (based on current market share) in Denmark, Poland, Romania, Slovenia, Spain, Sweden and the United Kingdom. Data on the relevant MNO from each country is weighted according to the number of speed tests recorded for that operator.

The insights from our case studies and comparisons to "typical" operators indicate that consolidation has a beneficial impact on consumer outcomes, but these impacts are realised in different ways over different periods. This may explain why our econometric modelling found no evidence of a statistically significant impact of consolidation on outcomes. The next section will show that Ofcom's finding of a negative relationship between consolidation and investment is not robust.

4 CONSISTENCY OF OUR ANALYSIS WITH OFCOM'S DISCUSSION PAPER

The mixed methods analysis of the previous section indicates that consolidation in Ireland and Austria led to an improvement in Three's quality. This appears inconsistent with Ofcom's finding that consolidation reduces investment, and by implication, reduces average download speeds. This section critiques certain modelling decisions made in Ofcom's discussion papers, and subsequently shows that Ofcom's models imply a different conclusion when alternative, more appropriate modelling decisions are made.

4.1 The discussion paper makes some questionable assumptions

The findings in the discussion paper are inconsistent with our own econometric analysis, our mixed methods analysis and the consensus of the existing literature. It is prudent to constructively scrutinise the analysis presented in the discussion paper to understand why this departure occurs.

We have identified several issues with the discussion papers. However, there are two issues in particular which drive the result: an assumption about the similarity of the effects of entry and exit in the mobile market, and the specific measure of investment used. As we will show, the findings in the discussion paper depend on the approach to these two issues. Ofcom has made further modelling decisions and assumptions which we do not agree with; these are discussed in Annex B.

4.1.1 The assumption that the effects of entry and exit are symmetrical is not justified

The preferred specifications presented in the discussion paper, both for investment and average download speeds, assume that the impact of having an additional MNO in the market is symmetrical to that of having one fewer MNO. This is a strong assumption: there is no a priori reason to expect that the impact of entry into the market on investment or quality is similar to the impact of a merger when these occur under different market conditions and at different points in time.

The merger of two MNOs could lead to some fixed cost savings, but would also require investment in the short-term to integrate the two networks. On the other hand, entrants are likely to incur significant start-up costs to roll out their networks. Entrants also typically need to invest in launching new brands and to establish a significant high street retail presence.

When merging parties maintain their respective brands there is a limited opportunity to save on brand investment costs. In addition, the increasing trend for MNOs to retail their products online has reduced the scope for merger related retail investment cost savings. Investment is affected differently by entry and exit, it is simplistic and unrealistic to assume that entry's impact is symmetrical of the exit impact.

Because there are more entries than mergers in the sample, the estimated effect of a change in the number of MNOs more closely reflects the impact of entries than the impact of mergers. If the merger impact on investment or average download speeds differs to the entry impact, then the preferred specification presented in the discussion paper is mis-specified, and the results of this specification cannot be relied upon.

In Annex 4 of the discussion paper, an alternative specification is considered, which indicates that there is a difference between the impact of entry and mergers, both in terms of materiality and statistical significance. Figure 16 contains the estimated long-run effect of a change in the number of MNOs on investment from the discussion paper's preferred specification (in which the impact of entry and mergers on investment are assumed to be symmetric) and estimates of the effect of entry and mergers from a more flexible specification.

Figure 16 Estimated long-run effects on investment under the preferred and alternative specifications

	"Preferred specification" – number of MNOs	"Robustness check" – Entry effect estimate	"Robustness check" – Merger effect estimate
Long run effect	0.17***	0.24***	-0.13*

Source: Adapted from Table A4.2, Column 1 (Ofcom 2020b)

*Note: *p-value <0.1; **p-value <0.05; ***p<0.01. Ofcom use robust standard errors.*

The preferred specification finds that having one more (fewer) MNO in a market increases (decreases) investment in the long-run by 17%. However, the alternative specification shows that entry increases long-run investment by 24%, whereas a merger reduces investment by 13%. This suggests that entry has twice the impact on investment than a merger. Yet Ofcom seems to consider that a specification that 'assumes' entry and mergers have a symmetric effect on investment is preferable.

Furthermore, the first two effects are statistically significant at the 1% level, whereas the latter effect is only statistically significant at the 10% significance level.

Therefore, the discussion paper's robustness check provides evidence that its preferred specification is mis-specified, as the effect of entry on investment appears to be different to the effect of a merger. Considering this finding, Ofcom's choice of preferred specification is not justified and the impact of mergers on investment is overstated.

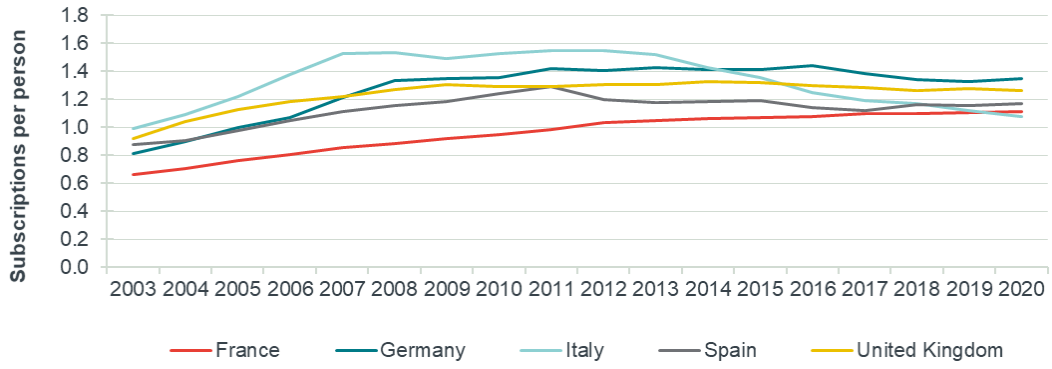
4.1.2 Investment per connection, not investment per capita, determines quality

In the discussion paper, investment per capita is used as the measure of investment, instead of investment per subscriber. This is not the right measure to use. We understand from Three that MNOs invest in their networks to support the expected number of subscribers to their network, and the traffic they are expected to bring. Three do not expect that any MNO bases their investment plans on expected population growth in the country that they operate.

If a country's population does not equal the number of mobile subscribers that it has, then investment per capita is not the appropriate outcome variable. Figure 17 shows the number of subscriptions per person for five European countries between 2003 and 2020. The figure shows that there can be more, or less, than one subscription per person. Specifically, the figure shows that:

- the number of mobile subscribers per person varies by country; and
- the number of mobile subscribers per person varies over time.

Figure 17 Subscriptions per person over time across European countries



Source: Telegeography data.

Note: These countries are presented as they are the five largest (by population) in Ofcom's sample

The discussion paper argues that using investment per connection is not appropriate because the number of mobile connections that an individual has is related to the number of MNOs in the market.[56] Therefore, "using investment per subscriber […] could introduce bias in our results".[57]

Ofcom's concern is that the probability that an individual has more than one subscription is linked to the number of MNOs.

We do not share this concern. Indeed, we have found no evidence of a relationship between the number of MNOs and connections per capita for the countries in Ofcom's sample. Specifically, we estimated a panel data model using data on penetration (sourced from Telegeography) and the number of MNOs (as per Ofcom's technical annex) for the 30 countries in Ofcom's sample for the period 2003 to 2018. The number of MNOs did not have a statistically significant effect on connections per capita. [58]

However, even if, as Ofcom believe, there were a link between the number of MNOs and multi-SIMing, then using investment per subscriber as the outcome would still not introduce any bias.[59]

[56] Specifically, Ofcom argue that it was "quite popular during the 2000s" that "a single subscriber can also have more than one connection to avoid paying high off-net fees when making calls to contacts in alternative mobile networks." Ofcom (2020a), footnote 25.

[57] No evidence is provided to support this statement

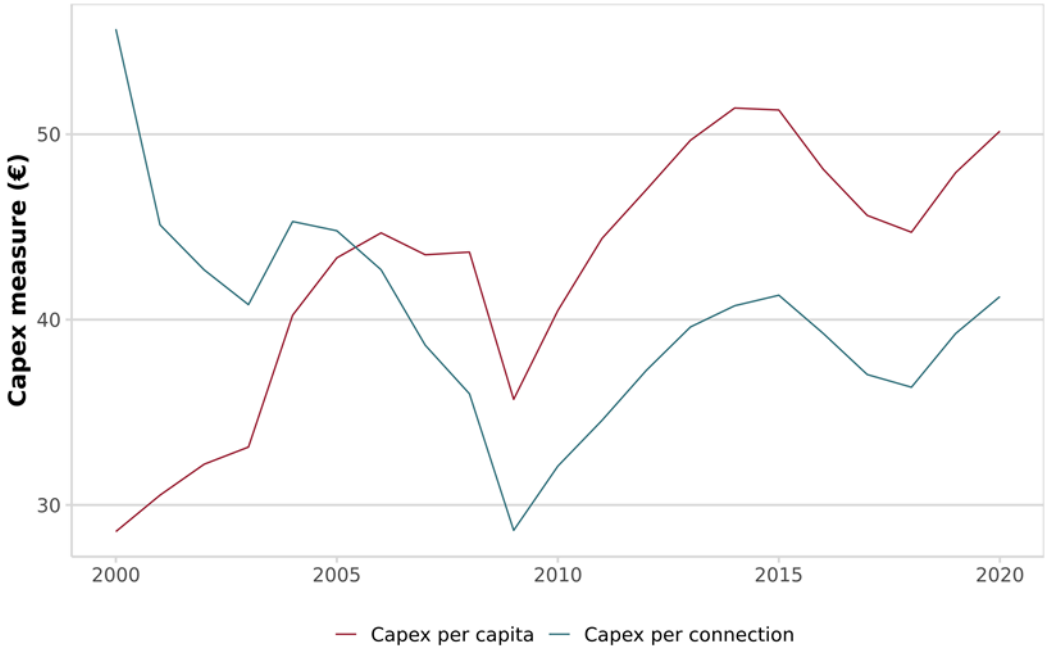
[58] We estimated a model in which the dependent variable was the number of subscriptions per 100 population members and the independent variable was the number of MNOs in a country. We included country and year fixed effects, and estimated standard errors clustered at the country level. We found that an additional MNO increased the number of subscriptions per 100 population members by 3.3, but that this effect had a p-value of 0.211.

[59] Whether the link between the number of MNOs and multi-SIMing introduces bias depends on the direction of causality. If the probability that an individual has multiple connections (subscriptions) affects the number of

Due to increasing mobile market penetration in the first part of Ofcom's sample, investment per capita will grow faster than investment per connection in this part of the sample. Therefore, the relationship between market structure and investment per capita is not guaranteed to be informative of the relationship between market structure and investment per connection. The latter relationship is what is relevant for consumers, not the former: investment per connection determines network quality, and investment per connection and investment per capita are very different (as demonstrated below).

Figure 18 shows the weighted average investment per capita (red line) and investment per capita (teal line) for the 30 countries in the Ofcom sample. From 2009 onwards, once mobile market penetration had stabilised, the relationship between the two are measures are broadly similar. Whereas, between 2000 and 2009, when mobile market penetration was increasing, the relationship between the two measures is dissimilar.

Figure 18 Trend in investment per capita and investment per connection (across the 30 European countries in Ofcom's sample, 2000 to 2020)



Source: *Frontier Economics analysis of GSMAi data.*

Note: *Graphs are weighted averages of investment per capita and investment per connection for the 30 countries in the GSMAi dataset. Countries are weighted according to the number of connections in each country.*

This is important, because 2000 to 2009 was a period when entry was commonplace, this could lead to a stronger estimated positive relationship between entry and investment, than would be the case if investment per connection was used. Given that Ofcom's model assumes that the effects of entry and exit are symmetrical, the choice of investment per capita as the measure of

MNOs, then using investment per connection would introduce reverse causality bias. However, if the number of MNOs affects the probability of having multiple connections, then bias is not an issue. Ofcom describes a situation in which individuals take out multiple subscriptions to avoid high off-net fees, which suggests the number of MNOs affects the probability of having multiple subscriptions (not the other way round). As such, Ofcom's concern that bias would be introduced by using investment per subscriber is unfounded.

investment could lead to a stronger estimated negative relationship between mergers and investment, than would be the case if investment per connection was used.

We discuss further issues with Ofcom's approach in Annex B.

4.2 When the investment per capita issue is corrected, its findings no longer hold

The preceding subsection outlined two critical issues, in our judgement, with the models presented in the discussion paper. In this subsection we show that Ofcom's findings are driven by its choice of measure of investment.

Figure 19 contains a series of econometric results. Each row refers to a different specification presented by Ofcom.

- Column (A) shows the discussion paper's "main results" in terms of the relationship between number of MNOs and investment per capita (as reported in the discussion paper's technical annex).
- Column (B) shows Frontier's results when we replicate Ofcom's model as closely as possible. When replicating the model, we use as similar data as possible (e.g. country level observations, over the same timeframe, using the same datasets whenever possible) and an identical methodology. A comparison of Columns (A) and (B) indicates that we can closely replicate the discussion paper's results.
- In Column (C), the measure of investment is changed from investment per capita to investment per connection. When we change the investment measure, we find no statistically significant relationship between the number of MNOs in the market and investment.

Figure 19 Ofcom's results and Frontier's results

Specification	Capex per capita (Ofcom report) (A)	Investment per capita (Frontier replication) (B)	Investment per mobile connection (C)
Short term impact of number of MNOs (Table A4.1, col. 1)	0.040**	0.031**	0.014
Short term impact of number of MNOs (Table A4.1, col. 2)	0.085***	0.116***	0.025
Short term impact of number of MNOs (Table A4.1, col. 3)	0.057**	0.059**	0.001
Short term impact of number of MNOs (Table A4.1, col. 4)	0.041***	Cannot be replicated	Cannot be replicated

Source: *Column A: Ofcom (2020X) Table A4.1. Columns B and C: Frontier Economics analysis.*

Note: *(1) ***, ** and * denote statistical significance at the 10%, 5% and 1% significance levels respectively. (2) Ofcom estimated the same model specification using four different estimation methods (the fixed effect estimator and multiple implementations of the Arellano-Bond estimator). Each row represents the results from each estimation method.*

(3) We have not been able to replicate the fourth estimation method used by Ofcom. This is likely explained either by: Ofcom and ourselves using different estimation commands (which have different default assumption), or an incomplete or possibly inaccurate description of the fourth estimation method.

To summarise: we achieve similar results to those presented in the discussion paper when we measure investment using investment per capita, but not when we use investment per connection. This suggests that the discussion paper's results are driven by its choice of investment measure (which we note is unique to the discussion paper, and not used elsewhere in the literature). Furthermore, as we noted earlier, there is an issue of the discussion paper's treatment of entries and mergers as symmetrical. The discussion paper's own technical annex provides evidence which shows that this assumption is not supported by the data. Therefore, its finding of a significant negative impact of mergers on investment is overstated. There are also further issues with the methodology used in the discussion paper, which are discussed in Annex B.

4.3 The discussion paper's synthetical control method analysis should be interpreted cautiously

The previous section presented econometric findings suggesting that the results of Ofcom's panel models are driven by the specific measure of investment used by Ofcom. In addition, the discussion paper presents several country-specific analyses. These case studies are based on the synthetic control method. Although this method has attractive theoretical properties, these properties do not guarantee real-world credibility. This subsection highlights reasons why it is sensible to interpret the synthetic control method results cautiously.

Ofcom used the synthetic control method to compare investment and average download speeds in countries that experienced a merger to an estimate of what investment and average download speeds would have been in those countries had the merger not taken place. The synthetic control method attempts to create an identical replica of this country except that the replica (or synthetic) country does not experience the merger. The intuition is that the merger's impact on investment can be estimated by comparing the change in investment (before and after the merger) in the actual country to the equivalent change in investment in the 'hypothetical' country.

The 'hypothetical' country is not an actual other country chosen because it is most comparable to the country where the merger has taken place. It is 'determined' using statistical techniques to select a 'subset' of countries and weights 'comparable' to the country of interest. The method compares trends in a country that experienced a merger to a weighted amalgamation of other countries (the hypothetical country). The credibility of the method chiefly relies upon the credibility of the 'construction' of the hypothetical country. Unfortunately, this is difficult to assess as the hypothetical country is constructed using a purely data-driven procedure; the procedure determines the appropriate weights using its own chosen criteria.

The hypothetical country is used purely because it happens to have similar levels of investment or average download speeds in the years leading up to the merger as the country experiencing the merger. There is no institutional or theoretical reasoning which explains why the hypothetical country is constructed as it is. When selecting the hypothetical country, the synthetic controls method does not consider any aspects of the market it is analysing. This means there is also no evidence to

support the assumption that the hypothetical country would continue to look like its real-world twin had the merger not happened. This can result in the creation of questionable hypothetical countries. For example:

1. In the case of its Austrian average download speeds analysis, Ofcom compares "actual Austria" to a "hypothetical Austria." Hypothetical Austria is calculated as being 82% Romania and 18% Malta. We agree with Ofcom that "these countries do not intuitively feel the closest to the Austrian market".[60]
2. In the case of Irish average download speeds analysis, a hypothetical Ireland created by the procedure is 100% Estonia.

With Ofcom's implementation of the synthetic control method, a data driven procedure is followed to identify the variables which should be used to subsequently determine the composition of the hypothetical country. For example, hypothetical Austria was constructed as 82% Romania and 18% Malta based on the levels of GDP per capita, rurality of the population and average download speeds (in a single quarter) in the three countries. Factors which *a priori* could be considered relevant, such as the extent of the rollout of 4G or average download speeds across a longer set of quarters, were not deemed to be relevant by the synthetic control procedure. In summary: the composition of the hypothetical countries raises concerns, as does the procedure by which the composition of the hypothetical countries is determined.

Furthermore, the synthetic control approach is valid only if the single factor that distinguishes between the actual and hypothetical country is whether a merger happens. This effectively rules out the prospect of the actual country experiencing an unexpected "shock" to investment or average download speeds that coincides with or takes place after the merger. As time passes by, the likelihood of a "shock" taking place increases. Therefore, the synthetic control method is better suited to the study of short-term rather than long-term effects.

In summary: the synthetic control method has appealing theoretical properties. However, these desirable theoretical properties do not always translate into real-world credibility. Real world outcomes are compared to those of a hypothetical country that "just so happens" to have similar levels of investment or average download speeds in the years leading up to the merger as the country experiencing the merger. There is no institutional or theoretical reasoning which explains why the hypothetical country is constructed as it is. This means there is also no evidence to support the assumption that the hypothetical country would continue to look like its real-world twin had the merger not happened.

As such, synthetical control analysis should face a high standard of scrutiny before it can be considered credible. It is important to critically assess what the method requires us to believe before attaching any weight to its results. The discussion paper's country-specific analysis should be treated with extreme caution given the peculiarities that arise in the construction of the hypothetical countries as discussed above.

[60] Ofcom (2020b) paragraph A6.18

5 CONCLUSIONS

Ofcom's discussion paper studying mobile market structure, investment and quality found a negative relationship between the number of MNOs and investment per capita. Because the discussion paper also found a positive relationship between investment per capita and average download speeds, it effectively indicated a negative "indirect" relationship between the number of MNOs and average download speeds. These findings contrast sharply with the existing literature which either finds a positive relationship or no statistically significant relationship between consolidation and investment.

This report sets out to resolve the discrepancy that has emerged, and to shed further light on the relationship between mobile market consolidation and quality.

The theoretical impact of consolidation on investment and average download speeds is discussed. We highlight that consolidation can impact quality through both technical and economic channels. In terms of technical channels, consolidation may result in: the pooling and more efficient use of the standalone networks' spectrum holdings; the creation of a "denser" network of sites, and the creation of a more geographically-wide network. These technical implications of consolidation imply greater network capacity, which will improve network performance holding everything else constant, and greater network coverage.

In terms of economic channels, consolidation leads to synergy opportunities which in turn allow networks to maintain a given level of quality at a lower cost. As consolidated networks have larger customer bases, any given investment project becomes more feasible as the cost can be recouped over more subscriptions. However, the impact of consolidation on investment incentives can have a positive or negative impact on investment incentives – depending on whether the Schumpeterian effect or the 'escape the competition' effect dominates. Taken in the round, mergers can in principle lead to improved consumer outcomes and the question of whether they do is an empirical one.

Having considered what impacts we expect from consolidation in theory, we present novel econometric analysis and evidence-based case studies, which consider developments in markets that have experienced consolidation.

Our econometric analysis relies on data, provided by GSMA Intelligence (for investment) and Ookla (for average download speeds), covering European MNOs over the last decade. We estimate two regression models: one models the statistical relationship between mergers and investment per mobile connection, and the second models the relationship between mergers and average download speeds.

Based on our econometric analysis, we do **not** find a statistically significant relationship (either positive or negative) between mergers and investment per mobile connection, or between mergers and average download speeds. These results are not surprising given that:

- The absence of a positive or negative effect is consistent with the theory, especially for the type of mergers/entries in our sample (4-to-3 and 3-to-4),

- In relation to the impact of consolidation on investment and speeds, out of the 30 countries considered, there are effectively three countries in the sample which can provide insights into the impacts of mergers on investment and speeds.
- While we control for a number of market characteristics, there appear to be other factors which are harder to control for in a systematic way, e.g. the degree of network sharing (no/limited network sharing vs. passive vs. active), how many players are involved in network sharing and coverage obligations which could also be expected to impact investment. The presence of these unobservable factors makes it more difficult to identify the impact of mergers on investment per connection and average download speeds accurately.
- If quality is impacted over varying timeframes in different markets that have undergone consolidation, it may be challenging to identify a universal relationship between mergers and quality, especially if the data only covers a relatively short period of time after the mergers took place.

If anything, the econometric analysis would suggest that mergers do not have a material impact on capex per connection. In practice, to the extent that mergers are in general expected to lead to some capex cost savings between the merging parties, the analysis would be consistent with the merging parties re-investing at least some of the expected merger capex savings. All else the same, the evidence would therefore suggest that the subscribers of the merging parties could expect to see an improvement in the quality of service, with the impact on other mobile subscribers depending on the reaction of the non-merging parties.

Given the limitations of the econometric analysis, we additionally present evidence-based case studies. These case studies relate to the mergers in Ireland and Austria. We focus on these mergers as Three was one of the merging parties in both instances.

In both countries, Three was the smallest player (with c. 12% market share), had no 2G network and had no sub-1GHz spectrum. In Ireland, Three merged with the second largest network (O2), while Three merged with the second smallest network (Orange) in Austria.

The Austrian case study reveals that the network integration process in Austria was comparatively smooth, reaching completion within 18 months of the merger. Three's average download speeds grew by over 400% during this period, allowing Three to become the market leader before the other operators responded. Three Austria also expanded its 4G coverage, and has consistently outperformed its rivals on customer satisfaction surveys (since its merger).

By comparison, network consolidation proceeded more slowly in Ireland. Three needed to unwind an existing network sharing agreement, and also needed to replace a significant amount of RAN equipment to ensure vendor consistency across networks. This process took five to six years to substantially complete.

Three Ireland's average download speeds grew gradually during the network integration phase. However, following completion of the integration process, Three's average download speeds increased dramatically. Three is the market leader in Ireland in terms of average download speeds today.

We also compare Three Ireland's and Three Austria's average download speeds improvement to that of the "typical 3rd operator" and the "typical 4th operator" in four player markets. We find that shortly after its merger, Three Austria's average download speeds grew much faster than the typical 3rd or 4th operator; Three Ireland's average download speeds exceed those of the typical operators following the completion of the network integration.

Our analysis also shows that the typical 3rd operator's average download speeds grew faster than that of the typical 4th operator The latter finding underscores the importance of scale in mobile markets. It may be the case that that Three Ireland's and Three Austria's actual performance improvements would be similar to that of the typical 4th operator had their mergers not happened.

In our attempt to reconcile our findings with those of the discussion paper, we identified several important limitations with Ofcom's analysis which explain the difference between our findings.

The first issue is that the discussion paper assumes that the average impact of entry on investment is symmetrical to the average impact of a merger. We present theoretical and empirical evidence indicating that the assumption is not justified. This assumption means that the estimated effect of a merger in the discussion paper will be influenced by the strength of any effect of entry.

The second issue is that the discussion paper measures investment on a per capita basis, rather than investment per connection. Investment per capita captures both changes in investment per connection and in the number of connections per population member. Investment per connection reflects more accurately the investment that can be expected to have an impact on mobile subscribers, especially during the period when the market was growing (i.e. when the number of subscribers was different from the size of the population).

Due to these modelling decisions, the discussion paper's findings merely reflect the fact that, during the early 2000s, investment per capita was rapidly rising due to increased mobile adoption, and there was also a wave of entry. When we replicate these models, but replace investment per capita with investment per connection, we find no impact of consolidation. This demonstrates that the discussion paper's findings are not robust, and are instead highly dependent on its definition of investment.

ANNEX A ECONOMETRIC METHODOLOGY

A.1 Investment per connection models

We estimate two panel (fixed effects) models of varying sophistication. Specification 1 is:

$$\ln(\text{IPC}_{oq}) = \alpha_0 + \beta_1 \text{Exit}_{oq} + \beta_2 \text{Entry}_{oq} + \gamma \ln(\text{IPC}_{o,q-t}) + \delta' \text{X}_{oq} + \lambda_q + \varepsilon_{oq} \quad (1)$$

Where:

- $\ln(\text{IPC}_{oq})$ is the log of operator o's investment per connection in quarter q.
- Exit_{oq} equals 1 if there is a merger in operator o's market before or during quarter q, and 0 otherwise. Entry_{oq} is defined similarly. There are no cases of countries experiencing multiple entries or multiple mergers.
- $\ln(\text{IPC}_{o,q-t})$ is a lagged value of the log of the operator's investment per connection. In our preferred specification, we include five lags of investment per connection, as these lags are statistically significant in their own right, whereas the sixth lag is not. However, our findings do not depend on whether lags are included or the number of lags if they are included.
- X_{oq} is a set of control variables. We include the following control variables: population density; percentage of the population that is rural; unemployment rate; logarithm of GDP per capita; nationwide 4G population coverage; an indicator of whether nationwide 4G population coverage is greater than 90%; percentage of the country's mobile connections that are prepaid, and the smartphone adaptation rate (%) for the country.
- λ_q is a linear time trend. We experiment with a linear time trend and time (quarter) fixed effects. Our results do not depend on which approach is adopted.
- ε_{oq} is the error term which reflects the remaining unexplained variation in the outcome. We assume that the error term is clustered at the operator level.

β_1 measures the percentage average effect on investment per connection of a merger, while β_2 measure the corresponding average effect but for entry.

In Specification 2, we replace the Exit_{oq} and Entry_{oq} terms. We include a set of Exit_{oqy} and Entry_{oqy} indicator variables. Exit_{oqy} is equal to 1 if during quarter q it has been p quarters since there was a merger in operator o's market, and zero otherwise. p is either 0 to 15. Meaning the effect of a merger is allowed to vary in each of the 16 quarters following a merger. Entry_{oqp} is defined similarly. Formally, Specification 3 is:

$$\ln(\text{IPC}_{oq}) = \alpha_0 + \Sigma_{p=0}^{15} \left(\beta_{1p} \text{Exit}_{oqp} + \beta_{2p} \text{Entry}_{oqp} \right) + \gamma \ln(\text{IPC}_{o,q-t}) + \delta' \text{X}_{oq} + \lambda_q + \varepsilon_{oq} \quad (3)$$

All remaining terms in Specification 2 are identical to Specification 1.

Each model is estimated using the standard within estimator (as implemented by the reghdfe package in Stata). Given the length of the time series, Nickell bias will

be minimal, and, in our judgement, the complications that arise from using the Arellano-Bond estimator (or similar GMM estimators) does not outweigh the benefit of eliminating Nickell bias.

A.2 Average download speed models

To avoid a duplication of discussion, this section only sets out the differences between the models used for our average download speeds analysis and the models used for the investment per connection analysis. There are three differences:

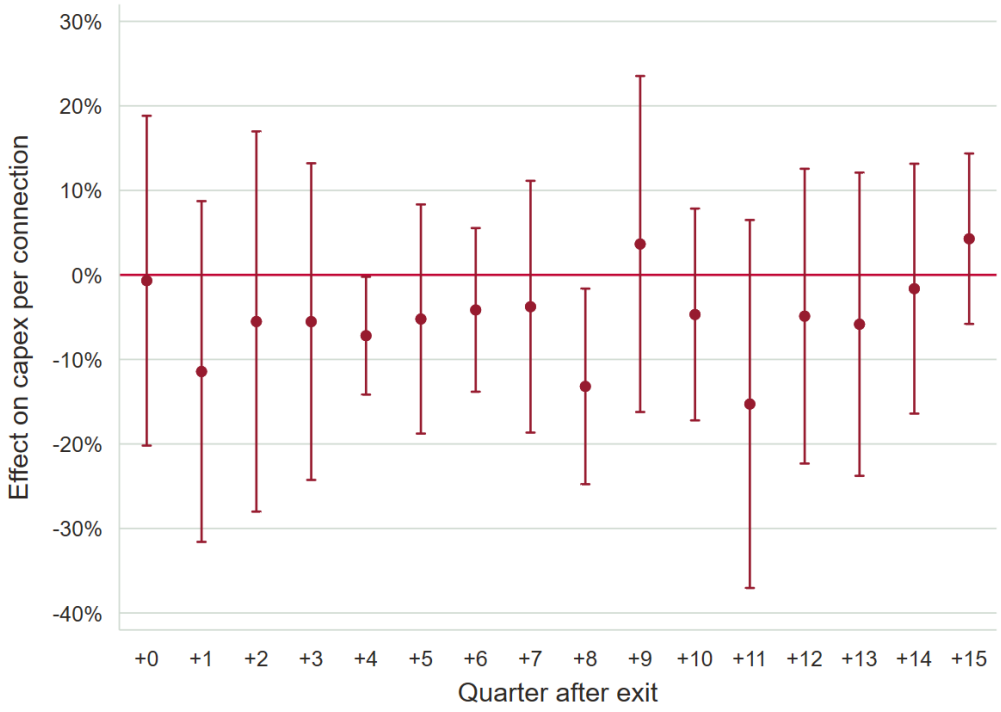
- The outcome variable is different. The outcome variable is $\ln(\mathrm{ADS}_{oq})$ which is the log of the average download speed of operator o in quarter q.
- We include four lags of average download speed. We selected this number of lags by including one lag in our model and added additional lags until the longest lag became statistically insignificant. That insignificant lag is not included in the presented model.
- We include the following control variables: population density; percentage of the population that is rural; nationwide 4G population coverage; an indicator of whether nationwide 4G population coverage is greater than 90%, and the smartphone adoption rate (%) for the country.

A.3 Specification two results

This subsection presents the results of the investment per connection and average download speed analysis when modelled using Specification 2.

Figure 20 contains estimates of the impact of exit on investment per capita when the impact is allowed to vary in each of the 16 quarters following the merger. Each dot represents the coefficient estimate, and the whiskers denote the 95% confidence interval. Where the whiskers cross the red line representing a 0% impact, there is no statistically significant impact of exit on investment per connection in that quarter.

Figure 20 Estimated impact of exit on investment per connection (Specification 2)

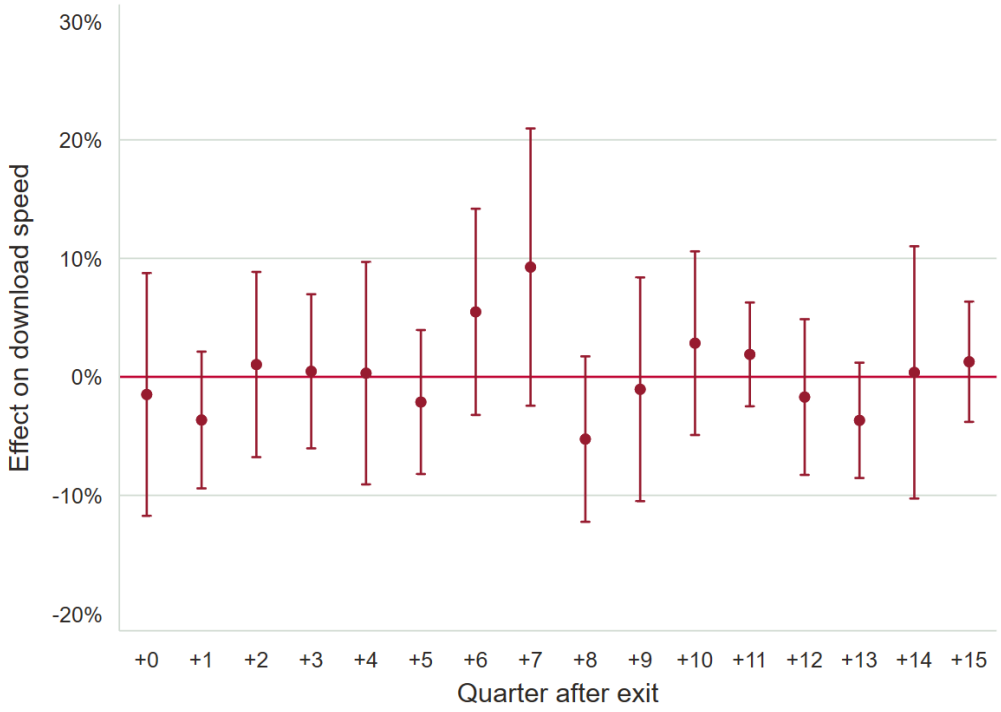


Source: *Frontier Economics analysis*

Note: *Quarter 0 is the quarter that coincides with the consolidation of the parties to the merger; red dots denote coefficient estimates, and the whiskers denote 95% confidence intervals*

Figure 21 contains estimates of the impact of exit on average download speeds when the impact is allowed to vary in each of the 16 quarters following the merger. Each element of Figure 21 is to be interpreted similarly to the corresponding element in Figure 20.

Figure 21 Estimated impact of exit on average download speeds (Specification 2)



Source: *Frontier Economics analysis*

Note: *Quarter 0 is the quarter that coincides with the consolidation of the parties to the merger; red dots denote coefficient estimates, and the whiskers denote 95% confidence intervals*

ANNEX B ADDITIONAL ISSUES WITH OFCOM'S ANALYSIS

This Annex sets out a number of other issues with Ofcom's analysis. These issues are:

- Ofcom's approach to analysing the impact of market structure changes on average download speeds; and
- Ofcom's approach to selecting the number of lags in its investment per capita model.

B.1 Ofcom's approach to combining the investment and average download speed models is not appropriate, especially given that Ofcom's investment model is mis-specified

Ofcom's approach to estimating the indirect and direct effects of market structure on average download speeds is questionable. This subsection recaps Ofcom's approach, before discussing the issues with its approach.

B.1.1 Recap of Ofcom's approach

Ofcom estimates panel models of industry-level capex in which market structure is an explanatory variable. According to Ofcom's 'preferred' model, consolidation reduces investment. Ofcom then separately estimates panel models of average download speeds in which market structure and lagged investment are explanatory variables. These models show that:

- there is no relationship between average download speeds and market structure (holding everything else, including lagged investment, constant); and
- there is a positive relationship between average download speeds and investment (again, holding everything else constant).

In other words, on its own, the average download speeds model does not contain any evidence of a market structure impact on average download speeds. However, Ofcom argues that market structure has an "indirect" negative impact. The rationale is that:

- market structure negatively impacts industry-level investment; and
- industry-level investment positively impacts average download speeds.

To estimate this "indirect effect", Ofcom multiplies the estimated coefficients on market structure (in the investment model) with the estimated coefficients on investment (in the average download speeds model).

B.1.2 Issues with Ofcom's approach

It is more appropriate to estimate the impact of concentration on speed and investment jointly as a system of equations

Ofcom's methodology is not appropriate. Ofcom should have jointly estimated a system of average download speeds and investment equations. This is common when econometric models are used to study several outcomes which are related. A system approach would account for the nature of the dependency between the outcomes – i.e. that investment is an outcome in its own right, but it also a determinant of average download speeds. Instead, Ofcom's approach of estimating two independent equations ignores the dependencies between the outcomes.

Ofcom's methodology is also unnecessary. It is unclear why Ofcom have separately estimated the "indirect" and "direct" effects of market structure on average download speeds, when the "total" effect determines the impact on consumers. Indeed, investment is a "mediator variable". By omitting it from the average download speeds model, it is possible to estimate the "total" effect of market structure.

This simpler approach is a useful robustness check for Ofcom's actual approach. The estimated total effect of market structure should be comparable to the sum of the "indirect" and "direct" effect estimates. This alternative approach also provides an estimate of the standard error of the total effect; this can be used for statistical inference.

Ofcom should use the same time period for the assessment of both models (the impact of concentration on investment and the impact of concentration on speed)

Ofcom should also have harmonised the sample used in the two models. The investment models cover the period 2004 to 2018, while the average download speeds models cover 2011 to 2018. The relationship between market structure and investment may differ between 2004 to 2010 and 2011 to 2018. Indeed, voice services played a greater role pre-2010. During that period a particular emphasis was placed on extending coverage. The nature of MNO investment is different in the "data era" than in the "voice era", with investment in the former being mostly focused on increasing capacity and speed.

As a minimum, Ofcom should have demonstrated that their results are robust to estimating the investment and average download speed models on a common sample over the same time period.

Mis-specification of the investment equation impacts Ofcom's analysis of the impact of concentration on speed

A final issue is that any mis-specification in the investment panel models will affect the "indirect effect" of market structure estimate. As discussed in Subsections 4.1 and 4.2, there is evidence to suggest that Ofcom's preferred investment model is

mis-specified and the impact of mergers on investment overstated.[61] Ofcom uses coefficients from this mis-specified equation when estimating the "indirect effect" of concentration on speed. Notwithstanding the other concerns described above, the use of a mis-specified investment model invalidates Ofcom's estimates of the "indirect effect" of market structure.

B.2 Lagged dependent variables are useful to include when used sparingly

Existing studies of the relationship between market structure, investment and average download speeds use static panel data models. In these models, the outcome variable (either investment or average download speeds) is modelled as function of explanatory variables. When estimating the relationship between market structure and investment, Ofcom uses a dynamic panel data model: investment is modelled as a function of explanatory variables and past values of investment.

Ofcom considers the inclusion of lagged values of investment in their model as "an important contribution of our analysis".[62] Ofcom's view is that the results of previous studies are biased due to their static rather than dynamic nature.[63]

There is some merit in using a dynamic panel model. As argued by Ofcom, MNOs make long-term investment plans. This means that the level of investment in one quarter is probably informative about investment in the next quarter since a long-term plan influences the investment decisions made in both quarters. Therefore, a dynamic panel model is likely to better predict investment than a static panel model.

However, a potential problem with Ofcom's implementation of a dynamic panel model is that it may have too many lags.

Ofcom's preferred investment model includes 16 quarterly lags of investment.[64] Ofcom also estimates an alternative specification with 9 quarterly lags.[65] Including too many lags can be a problem. It reduces the "efficiency" of the model – meaning that standard errors are not as small as they could be – and it can lead to bias.

It is therefore important to assess whether the number of lags is appropriate. However, it is not possible for readers of Ofcom's work to do this. To assess the appropriateness of the lag structure, the reader would need to consider the size, sign and statistical significance of the coefficients on each lag of investment. But, Ofcom only reports these details for the first lag of investment. The sum of the coefficients on all 16 lags of investment is reported but this is not relevant for the assessment.

A thorough assessment of the most appropriate lag structure is beyond the scope of this report. However, we find that the magnitude of the estimated impact of the

[61] Ofcom's preferred model restricts the impact on investment of entry to equal the impact on investment of mergers. Ofcom's own robustness tests show that this restriction is not appropriate (see Ofcom (2020b), Table A4.2).

[62] Ofcom (2020a), paragraph 5.8 (b)

[63] Ofcom (2020a), paragraph 5.8 (b)

[64] Ofcom (2020b) A4.4

[65] Ofcom (2020b) A4.10

number of MNOs on investment varies as the number of lags changes (although the direction and significance of the impact is unchanged). In our judgement, based on the data available to us, 9 to 16 lags is an excessively long lag structure.

In addition to these econometric considerations, it is also appropriate to consider how realistic Ofcom's models are. Under Ofcom's preferred model investment today is affected by investment made four years ago. This does not seem plausible given the multitude of other factors, which are controlled for, that affect investment decisions. The credibility of Ofcom's lag structure could be improved if Ofcom could explain why investment from four years ago affects investment today.

Furthermore, we also question the appropriateness of Ofcom's approach to determining the number of lags to include. Their approach is to estimate a model with 20 lags of investment and then to "run an iterative sequence of linear restriction tests on the coefficients of the lags of investment".[66] It is not clear what this means in practice, however, we suspect that the approach resulted in Ofcom including too many lags in their preferred specification. Ofcom notes that few lags of investment "appeared statistically significant" after the ninth lag.[67] Lags should not be included once they become statistically insignificant. As such, Ofcom's approach to determining the optimal number of lags may not be appropriate.

[66] Ofcom (2020b) A3.22

[67] Ofcom (2020b) footnote 60.

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