SPC Network

Economically Sustainable Ultrafast Broadband Markets: A two sided market analysis

Discussion Paper for Liberty Global

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About SPC Network

SPC Network was founded in 2003 and has worked for over 50 clients worldwide. We undertake Strategic Policy Development in platform and networked industries, by combining the knowledge of our consultants with specific and valuable skills to ensure rigorous analysis and exceptional advice. Our core consultancy team and network of partners have substantial experience in industry and consulting meaning that we understand the practical issues and challenges facing the market. Through advanced academic training, we have developed the key skills and rigorous approach needed to support our clients in the policy debate.

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1 EXECUTIVE SUMMARY

1. Regulators of electronic communications markets and academic researchers have generally agreed that three operators separate a non-competitive from a competitive market.[1] However, what has not been analysed is how many operators a market can economically sustain such that each has the opportunity to earn a reasonable return on investment. This is particularly concerning given that efficient investment is an objective of the European Electronic Communications Code (EECC).

2. Investment in Gigabit networks based on Fibre to the Premises (FTTP) or DOCSIS 3.1 is a political and economic goal in the European Union and in non-EU countries such as Switzerland and the UK. There is considerable investment taking place in these countries by incumbent operators, cable companies and new entrants to deliver Gigabit networks rapidly, but an estimated further €180 billion investment is needed to meet governments' coverage objectives.

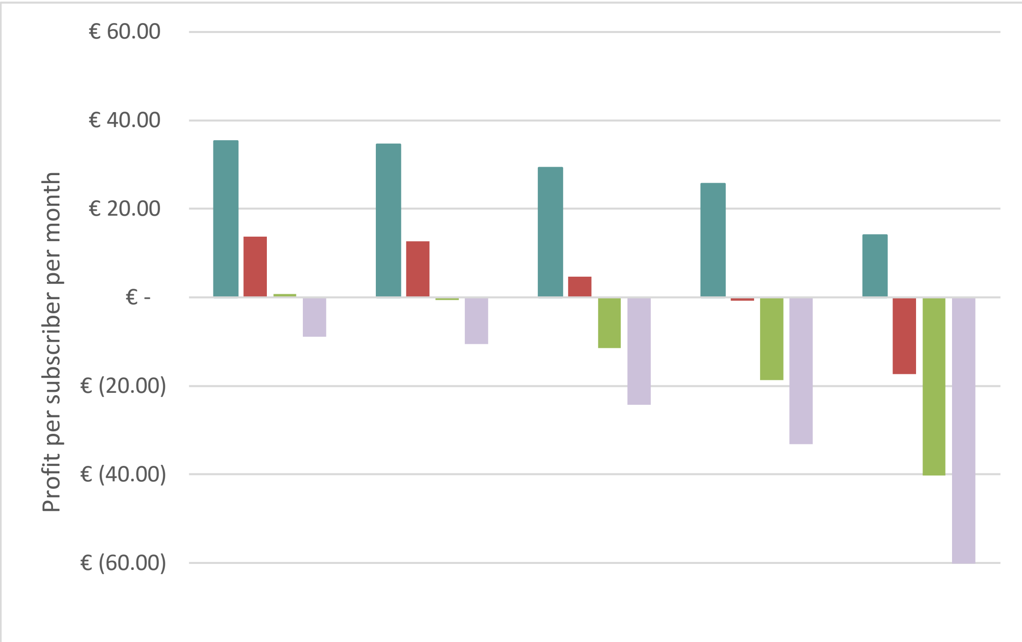
3. However, networks are subject to large economies of scope and density such that in any geographic market only very few may reach the minimum economic scale needed to earn a reasonable profit. So, whilst there are many networks being built today, consolidation in the market is likely to be necessary to ensure economic sustainability.

4. The challenge for regulators and competition authorities reviewing potential consolidation is that the market may be able to sustain fewer networks than they regard as necessary to ensure an effectively competitive market. What constitutes sustainable competition from the supply-side, by which we mean how many suppliers earning a positive profit a market can support, is the principal subject of this paper.

5. To examine this question, we have developed an indicative model of sustainable markets based on supply and demand conditions in areas of different population densities (geo-types). Based on our assumptions, these markets could sustain between one and three networks with all operators able to earn a positive profit, as shown in Figure 1.

[1] Throughout this report the term "*market*" is used informally rather than the formal use of the word in competition and regulatory policy. Where it is used formally we will use the term *"relevant market"*.

Figure 1: Operator Profitability by Geo-type



	Dense Urban	Urban	Suburban	Rural	Sparse Rural
1	€ 35.31	€ 34.62	€ 29.25	€ 25.65	€ 14.07
2	€ 13.73	€ 12.70	€ 4.61	€ (0.76)	€ (17.28)
3	€ 0.73	€ (0.66)	€ (11.48)	€ (18.65)	€ (40.33)
4	€ (8.89)	€ (10.62)	€ (24.21)	€ (33.19)	€ (60.16)

Source: SPC Network

6. The chart shows the profit or loss per subscriber per month for all networks when there are up to four suppliers. For example, in dense urban areas if there is only one supplier it would earn €35.31 per subscriber/month, but if there were two then both suppliers would earn €13.73 per subscriber/month and with three, all would earn €0.73 per subscriber/month.

7. As with any model, ours demonstrates how outcomes change with variations to input assumptions. In this case, it shows that the number of economically sustainable networks in a market is a function of build costs, elasticity of demand and demographic conditions. It cannot be presumed that a market can always support the number of networks often considered necessary for a market to deliver consumer benefits through competition. It would be up to relevant national authorities to develop their own models of sustainable investment and competition.

8. Evidence from academic research of consolidation in mobile markets shows that more concentrated markets do lead to higher consumer prices but also to higher levels of investment. One of the research papers reported here finds that asymmetric four-to-three mergers raised consumer prices by 4% - 7% and investment per operator by twice that rate.

9. Our analysis shows that the economies of scale and density that characterise Gigabit network markets mean that in some geographic areas the market may not be able to sustain the number of firms generally accepted as needed to support good consumer outcomes. However, given the objective of efficient investment that allows firms to earn a reasonable return on their capital, it may be necessary for regulators and competition authorities to accept a more concentrated market than they would prefer.

10. Decisions that force a market structure designed around short-term demand-side outcomes may produce long-term results that are harmful to consumers if firms cannot earn a reasonable return and so exit the market. A more concentrated market may result in higher prices and margins, which can lead to more investment and better long-term consumer outcomes, rather than extra profits being returned to shareholders.

11. Ultimately, what we have shown in this report is that it would be wrong to set a *per se* rule on the minimum number of suppliers in a market if that number is economically unsustainable, deterring efficient investment. Instead, relevant authorities should treat each case on the merits and assess how many firms a market can sustain based on both supply and demand-side conditions.

2 INTRODUCTION

12. The number of competing suppliers needed in a market to create effective competition and good outcomes for consumers has been widely researched by academics and has usually been found to be around three firms.[2] Similarly, National Regulatory Authorities (NRAs) in the telecoms sector have settled on three suppliers in a separate geographic market, sometimes qualified by the leading operator's market share, as the minimum necessary to find that market might be effectively competitive.[3]

13. What has been less considered, however, is how many firms can efficiently invest in a market, earning a reasonable return on that investment and, therefore, how many suppliers a market can economically sustain. This is particularly remarkable as the EECC recognises the need for efficient investment to earn a reasonable return on investment.

14. Many firms across the EU, Switzerland and the UK are investing in building Gigabit networks (also known as Very High Capacity Networks – VHCN[4]) and it is possible that these network builders will consider consolidation if market conditions cannot sustain the current number of networks. There is a risk that competition authorities may adopt a similar approach to that which they take concerning consolidation of mobile networks and object to mergers or acquisitions that result in *"too few"* providers for effective competition. However, in so doing they may be trying to keep the number of suppliers below the level at which all suppliers can earn an economic profit and hence continue to invest and operate in the market.

15. Liberty Global has commissioned this paper from SPC Network to explore the number of suppliers of Gigabit fixed networks that can compete profitably in the same geographic

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[2] Bresnahan, T. F., & Reiss, P. C. (1991). Entry and competition in concentrated markets. Journal of political economy, 99*(5), 977-1009.* Xiao, M., & Orazem, P. F. (2011). Does the fourth entrant make any difference?: Entry and competition in the early US broadband market. *International Journal of Industrial Organization*, *29*(5), 547-561. OPTA (2006) *Is Two Enough?* Economic Policy Note No. 6. Huck, S., Normann, H. T., & Oechssler, J. (2004). Two are few and four are many: number effects in experimental oligopolies. *Journal of economic behavior & organization*, *53*(4), 435-446.

[3] See for example Electronic Communications Office of Iceland (ECOI) (2021) 'Decision no. 5/2021 on designation of companies with significant market power and imposition of obligations on the wholesale markets for local access provided at a fixed location (Market 3a) and central access provided at a fixed location for mass-market products (Market 3b).' Appendix A-1

[4] Gigabit Networks and VHCN will be used interchangeably throughout this report. Examples of Gigabit networks are Fibre to the Home (FTTH) and DOCSIS 3.1, and future evolutions.

area. We have also been asked to consider the policy implications when consolidation in the Gigabit fixed network market may take the number of suppliers below the threshold needed for perceived effective competition.

16. We conclude that there should not be a *per se* rule on the number of suppliers needed to ensure effective competition. The best possible consumer outcomes are a function of both the cost conditions in the market, in particular the ratio of fixed to variable costs, and the number of firms needed to deliver consumer choice. Any analysis of the effect of consolidation needs to be two-sided and consider both cost and demand conditions.

17. The paper is structured as follows:

    - Section 3 provides a high-level policy and economic background to the issues;
    - Section 4 sets out our economic model of sustainable networks and examines three country case studies of multi-network markets;
    - Section 5 draws on experience in mobile markets that have been subject to consolidation;
    - Section 6 concludes.

3 ECONOMIC AND POLICY BACKGROUND

18. Gigabit networks, whether FTTP or DOCSIS 3.1, are widely considered to be essential to economic competitiveness and growth in a digital society. For this reason, both the EU and the UK have set the provision of Gigabit networks to the vast majority of citizens as key policy objectives in the next decade, see Figure 2.[5]

Figure 2: EU and UK Gigabit Network Targets

Current Coverage: 70%

Target: 100%

Target Date: 2030[6]

Current Coverage: 64%

Target: 85%

Target Date: 2025[7]

19. Competition between private sector companies making efficient investment decisions is seen as essential to deliver these targets. Both the EU and the UK recognise that some degree of network duplication will take place to deliver competition, but that investors need to be able to make reasonable returns on that investment even when assets are duplicated.

[5] We understand that Switzerland will be publishing a high level broadband strategy in the summer of 2023 which will include a coverage target.

[6] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[7] Hutton, G. (2022) Gigabit Broadband in the UK: Government Targets and Policy House of Commons Library

20. The EECC, states:

> *Competition can best be fostered through an economically efficient level of investment in new and existing infrastructure, complemented by regulation, where necessary, to achieve effective competition in retail services. An efficient level of infrastructure-based competition is the extent of infrastructure duplication at which investors can reasonably be expected to make a fair return based on reasonable expectations about the evolution of market shares.*[8]

21. The definition of the efficient level of investment set out above is extremely important as it recognises that investors need to earn a fair return on capital. If their expected market share is too small to recover fixed costs, including their cost of capital, then they will not be able to make a fair return and so investors may not make the necessary investment. They must have an *ex ante* – forward looking – expectation of reasonable profits to invest. Economically, a return on capital approximately equal to the cost of capital is referred to as *"normal profits"* as this is considered the minimum amount necessary to attract entrepreneurial investment.[9] This term is used in this report.

22. The cost of increasing the existing level of coverage to meet the EU's and UK's targets is substantial. In a report for the European Telecommunications Network Organisation (ETNO), Boston Consulting Group (BCG) estimated that with fibre coverage at 43% of European homes in 2020, a further €150 billion would be needed to achieve 100% Gigabit coverage across Europe.[10] The current official estimate of the cost of meeting the UK target is £30 billion (€34.2 billion).[11]

23. The ability of investors to earn a fair return on this investment is strongly affected by the fact that networks have a high fixed to variable cost ratio and so are subject to significant economies of scale and density. Fixed and sunk costs, spread over a larger number of network connections in a limited geographic area, mean that average costs per user

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[8] DIRECTIVE (EU) 2018/1972 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 establishing the European Electronic Communications Code. (Recital 27). At the time of writing the EECC remains part of UK law.
[9] Bannock, G., Baxter, R.E., & Davis, E. (1998) *Dictionary of Economics*, *sixth edition.* Penguin Books, London.
[10] BCG (2021) Connectivity and Beyond
[11] Hutton (2022) Gigabit targets in the UK: Government targets and policy House of Commons Library. No. CBP 8392

decline.[12] The number of networks any geographic area can support is dependent on how rapidly the average cost falls to its lowest point: the minimum efficient scale (MES).[13] As a general rule, product markets with a high fixed to variable cost ratio can support fewer suppliers than markets with a low ratio as the MES is achieved at a higher market share.

24. It is likely, therefore, that Gigabit network markets with more suppliers than the market can support will consolidate and tend towards only a few suppliers as the scale of the largest firms allows them to deliver both dynamic and static efficiency gains that smaller ones cannot match.

25. This condition raises two questions that are the subject of this paper. First, how many suppliers can a Gigabit network market support such that each is able to invest efficiently and earn normal profits? Secondly, how should policy makers respond if network economics support fewer operators than that which creates an effectively competitive market for consumers?

26. We address the first of these questions in the next section by means of an indicative economic model of competition between networks in different geo-types (urban, semi-urban and rural). The second of these questions is considered in Section 5.

[12] Spulber, D. F., & Yoo, C. S. (2009). *Networks in telecommunications*. New York, NY: Cambridge University Press.
[13] The scale of production at which further increases in scale would not lead to lower unit costs.

4 SUSTAINABLE MARKET STRUCTURE

4.1 Introduction

27. This section considers how many Gigabit networks a market can sustain, given their economies of scale and density. We do this by developing an indicative model of competition based on the long-established Cournot model.[14] Our model is based on actual costs of Gigabit network deployment experienced by Liberty Global operating companies but is not intended to represent any specific national market. Rather, it is indicative of national markets and highlights some of the issues that regulatory and competition authorities may need to consider, in particular how many Gigabit networks a market can sustain.

28. We then provide three brief case studies of national Gigabit markets where competitive development has taken place and ask whether these case studies raise any concerns with our model.

4.2 A model of the viability of competition in Gigabit networks

Summary

29. Our model is based on the Cournot model to derive a relationship between the number of competitors and the profit margin available to competitors. More competitors in a market mean that each would have a lower market share and higher unit costs but market prices and profit margins would be lower. This allows us to estimate the number of suppliers the market can support so that all suppliers can cover the fixed costs of network rollout, including their cost of capital, and so make a normal profit.

30. Based on the assumptions we adopt in the base case, our model shows that:

    In **dense urban areas** (central business districts), three Gigabit networks are economically sustainable, but each only just covers that cost of capital.
    In **urban and suburban areas** two networks are economically sustainable.
    In **rural and sparse rural areas** only one network is economically sustainable.

[14] For a textbook explanation of the Cournot model, see Varian, H. R. *"Intermediate Microeconomics"*, Norton, 5th edition, pp 477-482.

Overview of the economic model

31. The model consists of two stages: In the **first stage** one or more companies build Gigabit networks in a certain coverage area. We assume that each builds a similar network with similar costs, passing all homes in a coverage area.

32. In the **second stage** the companies compete in market share and price, aiming to maximise their own profit. In doing so they take account of the following:

    i. Each company knows that if it reduces its price, its competitors will respond to avoid market share loss;

    ii. However, a lower price will grow the overall market take-up for Gigabit connections from homes passed.

33. The model is neutral as to whether end-customers are direct customers of the network operator or acquired through a wholesale arrangement with a downstream firm. We recognise that some network operators follow an *"anchor tenant"* strategy to acquire market share, but the chosen customer acquisition strategy is not part of our analysis in this report.

34. Competitive interaction between the companies results in a single market price, known as a *"Cournot equilibrium"*. The equilibrium price occurs without any explicit collusion and balances the loss of revenue from a lower price with the overall increase in the market. The equilibrium price will never be below variable cost since at this level companies would cease to connect any customers.

35. Two parameters in the model will determine how far the equilibrium price is above variable cost:

    The market elasticity of demand. If demand is price elastic network providers will find it profitable to lower prices towards variable cost because the lost revenue will be offset by a larger take-up from homes wanting Gigabit connection.

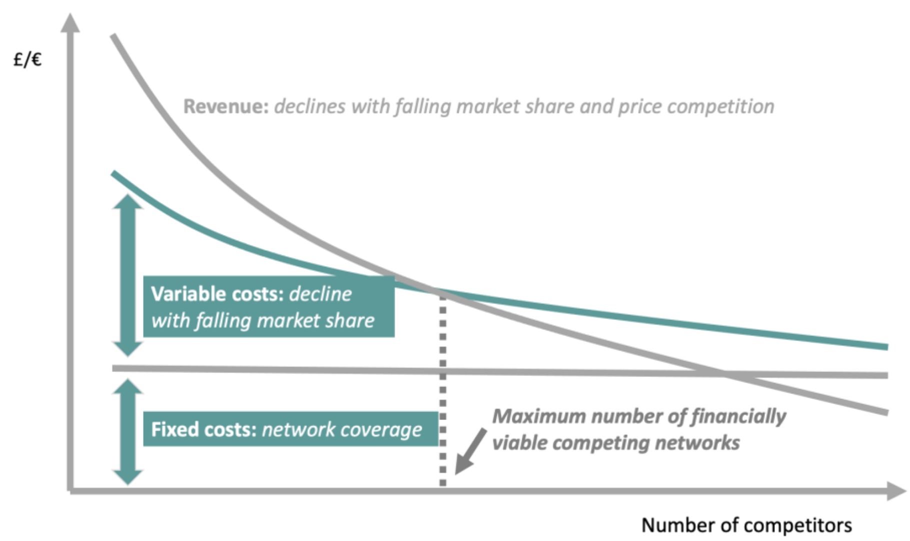
The number of companies providing networks. With more networks, each company has a smaller market share and so companies will intensify competition with a lower market price to achieve a share of a larger overall market, subject to the market price never falling below the variable cost of a connection.

36. The margin between revenue and cost will decline as the number of competing companies increases within the same coverage area, as shown in Figure 3. This is because as the number of competitors increases:

- The revenues of each reduces with its lower market share;
- The variable costs of each reduces with fewer connected customers; but
- Each company still faces the same fixed cost of network coverage.

37. Beyond a critical number of competing companies, shown by the dotted line in Figure 3, the market will be loss making. It is this critical maximum number of network companies that is of interest to us.

Figure 3: Financial viability of networks vs. number of competitors



Source: SPC Network

38. Our implementation of the model diverges from the textbook approach as we allow for some networks needing to offer a discount against the market price due to being late entrants or having a lower brand recognition or offering a lower quality.[15]

39. The full mathematical formulation of our Cournot model is provided in Annex A.

Overview of the network model

40. Our model characterises the network into the following parts:

Connections to each connected home: These are costs of providing the fibre or coaxial connection from the local network to the customer's home and the associated customer premsies equipment (CPE). This cost is only incurred for homes that become customers of the network company.

Local network: This is the network in any geographical region that the network company seeks to serve. The cost is incurred according to the extent of the network companies' coverage area measured by the number of homes passed and is assumed to be independent of the number of connected customers. It is the fixed cost to serving the coverage area.

Core network, customer billing and care systems, and overheads (such as finance, HR, marketing, legal and strategy): There will be fixed components of these costs but mostly they are assumed to scale with the overall size of the network measured by the number of connected customers. For example, more customers will imply more traffic on the core network, larger capacity billing and customer care systems, larger head office functions, and a more highly paid CEO.[16]

41. The total costs of the access network therefore comprise:

[15] We could also have allowed these late entrant / lower brand recognition / lower quality network providers to have a lower market share when offering the same price (or indeed a combination of discounted price and lower market share). This would have led to an equivalent model with the same overall conclusions.

[16] This assumes that network providers reach a size where economies of scale in the core network and central overhead functions have been exhausted. For example, a smaller network provider will, in effect, be able to gain economies of scale by outsourcing many of these functions. This conjecture can be seen by the observation that, above a minimum size, the overhead cost per customer of a network serving a small geographic area is often similar to that of a network serving a larger geographic area.

Variable cost of connecting each customer - the customer connection and variable impact on core network capacity, customer billing and care systems and central overheads; and

Fixed cost of serving a particular geographic coverage area.

Data and assumptions

Costs

42. Whilst the model is indicative, and not calibrated to any particular market, we have informed our cost and market assumptions using data provided by Liberty Global's operating companies. In most instances we have taken the median of the unit cost data for each cost category provided by the operating companies. This ensures that the costs we use are not distorted by any outlier countries with particularly low or high costs.

43. All capital costs are annualised over an assumed asset life using a real pre-tax discount rate of 4.7%. This is based on the following reasoning:

    - A **real discount rate** is appropriate since network providers will anticipate being able to increase prices in line with general inflation;[17]

    - We use a **pre-tax discount rate** since we are not otherwise capturing the tax cost within the calculation.[18]

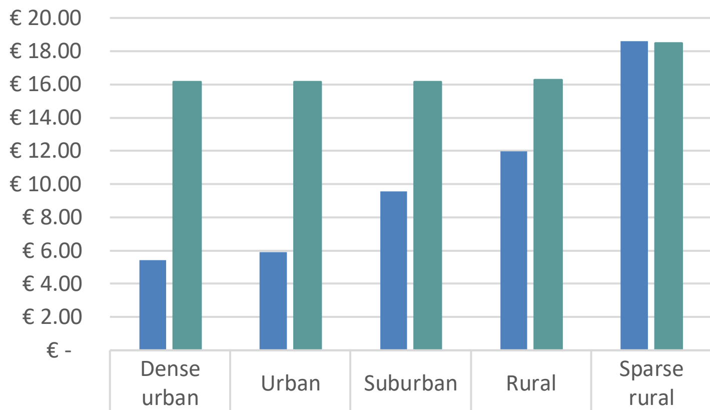
44. The value for the real pre-tax discount rate is derived from Ofcom's Wholesale Fixed Telecom Market Review ("WFTMR"), 2021-26.[19] We follow Ofcom's approach of assuming the investment risk of FTTP matches that of Other UK Telecoms ("OUKT"), defined as BT less Openreach (essentially a low-risk copper access network) and non-core activities such as IT networks and consulting (seen as higher risk).

[17] Alternatively, we could have used a nominal discount rate, but would then have needed to account for the impact of inflation on future prices and operating expenditures. For simplicity we opted to build the model in real price terms.
[18] Alternatively, we could have used a post-tax discount rate and then incorporated a corporate tax computation into the model. For simplicity we opted to use a pre-tax discount rate.
[19] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/216084/wftmr-statement-annexes-1-26.pdf The rate of inflation has increased considerably since Ofcom drafted this document and would need updating if any country specific model were developed.

45. We assume an average asset life of 20 years for local network assets,[20] 12 years for core network assets and 10 years for home connections taking account of customer churn.

46. Annex B provides a listing of the principal cost data used, and Figure 4 shows the calculated monthly cost of both opex and capex investment spread over the asset lives and applying the real pre-tax discount rate used in our base case results.

Figure 4: Calculated monthly cost per Geo-type



	Dense urban	Urban	Suburban	Rural	Sparse rural
Monthly variable cost per home passed	€ 5.44	€ 5.91	€ 9.57	€ 11.97	€ 18.59
Monthly variable cost per home connected	€ 16.14	€ 16.14	€ 16.14	€ 16.26	€ 18.48

Source: SPC Network model calculations using cost data from Annex B.

Pricing

47. Our model requires a demand curve that gives the monthly price for a Gigabit connection that will yield a certain level of take-up. We assume a straight-line demand curve calibrated on the following price points:

- the monthly price that would give 80% take-up, whuch we take to be €65[21]; and
- the hypothetical monthly price for a basic Gigabit connection, to give internet connectivity (excluding any content), that would eliminate virtually all customer

[20] This is a blend of underground assets such as ducts and cables and overground street equipment.
[21] This is a typical price based on the median level of market data provided by Liberty Global operating companies, annualised over a 5 year period taking account of any set-up charges and initial period discounts.

demand (95%). In the base-case we take this to be twice the price that would lead to 80% adoption, i.e. €130/month.

48. A key assumption used on the model is that successive entrants into the market will need to offer discounts compared to the early entrants to counteract brand loyalty and/or inertia. Table 1 shows the discounts we assume for each successive network provider relative to the price offered by the first entrant.

Table 1: Network provider discounts relative to early entrants

Entrant order	Discount relative to 1st entrant
1	0%
2	5%
3	10%
4	15%
5	20%
6	25%

Source: SPC Network

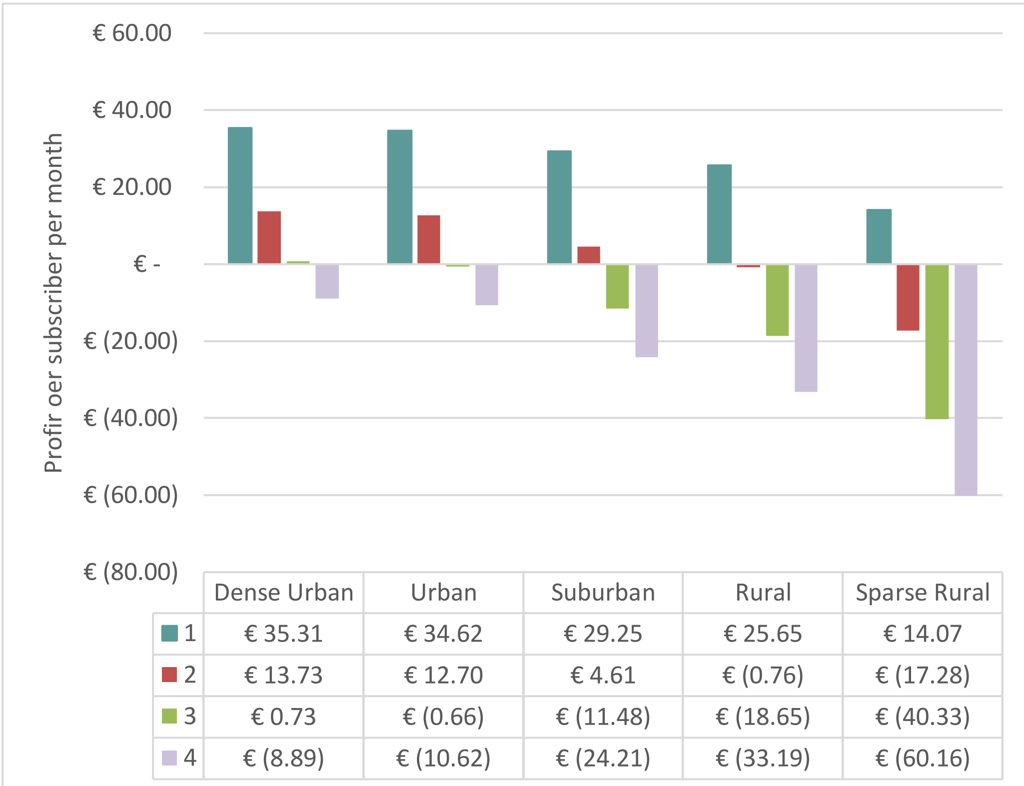
Results

49. Figure 5 shows the profit per subscriber per month when there are up to four Gigabit competitors in each geo-type. Profits are symmetrical for each number of operators. For example, when there are two operators in the dense urban geo-type, all operators will earn a profit of €13.73 per subscriber per month. Conversely, if there are four operators all will make a loss of €8.89 per subscriber per month. This is done to show the financial viability of the market supporting this number of competitors and not to predict the individual profitability of each firm. A full table of results is shown in Annex C.

50. From Figure 5 our findings are:

- **Dense urban environments** can economically sustain up to three network competitors, though each would earn a very low profit per user;
- **Urban and suburban environments** can economically sustain up to two network competitors. A third network would mean all would make a small loss per user;
- **Rural and sparce rural environments** can only economically sustain one network.

Figure 5: Operator Profitability by Geo-type



	Dense Urban	Urban	Suburban	Rural	Sparse Rural
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4	€ (8.89)	€ (10.62)	€ (24.21)	€ (33.19)	€ (60.16)

Source: SPC Network

Result sensitivities

51. As with any modelling, results are sensitive to assumptions. It is, therefore, important to test how the results of the model are materially changed if the underlying assumptions are changed within reasonable parameters. In this model of financial viability there are two principal sources of assumption uncertainty:

- **Costs**: Whilst there are many elements of cost, including asset lives and the cost of capital, these are all encapsulated in:
  - The overall variable cost per home passed;
  - The overall variable cost per home connected.
- **Prices**: In particular the calibration of the demand curve given by:
  - The base FTTH price level to achieve 80% take-up;
  - The price elasticity captured by the price level that would effectively eliminate 95% of demand.

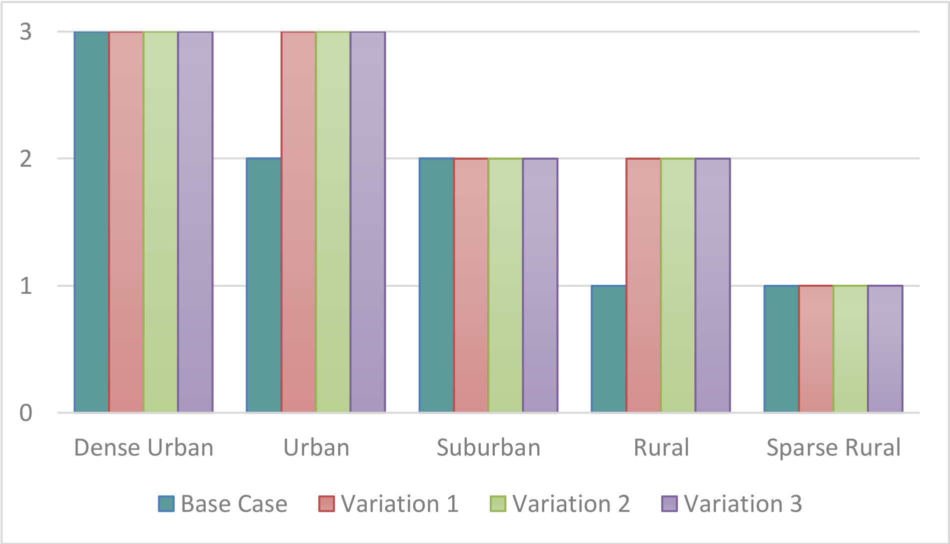
52. We have tested these sensitivities by varying the assumed values and have found that the depreciation period for the cost per home passed and the price level that eliminates nearly all demand as a multiple of the current price have the most influence on the number of operators a market can economically sustain. The values in the model variants are shown in Table 2 below.

Table 2: Model Variations

Variation	Demand Elimination Price as multiple of current price	Depreciation period of access network (years)
Base	2x	20
Variation 1	3x	20
Variation 2	2x	25
Variation 3	3x	25

53. The results of the variations are presented in Figure 6 below. In the base case **three** network competitors are economically sustainable in dense urban areas, two in urban and suburban environments and one in rural and sparse rural. In the variations, three networks are sustainable in urban areas and two in rural areas. This is due to less price elasticity of demand and/or lower costs.

Figure 6: Sensitivity of number of sustainable operators



Source: SPC Network

54. As with any model, the one presented here demonstrates how outcomes change with variations to input assumptions rather than making predictions. Our model demonstrates that the number of economically sustainable networks is a function of build costs, elasticity of demand and demographic conditions. It cannot be presumed that a market can always support the number of networks often considered necessary for a market to deliver consumer benefits through competition.

4.3 Evidence of multiple co-existing networks

55. This sub-section examines empirical evidence of multiple Gigabit networks serving the same geographic market. Examples are drawn from Hong Kong, Ireland and the UK. Our purpose in reviewing these examples is to assess whether there is anything in the evidence that contradicts the results of our model.

56. An important condition of the companies we consider is that their networks have been developed primarily using their own physical infrastructure. Whilst they may share some physical assets, such as ducts, the companies have had to invest in their own civil engineering to some degree.

57. These examples are in line with the modelled results that urban and dense urban areas can support more competing networks than less populated areas.

Hong Kong

58. Hong Kong is the fourth most densely populated territory in the World, with a population density of over 7,100 persons per square kilometre.[22] It has a GDP per capita of approx. $46,250 (2020), making it a high-income territory. These two conditions are directly relevant to the history of broadband and Gigabit network rollout in Hong Kong and its ability to support multiple networks.

59. In 1995 three competitors to Hong Kong Telecoms (HKT) were granted licences. These operators built their own networks for business customers but relied on access to HKT's infrastructure for residential customers, generally via unbundled local loops (ULL).

[22] www.worldpopulationreview.com

60. In 2003 the Office of the Communications Authority (OFCA[23]), reviewed the ULL regulation and, based on responses from industry players, decided to withdraw the ULL obligation with the objective of promoting investment in alternative infrastructure by suppliers in the industry. The key determinant of where the ULL obligation would be withdrawn in a given area was the presence of at least one competitive, self-built, access network in addition to HKT.

61. The market began an upgrade to VHCN in October 2007, when Hong Kong Broadband Network Ltd (HKBN) announced an upgrade to FTTH in 100 housing estates. This announcement was followed by HKT in November, saying they would make fibre available to 66% of households, and by Hutchison in 2010. As at March 2022, some 64% of households have FTTH and a further 19% have fibre to the building (FTTB).[24] Importantly, between 80% and 85% of households have a choice of at least two fibre providers, reflecting the dense urban nature of Hong Kong.

62. In an assessment of Hong Kong's fibre market, McLaren[25] points to five conditions that give the territory an advantage that has allowed the development of a competitive market structure: high population density, high per capita incomes, an open information economy, a risk-taking investment culture and an independent regulator. The first of these is aligned with our model.

Ireland

63. Ireland has an average population density of just 72 persons per Km^2. However, there is substantial variation around this mean. Dublin, where approx. 25% of the population live, has ca. 1,500 persons per Km^2 whilst County Leitrim has just 20.1. Ireland is also a high-income country.

64. In 2023, there were three commercially funded major investments taking place in VHCNs in Ireland:

[23] At the time Office of the Telecommunications Authority (OFTA)
[24] OFCA https://www.ofca.gov.hk/en/news_info/data_statistics/key_stat/index.html Accessed 28th July 2022
[25] McLaren, G. (2017). Hong Kong's fibre broadband market: Busting the myth of residential fibre broadband always being a natural monopoly. *Journal of Telecommunications and the Digital Economy*, 5(3), 36-49.

- eir, which is expanding its FTTH network from 800,000 to 1.9 million households (84% of the total) with a target date of 2026;
- SIRO, a joint venture between the Electricity Supply Board (ESB) and Vodafone, which is expanding its FTTH network from 410,000 to 770,000 homes;
- Virgin Media which is upgrading its cable network to FTTH across all one million households passed.

65. In addition, the National Broadband Network (NBN), a state-owned network covering economically unviable areas, is planning to cover around 500,000 homes.

66. There is likely to be substantial overlap between eir, SIRO and Virgin Media, implying that investors expect the market can support multiple operators in at least some parts of the country that align with dense urban, urban and potentially some suburban areas identified in the model. It is too early in the investment cycle to know whether this is the case or not and therefore whether any consolidation will occur.

United Kingdom

67. The UK has an overall population density of 281 persons per Km^2. Like Ireland, there is considerable variation around this average. Whereas London has a population density of over 5,700 per Km^2 on a par with Hong Kong, the Scottish Highlands have just 8 persons per Km^2.

68. The UK has a lively and dynamic market for Gigabit networks with many companies, large and small, building fibre networks. We have identified 44 privately funded companies building VHCNs in the UK. A few can be classified as large with ambitions to build networks covering a significant proportion of the country. These large companies include BT Openreach, G.Network, Virgin Media O2 and CityFibre. There is a long tail of smaller companies with more limited ambitions in restricted geographic areas.

69. Openreach's network will be ubiquitous across the whole of the UK, whilst CityFibre's network will be focussed on cities outside London, Virgin Media O2's network is primarily located in the urban areas and G.Network is concentrated in London. There will, therefore, be substantial overlap between three of these four networks in many locations. Unsurprisingly, these larger Gigabit network builders are targeting dense urban,

urban and suburban areas. However, there are some network builders that focus on rural and sparse rural areas.

Table 3: Current and Planned FTTH Coverage by Major UK Fibre Providers

Company	Current Coverage (households)	Target Coverage (households)	Target Date	Geography
CityFibre	2 million	8 million	2025	Cities outside London
G.Network	400,000	1.5 million	2026	London
Openreach	7 million	25 million	2026	Nationwide
Virgin Media O2	15.5 million	20.5 million	2028	Nationwide

Source: company reports

Note: Virgin Media 02 already provides Gigabit capable broadband via Hybrid Fibre Coax but is planning to convert its entire network to FTTH by 2028.[26] It is also planning to connect a further 5 million homes by FTTH by 2026.

70. We are not familiar with the business strategies of these companies or indeed any of the smaller, geographically focussed fibre network builders. We can speculate that at least some of the smaller companies may be developing network assets in the hope of selling to larger networks at some point. However, we would expect the larger builders' business rationale to be to create a sustainable business in their areas and compete at least with Openreach and other surviving networks. Thus, they must have some expectation that the market can sustain at least two providers.

71. In a study of the determinants of mobile and fixed coverage in the UK, Ofcom found that population density accounted for a large proportion of the variation of fixed coverage. An area at the 75th percentile for the number of premises has a 45.3 percentage points higher probability of being commercially upgraded compared to an area at the 25th percentile. Ofcom also found that more affluent areas were more likely to be recipients of investment in fibre-based broadband.[27]

[26] Virgin Media O2 Press Release November 2021. https://news.virginmediao2.co.uk/virgin-media-o2-within-touching-distance-of-upgrading-entire-network-to-gigabit-speeds/
[27] Ofcom (2019) Economic Geography 2019: An analysis of the determinants of mobile and fixed coverage in the UK

72. Ofcom's findings are supported by research conducted by Frontier Economics that found population density and average income amongst the strongest indicators of ultrafast broadband availability.[28]

4.4 Conclusions from Model and Case Studies

73. Our model shows that dense urban areas can sustain a greater number of Gigabit network providers than urban, suburban and rural areas. This finding is in line with the conclusions of McLaren with regard to Hong Kong and with those of Ofcom and Frontier Economics in the UK. Whilst our model does not include average earnings, there is evidence that urban dwellers enjoy higher incomes than their rural counterparts.[29]

74. This suggests that our model is not undermined by evidence from the real world.

75. The case studies do not show any evidence of consolidation. This is not a surprise given that Gigabit network markets are still in the growth phase of their product life cycle. It is only when they become more mature that we are likely to see firms leave the market, either through financial failure or consolidation. Time is therefore likely to reveal how many networks the market can support in equilibrium.

[28] Frontier Economics (2020) The drivers of network deployment for the Gigabit age
[29] See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_people_at_risk_of_poverty_or_social_exclusion,_by_degree_of_urbanisation,_2015_(%25)_RYB17.png (Accessed September 2022)

5 IMPLICATIONS FOR CONSOLIDATION

5.1 Introduction

76. Our model has shown that the number of Gigabit networks that can efficiently invest in a market is a function of the geotype within which those firms operate. In some areas the number of operators that is economically sustainable may be less than the number often considered necessary for effective competition.

77. This would create a tension between the objective of ensuring markets are effectively competitive, working in the interests of consumers, and the promotion of efficient investment that requires investors earn a reasonable return.

78. Competition authorities assessing potential consolidation in the market must take account of this tension and may need to accept that there are circumstances in which *"too few"* operators for effective competition is the only viable number for efficient investment.

79. This situation has already been considered in the mobile market, where mergers that result in three remaining networks have generally been rejected for fear of excessive pricing. However, academic analysis shows that the effect of *"four-to-three"* mergers is nuanced. We report on two such papers below.

5.2 Lessons from the Mobile Market

80. The mobile market has already experienced some degree of consolidation in several EU countries, as shown in Table 4 below, and this consolidation has been the subject of much academic analysis. As the mobile telecoms network market is characterised by few suppliers and a continuing need for significant investment in new generations of technology, it has parallels with the fixed market for VHCNs. Whilst the fixed market has experienced some consolidation this has not been analysed to the same extent as mobile markets. Therefore, in our view, the lessons learned from mobile market developments are helpful when considering VHCN developments.

Table 4: European Mobile Mergers 2004 - 2018

Parties to transaction	Country	Year
TeleDenmark/Orange	DK	2004
KPN/Telfort	NL	2005
Stet Hellas (TIM)/Q Telecom	EL	2005
T-Mobile/tele.ring	AT	2006
Ben (T-Mobile)/Dutchtone (Orange)	NL	2007
Hutchison 3G/Orange	AT	2008
T-Mobile/Orange	UK	2012
Hutchison 3G/Telefonica	IE	2014
Telefonica/E Plus	DE	2014
T-Mobile/Tele2	NL	2018

81. Mergers and acquisitions in the mobile market have been subject to regulatory scrutiny at both national and EU level, especially when the transaction means that the number of suppliers in the market will reduce from four to three. Several such transactions have been rejected by competition authorities.

82. The effect of acquisitions has been subject to extensive academic analysis examining the economic impact of transactions *ex post*. In this section we assess two recent papers (Genakos et al[30] and Grajek et al[31]). The two papers study the effects of mergers in the mobile telecommunications market on prices and investment. If mergers are anticompetitive, we may expect to see prices (and profits) rise and/or investment decline.

83. Grajek et al describe their paper as asking whether within-market mergers, i.e. ones that lead to consolidation, have led to increased static and/or dynamic efficiency and whether there is a trade-off between the two. They use lower prices post-merger as an indicator of static efficiency gains and changes in capital expenditure post-merger as an indicator of changes in dynamic efficiency.

[30] Genakos, C., Valletti, T., & Verboven, F. (2018). Evaluating market consolidation in mobile communications. *Economic Policy*, 33(93), 45-100.
[31] Grajek, M., Gugler, K., Kretschmer, T., & Mişçişin, I. (2019). Static or dynamic efficiency: Horizontal merger effects in the wireless telecommunications industry. *Review of Industrial Organization*, 55(3), 375-402.

84. Genakos et al address the same area and study the relationship between prices, investment (indicated by capital expenditure) and market structure in mobile telecommunications. They note that changes in market structure over time may be due to factors such as organic growth and market entry. However, their conclusions are focussed on the impact of mergers as this is the area of interest for policy makers and has received the most attention.

85. Whilst the question addressed by the two papers is similar, the studies take different approaches. Genakos et al developed an econometric model using data from 33 OECD countries between 2002 and 2014, whereas Grajek et al conduct *ex post* evaluations of five mergers in European countries that *"increased market concentration considerably"* (page 377).

86. Despite the differences in approach, there are similarities in the findings of the two papers. To demonstrate these similarities, we quote extensively from each of the two conclusions below, starting with Genakos et al:

> *We find that, during the analysed period, when mobile markets became more concentrated, prices increased to end users with respect to the case in which no concentration happened. […] At the same time, capital expenditures increased. […] At the country level, we found an insignificant effect of market structure on total industry investments, which is possibly influenced by the smaller sample size and reduced variability […]. Nevertheless, […] theoretical work has shown that an increase in concentration would lead to a decrease in total industry investment in the absence of efficiencies. Hence, our finding that concentration has no effect on industry investment suggests that efficiencies from coordinating investment among fewer firms are present. An obvious possibility is that there are fixed cost savings, because fewer firms avoid duplicating the same fixed costs. Such savings can be welfare improving, but do not benefit consumers. A second possibility is that there are economies of scope or spill-overs that generate marginal cost savings or quality improvements to the benefit of consumers.*
>
> *A hypothetical average 4-to-3 symmetric merger in our data would have increased the bill of end users by 16.3%, while at the same time capital*

expenditure would have gone up by 19.3% at the operator level, always in comparison with what would happen in the case of no merger. More realistic asymmetric 4-to-3 mergers (between smaller firms in European countries) are predicted to have increased the bill by about 4-7%, while increasing capital expenditure per operator by between 7.5-14%.

87. It should be pointed out that due to the fact that fixed networks have a higher degree of sunk costs than mobile networks (as discussed in the preceding sub-section), the fixed costs savings highlighted in the first paragraph above may be less viable in fibre.

88. Grajek et al's conclusions are similar and quoted below:

The evidence from the Netherlands and Denmark supports the conventional wisdom of mergers being associated with a higher price level for consumers.

Focusing on the effects of mergers on prices alone, however, ignores important issues, such as changes in product choice and service quality that can have a mitigating effect on consumer welfare. Particularly, the growth in data services has become an important feature of the services that have been offered by mobile carriers over the last decade with associated requirements of huge sunk capital expenditures. Therefore, we analyze both price and the investment effects of mergers: We examine the issue of whether there is a trade-off between static (i.e. price) and dynamic (i.e. investment) efficiency.

We find that for the five mergers under scrutiny, prices and investment move in the same direction: For those mergers where we find a dominance of market power effects (Netherlands and Denmark), we also find significant increases in investment spending post-merger. For mergers where we find a preponderance of cost efficiency (Austria and Greece), we do not find significant increases in post-merger investment spending. Thus, we find evidence of a trade-off between static and dynamic efficiencies in mergers in a large sunk cost industry.

89. Both papers find that prices tend to increase when there is a concentration in the mobile market. However, they also find that there is an increase in investment by the merged parties of around twice the level of price increases, according to Genakos et al, and that

investment may be more efficient due to not duplicating costs and benefiting from economies of scope.

90. Neither paper draws the simple conclusion that consolidation is harmful to consumers due to more concentrated markets raising prices to the benefit of shareholders only. It appears that at least some of the increased revenue is used for investing in new generations of mobile technology with dynamic efficiency benefits for consumers and the economy.

91. Although neither of the papers addresses this, the increase in prices could have moved firms to a point at which they could earn their cost of capital and hence resume investment. This would align with our model which shows that a threshold level of firms may exist in a market and that if the number of firms is above that threshold they would not be able to earn normal profits and hence future investment could be curtailed.

6 SUMMARY AND CONCLUSIONS

6.1 Summary

92. The level of investment in Gigabit networks currently taking place in some markets means that it is likely that there will need to be consolidation as markets can only support a finite number of firms. This is particularly the case in markets where firms benefit from economies of scale and density due to a high fixed to variable cost ratio. We have seen the start of this consolidation process in the UK where Fern Trading has consolidated three of their FTTP network operators: Jurassic Fibre, Swish Fibre and Giganet.[32]

93. There is a risk, however, that the number of networks a market may be able to sustain profitably is less than the number that regulators and competition authorities deem necessary to provide effective competition leading to good consumer outcomes. It is this tension and trade off that has been the subject of this discussion paper.

94. We have developed an illustrative economic model of sustainable competition in Gigabit network markets, which highlights two important points. Firstly, economies of density are a strong driver of economic sustainability. Densely populated urban areas, such as central business districts, can support more competing operators than urban, suburban or rural areas. Secondly, the sustainable number of networks in each geotype is sensitive to both supply and demand-side conditions, specifically the unit costs of the access network and the price elasticity of demand.

95. Empirical evidence from Hong Kong, Ireland and the UK support this finding. Most commercial investment in Gigabit networks has taken place in urban areas, which has made Hong Kong a particularly vibrant Gigabit network market. In both Ireland and the UK most commercial investment is taking place in urban areas.

6.2 Conclusion

96. This report has highlighted that the economies of scale and density that characterise Gigabit network markets mean that in some geographic areas the market may not be able to sustain the number of firms generally accepted as needed to support good consumer

[32] ISP Review, 8th February 2023 https://www.ispreview.co.uk/index.php/2023/02/fern-consolidates-uk-isps-jurassic-fibre-swish-fibre-giganet-and-allpoints-fibre.html#respond

outcomes. However, given the objective of efficient investment that allows firms to earn a reasonable return on their capital, it may be necessary for regulators and competition authorities to accept a more concentrated market than they would prefer.

97. Decisions that force a market structure designed around short-term, demand-side outcomes may result in long-term results that are harmful to consumers if firms cannot earn a reasonable return and so exit the market. A more concentrated market may result in higher prices. However, as the two articles on mobile market concentrated reviewed above show, higher prices and margins can lead to more investment, and better long-term consumer outcomes, rather than being returned to shareholders.

98. Ultimately, what we have shown in this report is that it would be wrong to set a *per se* rule on the minimum number of suppliers in a market if that number is economically unsustainable, deterring efficient investment. Instead, relevant authorities should treat each case on the merits and assess how many firms a market can sustain based on both supply and demand-side conditions.

Annex A: Application of the Cournot Model of competition

Historical note

Augustin Cournot (1801-1877) was a French mathematician and economist who pioneered mathematical analysis of monopolies, duopolies and oligopolies.

In 1835 Cournot became Professor of Mathematics at the University of Grenoble and in 1838 published *"Recherches sur les Principes Mathématiques de la Théorie des Richesses"* which outlined his model of competition. It is thought his analysis was inspired by insights whilst travelling through rural villages and observing the behaviour of the owners of fresh water springs, comparing cases of monopolists and those that competed in a duopoly with other fresh water springs in the local community.

There is a clear analogy between Gigabit networks and village wells. Both have high fixed sunk costs of construction and so there will ever only be a small of competitors. They also bothprovide almost homogenous products - the quality of water may vary a little between wells as will the quality of two fibre networks. In both cases they will essentially compete for the same market.

Theoretical model of the market equilibrium based on the number of competitors

We build a competitive model based on a Cournot equilibrium with the following market characteristics:

- a number of competing companies build FTTH/Gigabit networks to pass all homes within a defined geographic area;
- each networks faces the same cost structure: a fixed cost of passing all homes in the coverage area and a variable cost of connecting each customer requesting service;
- the networks compete to connect the same homes, charging a monthly price;
- some networks need to offer a discounted price to allow for a lack of brand recognition or perceived quality.

We use the following notation:

P	the market price (i.e. monthly charge) for a fibre connection provided by the *"most established"* network provider (e.g. the first to enter or the highest brand recognition);
ρ_i	the price discount factor offered by network i relative to the *"most established"* network provider to allow for a lack of brand recognition or

	perceived quality, e.g. $\rho_1 = 1$ for the most established operator, and a 5% discount by network i corresponds to $\rho_i = 0.95$;
Q	the total market of homes passed that are connected to one of the competing networks;
q_i	the percentage of homes passed that are connected to network i;
a, b	parameters of a linear market demand curve;
π_i	the profit earned by network i expressed as a lifetime monthly average;
m	the variable cost of connecting a customer from a passing network as a lifetime monthly average;
F	the fixed cost of passing all homes in the coverage area, expressed as a lifetime monthly cost;
n	the total number of networks built.

The market demand[33] curve for connected customers is:

$$P = a - bQ$$

This is a commonly used specification of the demand curve and has the plausible feature that the price elasticity will increase as the price rises:[34]

$$\varepsilon = -\frac{\partial Q}{\partial P}\frac{P}{Q} = \frac{1}{b}\frac{P}{Q} = \frac{P}{a-P}$$

The market demand is made up of the sum of demands for connection from each network:

$$Q = \sum_{i=1}^{n} q_i$$

The profit made by each network provider is:

$$\pi_i = (P\rho_i - m)q_i - F \quad ; \quad i = 1,2,3,\dots,n$$

Each network provider attempts to maximise profits, aware that connecting more customers will require lowering its own price and thus causing other networks to respond in the same way. We find the Cournot Equilibrium by solving the first order conditions:

[33] In this context take-up of FTTH/Gigaclear connection at a given price.

[34] To show this:

$$\frac{d\varepsilon}{dP} = -\frac{a}{(a-P)^2} < 0$$

$$\frac{\partial \pi_i}{\partial q_i} = P\rho_i - m - b\rho_i q_i = 0$$

It can be checked that the second order derivatives are negative, confirming that this is a maxima.[35] Returning to the first order conditions and re-arranging for q_i:

$$q_i = \frac{P - m/\rho_i}{b}$$

Summing across networks:

$$Q = \sum_{i=1}^{n} q_i = \sum_{i=1}^{n} \frac{P - m/\rho_i}{b} = \frac{nP}{b} - \frac{m}{b} \sum_{i=1}^{n} \frac{1}{\rho_i} = \frac{a - P}{b}$$

So that:

$$P = \frac{\left(a + m \sum_{i=1}^{n} \frac{1}{\rho_i}\right)}{n + 1}$$

The equation above shows how as the number of built networks (n) increases the market price (P) will fall. Alternatively, this can be re-written replacing a by ε:

$$P = \frac{m \sum_{i=1}^{n} \frac{1}{\rho_i}}{n - \frac{1}{\varepsilon}}$$

In the simplified case where all networks charge the same price:

$$P = \frac{(a + nm)}{n + 1} = \frac{m}{1 - 1/\varepsilon n}$$

This gives two alternative ways of interpreting the equilibrium market price in our chosen case of a linear demand curve. It is either:

- a weighted average of a (the hypothetical high price that would eliminate all demand) and variable cost c. As the number of competitors increases more weight is given to variable cost;

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[35] For instance:
$$\frac{\partial^2 \pi_i}{\partial q_i^2} = -2b\rho_i < 0$$

- a mark-up on variable cost, where the mark-up reduces as the number of competitors increases and/or the price elasticity increases.

Annex B: Cost Data

	Value by geo-type				
	Dense urban Central business district of major cities.	**Urban** Other city or town centres.	**Suburban** Continuous residential areas surrounding cities and towns.	**Rural** Small groups of homes in rural areas.	**Sparse rural** Individual homes separated by rural spaces.
Fixed Costs per home passed - Capex					
Total capex for local network, including the capitalised cost of street works, the cost of the cable, cable laying, street cabinets with any power supply or air-conditioning requirements, local network equipment and installation, street reinstatement and the cost of connecting the local network to the core network	529 €	602 €	1,178 €	1,555 €	2,596 €
Core network	54 €	54 €	54 €	54 €	54 €
Fixed Costs per home passed – Annual Opex					
Average annual network opex for the local network, including power and aircon, and repair and maintenance	13 €	13 €	13 €	13 €	13 €
Variable Costs per home connected - Capex					
One-off average incremental cost of connecting an individual customer (essentially just installing the customer drop and network termination)	291 €	291 €	291 €	299 €	451 €
Variable Costs per home connected – Annual Opex					
Average incremental annual opex of maintaining the last drop to an individual customer	15 €	15 €	15 €	15 €	23 €
Customer services	74 €	74 €	74 €	74 €	74 €
Overheads	69 €	69 €	69 €	69 €	69 €

Annex C: Model Results

Geo-type:	Dense urban				
Marginal network	Revenue excluding VAT / sub / month	Average cost / sub / month	Profit / sub / month	Subs connected / network	Total market subs connected
One of one	59.44 €	24.13 €	35.31 €	68%	68%
2nd of two	41.90 €	28.16 €	13.73 €	45%	91%
3rd of three	32.96 €	32.23 €	0.73 €	34%	102%
4th of four	27.45 €	36.34 €	-8.89 €	27%	108%
Geo-type:	**Urban**				
Marginal network	Revenue excluding VAT / sub / month	Average cost / sub / month	Profit / sub / month	Subs connected / network	Total market subs connected
One of one	59.44 €	24.81 €	34.62 €	68%	68%
2nd of two	41.90 €	29.20 €	12.70 €	45%	91%
3rd of three	32.96 €	33.62 €	-0.66 €	34%	102%
4th of four	27.45 €	38.08 €	-10.62 €	27%	108%
Geo-type:	**Suburban**				
Marginal network	Revenue excluding VAT / sub / month	Average cost / sub / month	Profit / sub / month	Subs connected / network	Total market subs connected
One of one	59.44 €	30.18 €	29.25 €	68%	68%
2nd of two	41.90 €	37.28 €	4.61 €	45%	91%
3rd of three	32.96 €	44.44 €	-11.48 €	34%	102%
4th of four	27.45 €	51.66 €	-24.21 €	27%	108%
Geo-type:	**Rural**				
Marginal network	Revenue excluding VAT / sub / month	Average cost / sub / month	Profit / sub / month	Subs connected / network	Total market subs connected
One of one	59.48 €	33.83 €	25.65 €	68%	68%
2nd of two	41.95 €	42.71 €	-0.76 €	45%	90%
3rd of three	33.02 €	51.67 €	-18.65 €	34%	101%
Geo-type:	**Sparse rural**				
Marginal network	Revenue excluding VAT / sub / month	Average cost / sub / month	Profit / sub / month	Subs connected / network	Total market subs connected
One of one	60.36 €	46.29 €	14.07 €	67%	67%
2nd of two	43.09 €	60.37 €	-17.28 €	44%	89%
3rd of three	34.27 €	74.59 €	-40.33 €	33%	99%

The market metrics are:

- **Revenue/subscriber/month:** this declines as more companies enter the market and consequently competition intensifies. Note that this is higher than the price of the basic broadband service since it assumes that networks will make additional margin from content and other services. Revenue excludes VAT;

- **Cost/subscriber/month:** this includes a normal return on investment, i.e. a return approx. equal to the cost of capital. It increases as more competitors enter the market as network costs need to be spread over a smaller market share;

- **Profit/subscriber/month:** the difference between revenue and cost, providing the key conclusion on financial viability of the marginal competitor;

- **Subscriber shares:** this declines as more competitors enter the market;

- **Total market take-up:** this increases as more competitors enter the market and consequently retail prices fall.