Improving connectivity – stimulating the economy

Mobile network operators and the UK economy

A report by Capital Economics for EE

26 November 2014

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1 KEY FINDINGS

Capital Economics was commissioned by EE to produce this report on the economic contribution of the mobile industry, 4G LTE technology and the potential risks to growth and investment in the sector.

Our key findings are:

- Mobile is now a major British industry. The four largest mobile network operators provide a total of 35,400 full time equivalent jobs
- Overall, the industry supports nearly 140,000 jobs in the United Kingdom through its supply chain, its employees' spending and directly
- The total consumer surplus of mobile telephony was between £28 and £34 billion in 2013
- More than £25 billion has been paid by mobile network operators to the government for both 3G and 4G LTE spectrum since 2000
- The industry in the United Kingdom is less profitable than European and North American peers but offers consumers access to the third cheapest mobile phone services of Organisation for Economic Co-operation and Development countries
- The mobile network operators are currently investing around £5½ billion to upgrade the mobile network to 4G LTE spread over three or four years, in addition to routine maintenance and upgrade work
- Future improvements to 'densify' the network likely to involve investment which is similar in scale to the first phase of 4G LTE rollout
- The eventual productivity gains from 4G LTE mobile broadband could be in the order of up to 0.7 per cent of gross domestic product or £12 billion annually in today's prices
- The proposed increase in annual licence fees and introduction of national roaming could reduce investment by up to £582 million annually lowering gross domestic product by 0.2 to 0.3 per cent

2 INTRODUCTION AND SUMMARY

Capital Economics has been commissioned by EE to produce an independent report assessing the scale and significance of the mobile telephony industry, the economic benefits of 4G LTE technology and the factors affecting future growth and investment in the sector.

We start in chapter two by considering the importance of the mobile telephony industry to the United Kingdom economy. The mobile industry has been a great growth story over the past couple of decades. Mobile telephones were first introduced in the mid-1980s; by the turn of the century just over half of adults used a mobile telephone, while in 2013 that figure stood at 94 per cent. There are currently around 83 million mobile subscriptions, equating to 1.3 for each and every person in the country.

The four largest mobile network operators (i.e. EE, Three, Vodafone and O2) directly employ around 35,400 full time equivalent employees and create £4.5 billion of value in the economy each year, enabling consumers and businesses more efficient communication by providing people with mobile handsets, and voice and data services. Additionally, there are approximately 11,000 people employed by mobile virtual network operators (MVNOs), which use one of the four networks to provide mobile services to their customers, and specialist mobile retailers. Beyond the network operators and retailers the industry involves the manufacture and distribution of mobile devices, as well as network engineers and network component manufacturers. We estimate that these businesses employ approximately 13,500 people.

Not only does the mobile industry create jobs and economic activity, but it also breeds innovation and investment. The network operators are currently rolling out 4G LTE upgrades to their networks with a total investment package worth around £5½ billion over three or four years. On the back of large-scale investment the United Kingdom now has the fourth largest number of 4G subscribers in the world, despite being the 53rd country to launch 4G. The industry is likely to spend a similar amount to further 'densify' the network. This new technology enhances mobile communications by delivering a step change in mobile broadband speeds compared to the predecessor system, 3G. These are not one-off investments; unlike other capital intensive industries such as electricity or water distribution, the technological innovations in mobile communications require the network operators to invest in a major overhaul of their networks on a frequent cycle, in addition to the 'routine' upgrade and maintenance work.

The mobile network operators' activities also generate a healthy tax contribution through value added tax, business rates, employer and employee

related taxes, which total around £1.8 billion per annum. In addition, they have written cheques to HM treasury to the tune of £25 billion for both 3G and 4G LTE spectrum since 2000.

Chapter three assesses the 'knock-on' economic activity that is stimulated by the activities of the mobile network operators. The four operators spend large sums on suppliers each year, including 'normal' business operational expenditure, as well as spending on network equipment and repair, maintenance and upgrade activities. This spending supports over 85,000 jobs across a wide range of industries, and in all regions of the United Kingdom.

Furthermore, the spending of the mobile network operators' employees creates incomes for businesses, which themselves create value and jobs, as well as providing incomes for their own suppliers. In total, we estimate that their spending supports around 17,000 jobs.

Overall, including both direct jobs and those supported by the 'knock-on' economic activity stimulated upstream of the industry, the mobile network operators support nearly 140,000 jobs in the United Kingdom.

In chapter four we consider the benefits of mobile telephony generally, both to consumers and the economy at large, before focussing on the potential macroeconomic benefits of 4G LTE specifically.

The use of mobile telephony brings with it substantial economic benefits. It increases productivity by permitting greater and easier communication between consumers and businesses, facilitating greater mobility for consumers and workers, improving the efficient use of time, and stimulating the innovation of new products, services and business models.

Consumers value faster mobile broadband. It enables users to do what they already do more quickly, as well as opening up new possibilities in the way we communicate, work and create and distribute content and data. A survey of 4G LTE users highlights the value that consumers already place on the new technology; 60 per cent of respondents said that they would not consider returning to 3G, while nearly 80 per cent would recommend 4G LTE to friends and family.

Existing literature suggests that the total consumer surplus of mobile broadband was £7½ billion in 2013, so the introduction of 4G LTE services could readily increase this benefit by £2 billion per annum.

There are also significant productivity gains from faster and more reliable mobile broadband. We have based our calculations on one aspect of the benefits: the time saved by mobile broadband business users. We believe that

4G LTE could eventually deliver productivity gains worth up to 0.7 per cent of gross domestic product.

However, there are other elements of the potential benefits from 4G LTE, such as productivity gains for business through the ability to work differently or the wider catalytic and network effects. It increases the efficiency of time spent working on the move and encourages more flexible and efficient working practises. It also acts as a catalyst for further innovation elsewhere — stimulating new products, services and even business models. Although these are more difficult to quantify, it does not mean they should be ignored.

Finally, once 4G LTE is fully rolled out it will deliver superfast broadband to sections of the population, primarily in remote rural communities, that do not have access to fixed line alternatives. It will cover at least two per cent of the population that have no access to broadband above two megabits per second, plus more that are not on course to receive superfast fibre optic connections. There are widely varying estimates of the impact of broadband, and superfast broadband, penetration— but it is clear that it has a positive impact on the economy. The existing research suggests this could add up to 0.25 per cent to gross domestic product.

In chapter five we examine whether the mobile business model in the United Kingdom is robust enough to secure the investment needed for future growth in the sector and benefit to the broader economy.

As large investment intensive businesses, mobile network operators require access to the international capital markets. As such, they need to deliver adequate returns to satisfy their past investors, and ensure future funding from institutions able to pick and choose between competing investments globally. Indeed, the operators in the United Kingdom are all now subsidiaries of larger international groups, which operate at a scale greater than any national market.

In comparison with European and North American peers, mobile network operators in the United Kingdom are less profitable, in large part because they are saddled with the burden of expensive spectrum auctions. Achieving comparable rates of return to their international peers should deliver a substantial increase in investment, which could further improve coverage for consumers and businesses and drive economic growth.

We also find that cost increases, for example Ofcom's proposal to increase annual licence fees by nearly 400 per cent, could have serious adverse effects on the industry and the national economy.

There are different ways in which the mobile network operators could respond to these costs. First, they could reduce capital expenditure. We

estimate that the increase in annual licence fees could reduce investment by £182 million per annum and delay the rollout of 4G LTE in the United Kingdom and its broader benefits to the economy. Alternatively, the mobile operators may decide to cut costs elsewhere in the business, which could lead to poorer customer service or domestic jobs being outsourced. Finally, the industry could choose to raise revenues by increasing prices; if the additional cost burden is passed directly onto consumers, it could increase consumer bills by 1.3 percentage points before value added tax.

In chapter six we examine whether the currently consulted upon option of national roaming would produce a net benefit to the economy.

We find that national roaming would likely increase 2G geographical coverage by between two and four percentage points but at an estimated cost of £3 billion over a five year period. Whilst consumer surplus could increase by £136 to £175 million, this may be wiped out by 'signal locking' where mobile devices unnecessarily connect to another network and cannot access data services. Just one to two incidents per week for each data user would eliminate this benefit.

Furthermore, and contrary to the government's intentions, thinly covered rural areas could see significant reductions in investment. Mobile networks are currently 'excludable', meaning that an operator can stop non-subscribers accessing its services. They can compete on coverage, which gives them an incentive to provide infrastructure in areas where it would not be cost effective to do so on its own merits. But by ending this excludability and allowing 'free riding', national roaming would remove any incentive to provide coverage in unprofitable areas.

Switching resources to implement national roaming could delay the rollout of 4G by up to 24 months. The ongoing costs to support it could reduce the industry's capital expenditure by £400 million annually, lowering gross domestic product by 0.1 to 0.2 per cent.

3 THE MOBILE NETWORKS: BRITAIN'S GROWTH SUCCESS

In this section, we examine the mobile telephone industry as a whole — its recent growth, size and significance.

Our key findings are:

- **Mobile has grown to be the dominant telephone technology, and is especially important for businesses**

- **Mobile network operators represent a significant industry in their own right, providing around 35,400 full time equivalent jobs, turning over annual revenues of £19 billion and contributing £4.5 billion per annum to national economic output**

- **In addition to the four network operators, the provision of mobile telephony in the United Kingdom involves smaller mobile virtual network operators, specialist indirect retail channels, device manufacturers and businesses providing components and services for the networks; total employment in these companies is around 28,500**

- **The mobile network operators invest heavily in the United Kingdom's infrastructure and are currently mid-way through a £5½ billion first phase investment programme to rollout 4G LTE, in addition to 'routine' maintenance and upgrade work**

- **The operators generate taxes to the tune of £1.8 billion each year; adding in the cost of annual licence fees and an annualised cost of spectrum auctions, this increases to a £3.7 billion payment to the Chancellor**

3.1 The growing role of mobile telephony

The mobile telephone has become a vital part of everyday life for over 48 million adults in the United Kingdom[1] — and an essential tool for many businesses.

Mobile phones were first introduced to the United Kingdom in the mid-1980s. By 2000, just over half of adults used a mobile phone while in 2013 that figure stood at 94 per cent. There are currently around 83 million mobile subscriptions, equating to 1.3 for each and every person in the country.[2]

In the half-decade to 2012 alone, while the British economy was experiencing its worst recession since the 1930s, the volume of voice calls originating from mobile telephones rose by sixteen per cent.[3] Over the same period, the volume of calls made on the traditional 'fixed line' telephone networks fell by over 30 per cent. In 2012, 122 billion minutes of calls were made on mobile telephones — while over 2,300 text messages were sent for every man, woman and child.[4] In that year, the fixed line network carried almost 20 billion fewer minutes of calls than the mobile networks.[5] 'Cellular' has overtaken fixed line to become the dominant telephone technology.

The mobile telephone is firmly established as a business tool. Almost 60 per cent of businesses are now providing some or all of their employees with mobile devices for business use. (See Figure 1.)

Figure 1: Employees proportion of businesses using a mobile internet connection

Share of businesses, 2012	Businesses by number of employees				
	10-49	50-249	250-999	1000+	All
Businesses that provided employees with portable devices for business use	53.6	80.0	92.3	97.9	58.5

Source: Office for National Statistics. Note: Coverage is United Kingdom non-financial sector businesses with ten or more employees.

[1] Ofcom website. Proportion of adults who personally own/use a mobile phone in the UK: 94 per cent (Q4 2013). http://media.ofcom.org.uk/facts/ [viewed 22 May 2014].
[2] Mobile Operators Association. See http://www.mobilemastinfo.com/stats-and-facts/ [accessed 04 June 2014].
[3] Ofcom, *Communications Market Report 2013* (Ofcom, London), 2013. Data for 2007 to 2012.
[4] Ofcom, *Communications Market Report 2013* (Ofcom, London), 2013. 152 billion messages in 2012.
[5] Ofcom, *Communications Market Report 2013* (Ofcom, London), 2013. 102.5 billion minutes in 2012.

3.2 What is the mobile industry?

The industry behind the device has grown rapidly and is, today, one of the nation's largest and most vibrant economic sectors.

Recognising the changing importance of telecommunications generally, and mobile telephony businesses in particular, the government's statistical agency, the Office for National Statistics, now collates and reports economic information relating specifically to the sector. Part of a new telecommunications 'division' within the 2007 revision of their *Standard Industrial Classification*[6], the 'wireless telecommunications activities class' covers businesses primarily involved with:

- operating, maintaining or providing access to facilities for the transmission of voice, data, text, sound, and video using a wireless telecommunications infrastructure

- maintaining and operating paging as well as cellular and other wireless telecommunications networks

Although the Office for National Statistics recognises the industry in their classification, the data collected for it do not yet appear to reflect robustly what would commonly be described as the mobile telephone sector. Their data for 2012 suggest that the mobile telephone industry employed 12,000 people in Great Britain, compared with 5,000 in 'wired', 9,000 in 'satellite' and 166,000 in 'other' telecommunications activities.[7] EE alone has almost 13,000 full time equivalent employees, so these official data are not covering all of the activities of the mobile network operators. Likewise, data extracted from the official annual survey of businesses suggest that the total revenues generated by 'wireless telecommunications activities' was £1.5 billion in 2011[8]; Telefónica UK Limited, which trades under the O2 brand, turned over more than £5 billion then.

Given the ambiguity in official data, we have developed our own measures of the scale of the industry.

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[6] Lindsay Prosser (ed.) and Office for National Statistics, *UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007): Structure and explanatory notes* (Palgrave Macmillan, Basingstoke), 2009.

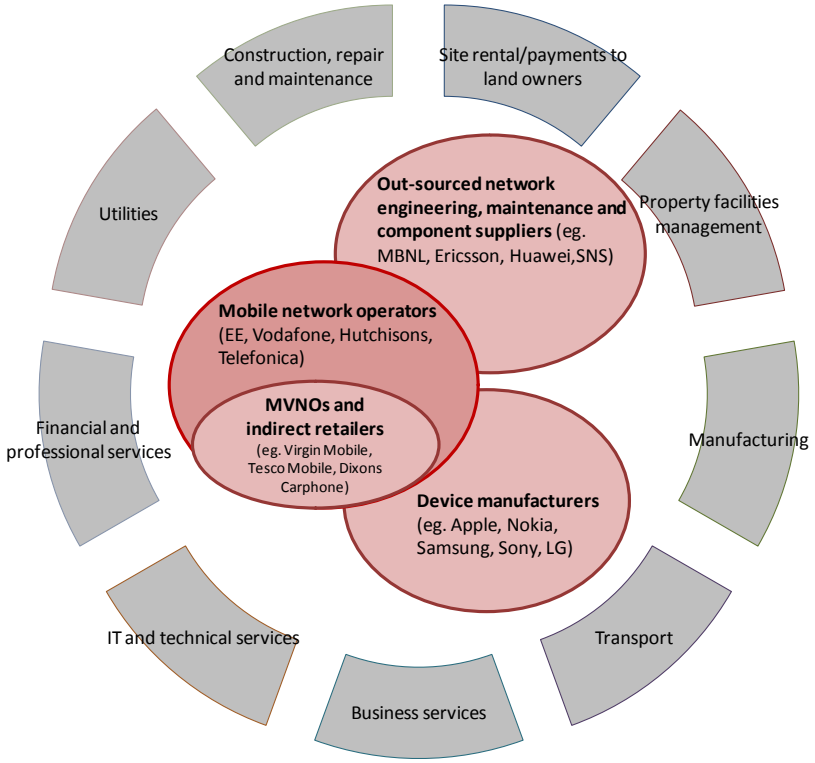
[7] Data downloaded from the Office for National Statistics Nomis website on 22 May 2014. Employment numbers rounded to the nearest thousand.

[8] Office for National Statistics, *Annual Business Survey: Section J - Information and communication* spreadsheet, released 23/11/2012. Data downloaded from the ONS's main website www.statistics.gov.uk on 23 May 2014.

Of course, there are a number of important components that are involved in the delivery of mobile telecommunication services. As well as the mobile network operators, who own the networks and offer mobile contracts to customers, there are also device manufacturers and manufacturing/engineering businesses which provide equipment and carry out repair, maintenance and installation services on the networks. (See Figure 2.)

In addition to the four mobile network operators, there are also mobile virtual network operators (MVNOs), such as Virgin Mobile and Tesco Mobile, who offer mobile telephony services to customers but do not own their own networks. Instead, they offer voice and data services by using spectrum from one of the mobile network operators. There are also retailers who specialise in the sale of mobile phone contracts and related accessories, such as Dixons Carphone. (See Figure 2.)

Figure 2: Overview of the mobile telephony industry in the United Kingdom



Source: Capital Economics and EE.

However, for the purposes of this report we focus predominantly on the combined activity of the four mobile network operators: EE, Three, O2 and Vodafone. We have estimated their scale based on the most recent published accounts of the four networks, supplemented where needed and appropriate

by confidential data provided by EE and official statistics published by the Office for National Statistics.[9]

3.3 Revenues and employment

We estimate that the four mobile network operators have the equivalent of 35,000 full time equivalent direct employees, or around 42,000 people working for them when taking into account part-time arrangements. This is 0.15 per cent of all jobs nationally.[10] Meanwhile, the industry turns over annual revenues of around £19 billion.

This makes mobile telephony a significant industry in its own right.

Employment is around the same scale as in the drinks manufacturing industry and the high profile pharmaceutical manufacturing sector. It has more jobs than ship and boat building (with 29,900), clothes manufacturing (22,700) and television broadcasting (25,800).[11]

[9] The four companies are: EE; Hutchison 3G UK Limited, which operates the 3 network; Telefónica UK Limited, which operates the O2 network; and Vodafone Limited. Where possible to identify, we have used employment and revenue figures that relate to operations in the United Kingdom only.

[10] Calculated using total Great Britain employment of 27,467,557 in 2012. Data downloaded from the Office for National Statistics Nomis website on 22 May 2014.

[11] Data refer to 2012 and are number of employees, including part time workers. Downloaded from the Office for National Statistics' Nomis website on 23 May 2014. Employment numbers rounded to the nearest thousand relate to the following 'three digit' sectors: 110 Manufacture of beverages; 141 Manufacture of wearing apparel, except fur apparel; 212 Manufacture of pharmaceutical preparations; 301 Building of ships and boats; 602 Television broadcasting and programming.

Figure 3: Employment and revenues of mobile network operators in the United Kingdom, 2013

	Jobs (number)	Turnover by employee location (£ billion, current prices)
North East	6,300	3.4
North West	3,800	2.1
Yorkshire and The Humber	900	0.5
East Midlands	1,900	1.0
West Midlands	2,200	1.2
East	4,000	2.1
London	7,200	3.9
South East	2,800	1.5
South West	2,500	1.3
Wales	1,900	1.0
Scotland	1,800	0.9
Northern Ireland	100	0.1
United Kingdom	**35,400**	**19.1**

Source: Capital Economics' analysis based on published annual accounts of the four networks, official statistics and confidential data provided by EE.

Our estimates of the industry's overall scale appear comparable to or conservative against others produced in the past few years. For example, a 2012 report by Analysys Mason found that employment in the industry was around 38,000 in 2010, while turnover in 2011 was £20 billion in 2011, including revenue from content and applications earned by companies other than the mobile operators.

The mobile business has expanded rapidly over the past couple of decades. In 1990 there were just two network operators: Vodafone Racal and BT Cellnet. At that point the total turnover of the mobile network operators was around £700 million, providing just under 3,000 jobs.[12] Over the last two decades the industry has grown more than ten-fold to become a significant employer nationally.

The industry also provides a wide range of employment, from call centre operatives to skilled software engineers in all areas of the country. (See Figure 4.)

[12] Vodafone annual report 1991.

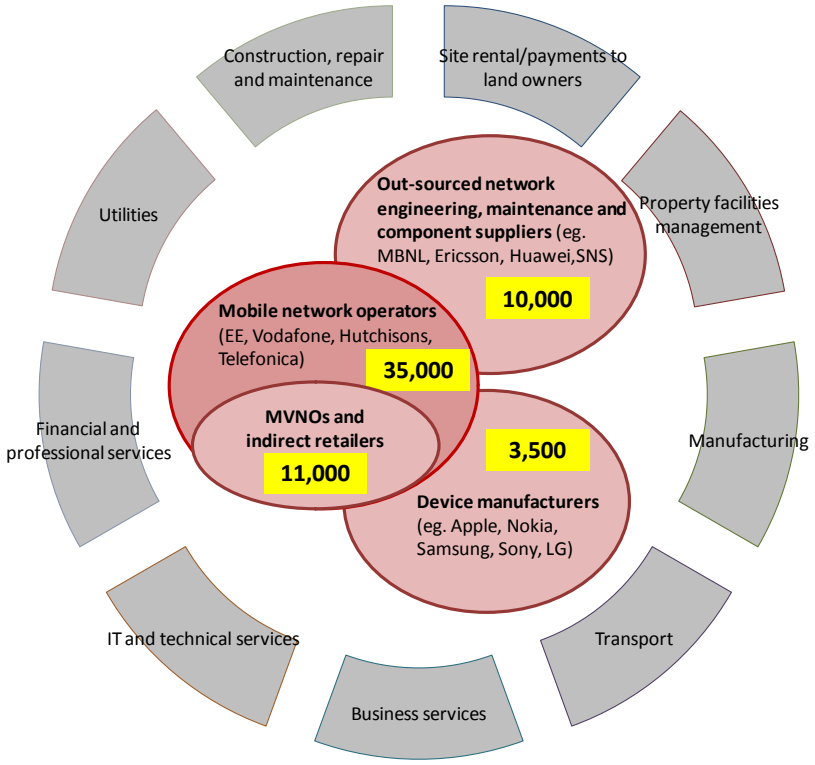
Figure 4: Average annual salaries of full time employees, 2013, current prices

	Number of jobs (full time equivalent)	Average salary (£)
Brand and marketing	610	53,839
Corporate and strategy	477	46,374
Customer service	17,052	17,903
Finance	1,440	38,900
Human resources	733	32,144
Non-consumer marketing	1,338	45,473
Performance	404	51,205
Sales	10,591	19,687
Technology	2,773	47,126
Total	**35,417**	**24,297**

Sources: Capital Economics' analysis of EE data and the Office for National Statistics' Annual Survey of Hours and Earnings 2013.

In addition, there are approximately 13,500 full time equivalent jobs provided by device manufacturers and network supply businesses which are essential for a functioning mobile telephony, as well as approximately 11,000 full time equivalent jobs at the mobile virtual network operators and specialist mobile phone retailers such as Dixons Carphone. (See Figure 5.)

Figure 5: Overview of employment in the mobile telephony industry in the United Kingdom, full time equivalent employment



Source: Capital Economics' estimates based on EE procurement data and published annual accounts for the industry's main suppliers.

According to the latest Ofcom data, retail revenues from mobile voice and data services account for almost half of the telecommunications industry's turnover.

However, revenue growth has been driven by the growing number of subscribers and purchase of increasingly expensive smartphones through the mobile network operators, rather than lining the pockets of the industry. Data from Ofcom show that the real cost of a bundle of mobile services including line rental, calls, texts and data, has fallen by 42 per cent from an average monthly cost of £24.32 in 2007 to £14.10 in 2012. As data from the Organisation for Economic Cooperation and Development show, the United Kingdom is the third cheapest of the 33 countries analysed for a representative mobile package including messages, calls and data.[13] And while prices have been fallen, the product offered by mobile network operators has improved. 'Post-pay' contracts often include mobile devices as part of the package, with more expensive smartphone devices being offered as

[13] Organisation for Economic Cooperation and Development, *OECD Communications Outlook 2013* (OECD, Paris), 2013. Data refers to the price of 'OECD 100 calls + 500MB' mobile basket in August 2012. The price in the United Kingdom was $11.10 adjusted for purchasing power parity compared to the highest cost of around $75 (PPP) in Japan.

the norm. Equally, there is a tendency for increasing volumes of voice minutes, messaging and data allowances.[14]

Meanwhile, the cost of fixed line access (including landline calls within the United Kingdom) has fallen by just 1.3 per cent over the period from 2007 to £18.11 in 2012.[15] This is despite the fact that there have not been any significant shifts in the product offered, as there has been with mobile services.

3.4 Innovation and investment

Mobile telephony is a capital intensive business which needs to maintain and upgrade a nationwide communications network as well as deliver industrial scale retail and customer service operations. In addition to the 'routine' spend of the operators on their network infrastructure, operators regularly overhaul their entire networks and systems to accommodate the latest innovations in telecommunications. They are currently implementing a significant investment programme to install equipment for the latest generation of mobile broadband technology, so called '4G LTE'.

4G LTE (or 'fourth generation long term evolution') is the successor mobile data transmission technology to the previous 3G and 3.5G systems, which was introduced to the United Kingdom in 2012 and is currently being rolled out across all four mobile networks. Although the United Kingdom was the 53rd country globally to launch 4G, it now has the fourth largest number of subscribers worldwide.[16]

As part of the rollout of 4G LTE services, the mobile operators are investing heavily in the upgrade of their networks, as well as carrying out general repair and maintenance of the existing network. In total, upgrading the mobile network to 4G LTE requires around £5½ billion of investment by the operators which is set to be spread over three or four years with a second similar wave to follow to further improve and extend coverage.[17]

This is a significant investment programme as these comparators demonstrate:

[14] Ofcom, *Communications Market Report 2013* (Ofcom, London), 2013.
[15] *ibid.*
[16] Data sourced from CCS insight.
[17] Capital Economics' estimate based on data from information from EE.

- The government's entire annual transport budget for 2015/16 is set at £8.6 billion[18]

- The total 'all inclusive' budget for Crossrail — which is the rail route currently under construction through London covering 37 stations and 21 kilometre of new twin bore tunnel, and is Europe's biggest engineering project — is £14.8 billion spread out (unevenly) over ten years[19]

- The cost of building a new nuclear power plant is in the order of £4-6 billion[20]

Indeed, a £5½ billion investment programme will register as a meaningful boost to business investment nationally. The United Kingdom is finally starting to show signs of growth again after a prolonged and painful recession. However, the growth is primarily being driven by the consumer sector. Household consumption grew by an annual average of 1.1 per cent over 2012 and 2013, compared to average investment growth of 0.1 per cent. The investment from the mobile sector is important to help rebalance the economy and ensure the recovery is sustained. The entire 4G LTE rollout investment programme is equivalent to 0.8 per cent of all gross fixed capital investment in the United Kingdom over the past three years.[21]

This is by no means a one-off investment. After the initial roll-out which will provide coverage to 98 per cent of the population, further investment will be made to 'densify' the network. The next phase of investment will see around the same amount invested again (£5½ billion) by the mobile operators in the coming years to improve indoor coverage, increase capacity in busy areas and generally improve the quality of the 4G LTE service.[22]

It is not only infrastructure that commands investment from the network operators. They have also invested significant sums in upgrading the fleet of smartphones from 3G to 4G, which are generally provided with the consumer not having to pay anything for the handset up-front.

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[18] HM Treasury, *Investing in Britains' future* (TSO, London), June 2013.
[19] Data from http://www.crossrail.co.uk/railway/funding as accessed on 22 May 2014. Enabling works commenced December 2008; services through the central tunnel section are expected to commence late 2018.
[20] Construction costs in the United States of $6-9 billion for a 1,100 MW plant in 2008. Source — David Schlissel and Bruce Biewald, *Nuclear Power Plant Construction Costs* (Synapse Energy Economics, Cambridge MA), July 2008. At the then current exchange rates, costs are equivalent to £3.7-5.5 billion sterling, and then up-rated for inflation.
[21] Office for National Statistics, *Second estimate of GDP Q1 2014.* Gross fixed capital formation totalled £226 billion in 2013 in current prices.
[22] Capital Economics' estimate based on data from EE.

Moreover, our £5½ billion estimate does not include the cost to the mobile telephone network operators of buying from the government the right to use the appropriate spectrum over which to operate 4G LTE services. Although these payments are very real financial transfers from the private sector to the public (and will help the Chancellor reduce government borrowing), they do not count as an economic flow; they are only a redistribution of the benefit from future economic activity.

Nevertheless, the 3G spectrum auction in 2000 earned the government a one-off windfall of around £22½ billion. This is equivalent to just less than half of the entire government spending on healthcare in that year.[23] The auction for 4G LTE spectrum was conducted in 2012 and provided the government with a further £2.1 billion — almost enough to fund the government's spending on pre-primary and primary education for the following three years.[24]

In addition to the cost of acquiring the spectrum, the four network operators spend around £65 million each year to hold legacy spectrum allocated before the auction system was introduced, which goes directly to the public purse. This amount is currently under consultation and could increase roughly four-fold.[25] (See section 6.2.)

3.5 Economic activity

The use of data from companies' annual accounts is problematic when attempting to measure the economic rather than financial dimensions of an industry, and especially one of the key measures of economic activity or output, 'gross value added'. This is particularly the case in the mobile telephone industry, where companies' financial reports are unlikely to properly and consistently reflect the underlying economics because of the large losses incurred subsequent to the purchase of spectrum from the government as well as the varying treatment of their sizeable capital expenditure programmes. As such, we have used official data for the whole of the telecommunications sector to calculate an average employee productivity figure, and have applied this to the mobile telephone industry to estimate its gross value added. This is a simplification — but it is reasonable, although likely to understate the mobile industry's gross value added.

[23] See: http://www.ukpublicspending.co.uk/ [accessed 27 May 2014].
[24] Ofcom. See: http://www.ofcom.org.uk/static/archive/spectrumauctions/auction/auction_index.htm [accessed 03 June 2014] and http://media.ofcom.org.uk/2013/02/20/ofcom-announces-winners-of-the-4g-mobile-auction/ [accessed 29 May 2014].
[25] Ofcom, *Annual licence fees for 900 MHz and 1800 MHz spectrum Further Consultation* (Ofcom, London), 2014.

In total, we estimate that the network operators generate £4.5 billion of gross value added, which is equivalent to 0.3 per cent of all economic activity and is larger than sectors such as the manufacture of electrical equipment, passenger rail transport, scientific research and development, or hospital activities.[26]

We have also estimated the distribution of the mobile network operators' activity across the regions of the United Kingdom based upon the Office for National Statistics' data[27] supplemented where necessary by information from EE on their operations (which we use as illustrative of the sector more generally). This shows that the industry supports economic activity across the country. (See Figure 6.)

Figure 6: Gross value added of the mobile telephony industry in the United Kingdom, 2013, current prices

	GVA (£ billion)
North East	0.8
North West	0.5
Yorkshire and The Humber	0.1
East Midlands	0.2
West Midlands	0.3
East	0.5
London	0.9
South East	0.4
South West	0.3
Wales	0.2
Scotland	0.2
Northern Ireland	0.0
United Kingdom	**4.5**

Source: Capital Economics' analysis based on published annual accounts of the four networks, official statistics and confidential data provided by EE. Note: Figures rounded to one decimal place. Northern Ireland figure is greater than zero.

3.6 Tax and other contributions to the exchequer

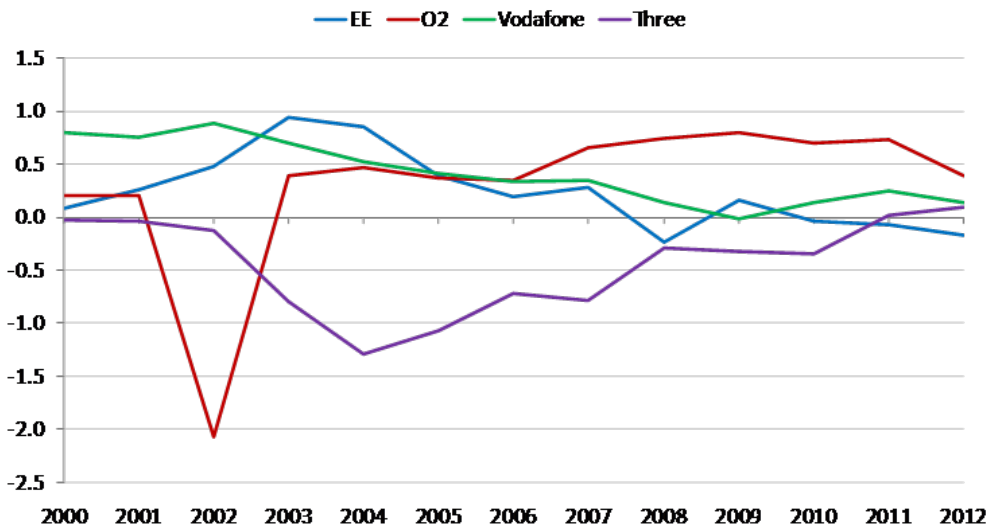
Mobile network operators contribute significant sums to HM Treasury each year through a range of taxes that are generated by their business activity. In

[26] United Kingdom gross value added at basic prices in 2012 was £1,383 billion according to the Office for National Statistics' regional accounts.
[27] Regional employment data for 'wireless telecommunications activities' from ONS's Nomis website. These data exclude Northern Ireland; in the analysis, it has been assumed that Northern Ireland's share of total mobile telephone industry is equal to its share of national gross domestic product.

total, we estimate that the total payments of value added tax, business rates, employer and employee related taxes by the operators amounted to £1.8 billion in 2013. (See Figure 8.)

The mobile network operators can pay little (and, sometimes, no) corporation tax. This is in part because they make substantial investments in the United Kingdom's infrastructure, which is encouraged by the government through the capital allowance scheme whereby such costs are partly offset against taxable profits. In addition, the mobile operators have contributed significant sums to the exchequer through spectrum auctions, as well as the annual licence fees that they are required to pay each year for legacy bandwidth. The scale of these payments have meant that some networks have been running at a loss, or with low levels of profits — which further reduces their liability for corporation tax. (See Figure 7.)

Figure 7: Operating profit made by mobile network operators, £ billion



Source: Annual accounts of individual companies.

We estimate that the government receipts from the industry excluding spectrum auctions equates to £1.8 billion each year. This includes over £1 billion of value added tax, £300 million of employee taxes and over £200 million of business rates. (See Figure 8.)

Figure 8: Estimated contribution to HM Treasury, 2013

	Mobile network operators (2013, £ million)
Value added tax	1,164
Employer taxes	118
Employee taxes	299
Business rates	225
Total	**1,806**
Annual Licence Fees	64
3G and 4G Spectrum auction	24,620
Average annualised spend on spectrum auctions since 2000	*1,894*

Source: Capital Economics' estimate based on scaling up of EE data.

Including their payments for spectrum, the network operators' contribution to the exchequer averages out at around £3.7 billion per annum, which is large compared to other firms and sectors. (See Figure 9.)

Figure 9: Contributions to HM Treasury for selected firms and industries relative to their size

£	Tax contribution	
	per £ of gross value added	per employee
Mobile network operators	**0.82**	**0.10**
Games industry	0.33	0.01
Financial and professional services	0.32	0.03
Energy sector	0.14	0.02
Vehicle leasing and rental sector	0.07	0.02

Sources: Capital Economics' analysis of a range of economic impact studies: Oxford Economics, *The economic contribution of the UK Games Development industry* (Oxford Economics, Oxford), 2008. The City UK, *Economic Contribution of UK Financial and Professional Services 2012* (The City UK, London), 2013. Tony Ward, Filippo Gaddo and Bill Easton, *Powering the UK* (Ernst and Young, London), 2012. Oxford Economics, *The economic impact of the motor-vehicle full service leasing and renting sector* (Oxford Economics, Oxford), 2012.

4 ECONOMIC ACTIVITY SUPPORTED

In this section we look at the economic activity supported by the spending of the mobile network operators on their suppliers and employees, including their substantial investment in the network as part of the rollout of 4G LTE.

Our key findings are:

- **The mobile network operators spent over £11 billion in 2013 on suppliers providing goods, business services and network support; around £6½ billion of this was spent on domestic businesses and recycled in the United Kingdom economy**

- **Over 85,000 jobs and economic activity worth £4.5 billion is supported by the mobile network operators' purchases from their suppliers**

- **The industry's employees spend over £1 billion each year on businesses across the country which supports in the region of 17,000 jobs**

- **Overall, including 'knock on' effects, the mobile network operators support nearly 140,000 jobs and economic activity worth almost £10 billion in the wider economy**

4.1 Mobile networks' purchases from suppliers

The direct activities of the mobile network operators stimulate further economic activity in the supply chain that they support.

We have made estimates of the scale of activity upstream of the mobile network operators. Our estimates are based upon information we have received from EE about their purchases from suppliers; from this, we have generalised for the four operators as a whole.

In 2013, we estimate that the four operators spent £9.5 billion on suppliers in relation to their general operational activities. The largest components include expenditure on devices and customer equipment, information technology systems, advertising, marketing, financial and legal services, and facilities management. However, not all of this has a direct impact on the national

economy; there is some leakage out of the United Kingdom when goods and services are procured from foreign suppliers. Accounting for imports on a conservative basis, we estimate that around £4.8 billion is spent annual by mobile network operators on domestic businesses.

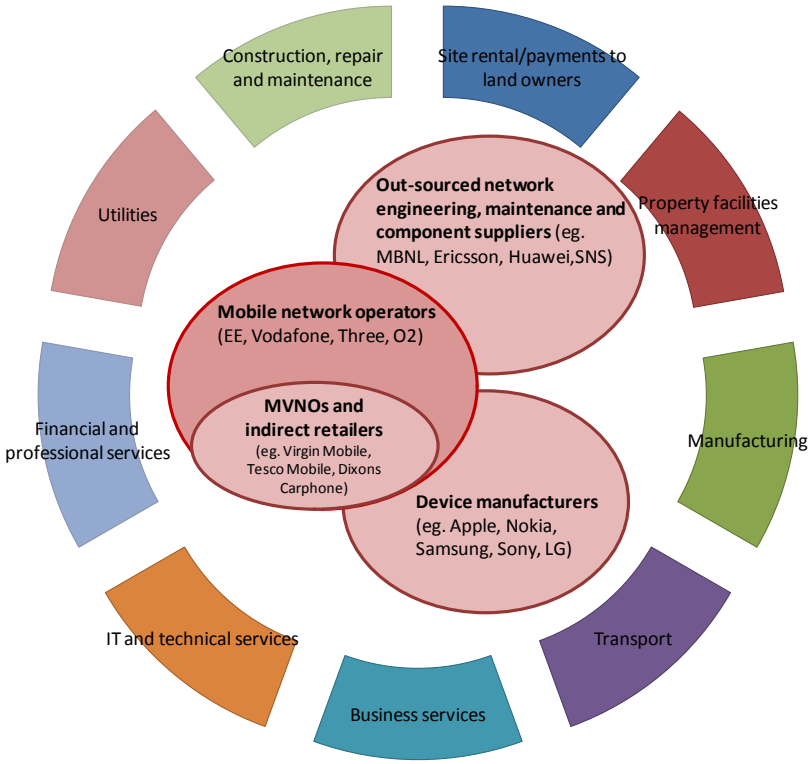
The operators' capital expenditure on their networks is also significant. Using procurement data provided to us by EE, we have estimated that total annual expenditure by all four network operators on network infrastructure amounted to almost £2 billion in 2013 (including 4G LTE rollout investment and other unrelated related repair, maintenance and upgrades).

Approximately 40 per cent of spending on the network goes on new components and equipment for the network upgrades, around one fifth on 'back-haul' connections (ie high capacity fixed connections between masts and other mobile telephony infrastructure) and a further five per cent on software. The rest is comprised of spending on site rental, construction, and repair and maintenance work. Again, some of the benefit of this spending will accrue to foreign businesses through imports. We suspect that many of the components bought by the operators are sourced from abroad with only a portion of the value chain located in the United Kingdom. By looking at the accounts of some of the industry's main suppliers, we estimate that the import share is almost double that of the telecommunications industry as a whole.[28]

In total, we estimate that the mobile operators' spend around £1.7 billion on the United Kingdom suppliers on their networks each year on top of £4.9 billion of operational expenditure.[29] (See Figure 10 and Figure 11.)

[28] We have made estimates using information on EE's suppliers which we have scaled up for the industry as a whole.
[29] Figures include investment related to 4G LTE rollout programme which will be phased out from 2015-2016. Further investment will be required in the future to accommodate the next generation of technology.

Figure 10: Mobile network operators' spending on suppliers



Source: Capital Economics and EE.

Figure 11: Total spending of mobile operators, 2013

	Total spending (£ million)	Spending on domestic suppliers (£ million)
Manufacturing	414	353
Computers and electronic equipment (including device manufacturers)	5,024	717
Construction, repair and maintenance	704	602
Utilities	176	161
Transport	499	458
Telecommunications	941	863
Financial and professional services	205	188
IT and technical services	1,558	1,421
Facilities management	254	233
Payments to landowners	501	501
Business services	1,195	1,095
Hospitality and recreation	4	4
Other services	6	5
Total	**11,481**	**6,602**

Source: Capital Economics' analysis of EE data and Office for National Statistics Input-output tables 2013.
Note: Spending on outsourced network engineering, maintenance and component suppliers is spread across computers and electronic equipment, construction, repair and maintenance, and IT and technical services.

4.2 Supply chain supported

The suppliers to the mobile network operators aren't the end of the story. They have their own suppliers, who in turn have theirs. The four networks are

sustaining a complex supply chain, which is generating value and supporting jobs.

To calculate the overall impact of the mobile network operators' spending, we have used the Office for National Statistics' *Supply and Use Tables* to simulate how much the suppliers to the network operators themselves will purchase from their suppliers, and so on — these are known as indirect effects.[30]

In total, we estimate that the spending by mobile operators on suppliers supports revenues of £11.3 billion for businesses in the supply chain. This equates to around £4.5 billion of value added and translates to over 85,000 jobs that are supported indirectly by the mobile telephone network operators' purchases from their suppliers.[31] (See Figure 12.)

The benefits will be spread across a range of industries which provide goods and supporting services all the way through the supply chain. (See Figure 13.)

[30] Office for National Statistics, *Input-Output Analytical Tables – 2010* (Office for National Statistics, London). (See http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/input-output/index.html.)

[31] We believe this to be a conservative estimate as we have assumed that all of the value chain for the supply of customer equipment such as handsets and tablets lies outside the United Kingdom. The employment multiplier is higher than what we might expect to see in a typical sector. This is because, given the capital intensive nature of the industry, there is a high level of expenditure for each employee in the industry. In 2013, the mobile operators' domestic expenditure was equivalent to £185,000 for each employee, compared to an average across all industries of just over £50,000. Our estimates are within the range of others' differing calculations. For example, a study by Deloitte on the Australian mobile industry found that 22,000 direct jobs supported around 35,000 indirect jobs.[31] CEBR's study suggested that (a broader definition of) the mobile telephone industry employed 174,302 jobs directly in 2003 which rises to 196,961 when the jobs created in other industries by the wealth generated by the mobile phone sector is taken 35,000 indirect jobs. CEBR's study suggested that (a broader definition of) the mobile telephone industry employed 174,302 jobs directly in 2003 which rises to 196,961 when the jobs created in other industries by the wealth generated by the mobile phone sector is taken into account — whereas Europe Economics' estimate of 103,627 people employed directly in 2004 by the radio spectrum using industries rises to 240,275 after multiplier effects.

Figure 12: Indirect effects spending on suppliers by the network operators by region

	Jobs (Number)	Turnover (£ million)	Gross value added (£ million)
North East	2,700	400	100
North West	8,300	1,100	400
Yorkshire and The Humber	5,900	800	300
East Midlands	5,300	700	300
West Midlands	6,700	900	300
East	7,800	1,000	400
London	18,600	2,100	1,000
South East	13,500	1,800	700
South West	6,000	800	300
Wales	2,600	400	100
Scotland	6,300	900	300
Northern Ireland	2,300	300	100
United Kingdom	**86,100**	**11,300**	**4,500**

Source: Capital Economics' analysis of data provided by EE, the Office for National Statistics' *Business Register and Employment Survey* and *Input-Output Analytical Tables.*

Figure 13: Indirect effects spending on suppliers by the network operators by sector, 2013

	Jobs (Number)	Turnover (£ million)	Gross value added (£ million)
Primary industries	100	100	50
Manufacturing	3,200	1,100	200
Computers and electronic equi	5,400	1,400	200
Construction, repair and mainte	5,100	800	300
Utilities	700	300	100
Wholesale and retail	800	50	20
Transport	6,200	700	300
Telecommunications	4,700	1,000	500
Financial and professional serv	3,800	600	300
IT and technical services	16,000	1,900	1,100
Property and facilities manage	14,100	900	500
Business services	21,800	1,800	800
Public sector	1,700	100	100
Hospitality and recreation	1,700	100	40
Other services	900	100	30
Total	**86,100**	**11,300**	**4,500**

Source: Capital Economics' analysis of data provided by EE, the Office for National Statistics' *Business Register and Employment Survey* and *Input-Output Analytical Tables.*

4.3 Employees and their spending

In addition to the economic activity stimulated by purchases from their suppliers, the mobile network operators support jobs and value creation through their employees' spending income in local shops, online, on their household bills, and elsewhere in the wider economy. In 2013, we estimate that the employees of the mobile telephone industry spent a total of £1.1 billion on goods and services, providing incomes for businesses across the country. (See Figure 14.)

Figure 14: Spending by employees in the mobile telephone industry, 2013

	Spending (£ million)
North East	43
North West	115
Yorkshire and The Humber	88
East Midlands	78
West Midlands	121
East	98
London	141
South East	161
South West	92
Wales	49
Scotland	89
Northern Ireland	30
United Kingdom	**1,106**

Source: Capital Economics' analysis of EE data and Office for National Statistics' Input-Output tables 2013.

We have made estimates of the knock-on impact that this spending has as it is recycled through the value chain by using Office for National Statistics' *'Supply and Use Tables'*, known as the induced effect. We estimate that the spending of the direct employees of the mobile network operators supported almost 17,000 jobs in the United Kingdom and £770 million of gross value added.[32] With employees living across the country, the benefit of this spending is felt in all regions of the United Kingdom. (See Figure 15.)

[32] Based on Capital Economics' analysis of human resources data provided by EE combined with employment data from the Office for National Statistics' *Business Register and Employment Survey*.

Figure 15: Induced effects of the mobile telephone industry

	Jobs (Number)	Turnover (£ million)	GVA (£ million)
North East	1,600	200	70
North West	1,400	200	70
Yorkshire and The Humber	1,100	100	50
East Midlands	1,000	100	40
West Midlands	1,300	200	60
East	1,700	200	80
London	2,500	300	110
South East	2,100	200	100
South West	1,800	200	80
Wales	700	100	30
Scotland	1,200	200	60
Northern Ireland	300	40	20
United Kingdom	**16,800**	**1,900**	**770**

Source: Capital Economics' analysis of data provided by EE, the Office for National Statistics' *Business Register and Employment Survey* and *Input-Output Analytical Tables.*

4.4 Overall impact

Overall, the activities of the four mobile network operators support over nearly 140,000 jobs and almost £10 billion of gross value added in the United Kingdom. (See Figure 16.)

In addition to the 35,400 direct jobs created by the operators, they support over 85,000 jobs through purchases from their suppliers and almost 17,000 jobs through the spending of their employees.

Figure 16: Overall impact of the mobile telephone industry in the United Kingdom, 2013

	Direct		Indirect		Induced		Total	
	Jobs (Number)	GVA (£ million)	Jobs (Number)	GVA (£ million)	Jobs (Number)	GVA (£ million)	Jobs (Number)	GVA (£ million)
North East	6,300	790	2,700	100	1,600	70	10,600	960
North West	3,800	490	8,300	400	1,400	70	13,500	960
Yorkshire and The Humber	900	120	5,900	300	1,100	50	7,900	470
East Midlands	1,900	240	5,300	300	1,000	40	8,200	580
West Midlands	2,200	280	6,700	300	1,300	60	10,200	640
East	4,000	500	7,800	400	1,700	80	13,500	980
London	7,200	920	18,600	1,000	2,500	110	28,300	2,030
South East	2,800	360	13,500	700	2,100	100	18,400	1,160
South West	2,500	310	6,000	300	1,800	80	10,300	690
Wales	1,900	240	2,600	100	700	30	5,200	370
Scotland	1,800	220	6,300	300	1,200	60	9,300	580
Northern Ireland	100	10	2,300	100	300	20	2,700	130
United Kingdom	**35,400**	**4,480**	**86,100**	**4,500**	**16,800**	**770**	**138,300**	**9,750**

Source: Capital Economics' analysis of data provided by EE, the Office for National Statistics' *Business Register and Employment Survey* and *Input-Output Analytical Tables.*

5 DOWNSTREAM CONSUMER, PRODUCTIVITY AND MACROECONOMIC BENEFITS

In this section, we consider the value of mobile technology to consumers and the wider economy, as well as assessing the potential impact of 4G LTE technology.

Our key findings are:

- **The total consumer surplus of mobile telephony was between £28 and £34 billion in 2013**
- **The consumer surplus of mobile broadband was around £7½ billion in 2013; 4G LTE could add £2 billion of value to consumers each year**
- **There is a substantial body of literature which finds a positive relationship between improvements in fixed line broadband, mobile telephony and mobile broadband and economic growth**
- **According to a survey of users, even in its short lifespan, 4G LTE is delivering benefits worth around £1½ billion per annum; with full penetration to business users who currently use mobile broadband this could increase to £11½ billion (or 0.7 per cent of national output)**
- **Once fully rolled out the 4G LTE network will cover 99 per cent of the population, and provide superfast broadband access to four per cent of the population who are not expected to be covered by fixed line services, even accounting for superfast rollout plans; increased coverage from 4G LTE could add up to 0.25 per cent to national output**

5.1 Consumer benefits of mobile telephony

There are lots of tangible and intangible benefits to users of mobile telephony from simply providing voice connectivity while on the move through to enabling the sharing of content and data. It is, of course, impossible to capture all this value in a single metric. Nevertheless, economists try; they deploy an analytical short hand called 'consumer surplus', which is the value that consumers are willing to pay for a good or service over and above the market price.

Overall, the evidence on surpluses is patchy, variable and at times implausible. However, it is possible to make some tentative conclusions. In 2006, Ofcom commissioned Europe Economics to evaluate the use of radio spectrum, including use by the cellular networks.[33] This included an assessment of the 'consumer and producer surpluses' created by the sector. Overall, the consultants found that almost £22 billion of benefit was generated in 2006, which comprised:

- £18.9 billion of consumer surplus, which is the amount over and above that actually paid by consumers that they would have been willing to pay to receive the service

- £2.8 billion of producer benefits[34], which is the amount revenue received by the networks over and above the economic cost of the services they provided

A more recent study by Analysys Mason updates Europe Economics' 2006 numbers, as well as providing separate estimates for voice and data services.

The study finds that in 2011 the consumer surplus of mobile voice services was between £19 and £23 billion, while for data services it was around £5 billion. Based on market forecasts they expect that the total benefit will increase over time, with the value to consumers standing at between £28 and £34 billion in 2013.[35]

They also estimate that the producer surplus was £4.8 billion for voice services and £1.0 billion for mobile data in 2011. However, they expect this to fall dramatically over the period that the mobile operators implement their capital expenditure programmes for 4G LTE rollout.[36]

[33] Europe Economics, *Economic impact of the use of radio spectrum in the UK* (Ofcom, London), 2006.
[34] Producer surplus represents the income that producers receive over and above what they would have been willing to sell for.
[35] Kende, M, Bates, P, Stewart, J and Vroobel, M. *Impact of radio spectrum on the UK economy and factors influencing future spectrum demand* (Analysys Mason, London), 2012.
[36] *ibid.*

5.2 Productivity benefits of mobile telephony

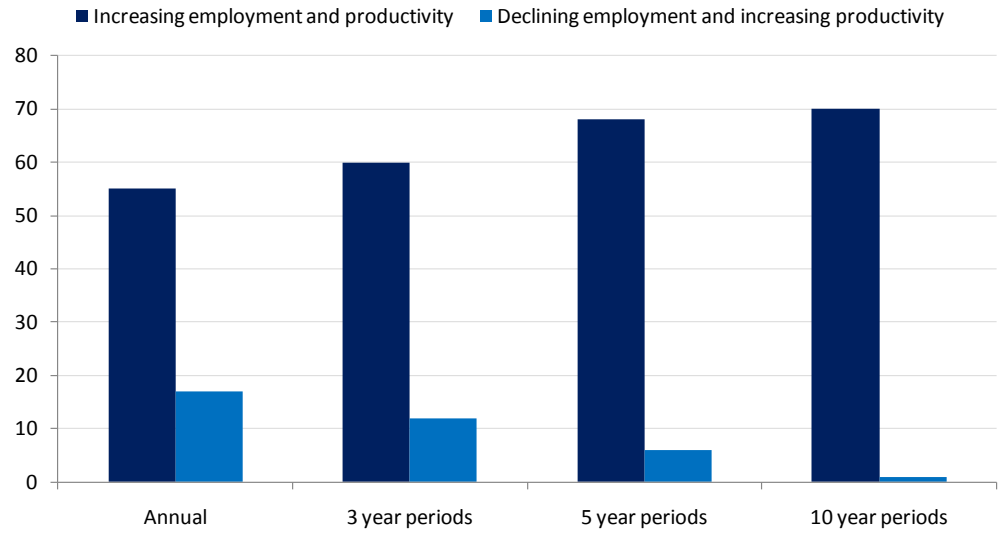
The value of improved mobile telephony is not just limited to enhanced consumer benefits; there are also benefits for the economy at large.

The use of mobile telephony has broader economic significance by:

- permitting greater and easier communication between consumers, between consumers and businesses, and between businesses
- facilitating greater mobility for consumers and businesses alike
- improving the efficient use of time for consumers and businesses
- increasing rates of productivity
- stimulating the innovation of new products, services and business models

Some argue that productivity-enhancing technologies, such as mobile telephony, only destroy jobs. This is a misconception. Although productivity improvements may lead to the loss of specific jobs as operational efficiencies are exploited in the short term, the lower costs of doing business stimulate growth in employment elsewhere in the firms or elsewhere in the economy in the mid and longer-term. To demonstrate this, research by the management consultants, McKinsey, shows for the United States that, over an 80 year period, there has been only one ten-year period where employment declined while productivity increased, whereas there were 70 ten-year periods where increasing employment and productivity coincided. (See Figure 17.)

Figure 17: Relationship between employment and productivity levels (number of rolling periods of employment and productivity change 1929 to 2009)



Source: McKinsey Global Institute, *Growth and Renewal in the United States: Retooling America's Economic Engine (McKinsey, London)*, 2011.

Instead, the evidence points strongly towards the widespread take-up of productivity-enhancing technologies stimulating overall growth in jobs, economic activity and prosperity.

There is a substantial body of academic and professional literature exploring the link between information and communications technologies in general and overall macroeconomic performance. For example, a recent study found that investment in information and communication technologies by firms in the United Kingdom had significant impacts on productivity and even larger ones when coupled with organisational change that such technologies makes possible. Since 1995, information and communication technology is estimated in a number of studies to have added around one percentage point each year to overall economic growth in many developed countries, including the United Kingdom.

More specifically, there is a developing literature on the macroeconomic significance of mobile telephony (although much of it is focussed on the impact in developing countries). Mobile telephones, and mobile broadband, are tools; they are an investment good with an economic return.

First, they make certain activities — such as communicating, finding information, comparing prices, getting directions, arranging diaries, making transactions, remotely monitoring — easier or cheaper to do. Countless peripatetic tradesmen and businesses from builders through emergency vets and midwives to management consultants and engineers depend upon their cellular devices to conduct their day-to-day business and respond to their

customers — but even companies with limited mobile activity benefit. In the business sphere, mobile technology improves efficiency and productivity. In the consumers' world, they can help shoppers make better informed decisions and enhance their mobility — saving time, money and effort. These productivity and efficiency gains have a knock-on benefit to overall macroeconomic performance by freeing up resource to do more.

Second, new technologies, like mobile broadband, can be catalysts for further innovation elsewhere — stimulating new products, services and even business models. Without mobile telephones there wouldn't have been Bluetooth car kits or pay-by-phone car parking. Without mobile data services, there wouldn't be mobile banking or mobile card payment machines for use in taxis and on trains, or by market traders, plumbers, home delivery and roadside recovery services — nor would there be Samsung Galaxies, iPhones or an 'apps industry', whose global worth was recently predicted to reach over $100 billion by 2017.[37] These 'catalytic effects' can be significant, especially for high technology products in fast growing markets.

Third, the nature of communications technologies means that their benefits accelerate as more people use them. A telephone, and any other communication tool, is pretty useless if you are the only person with the device, but it becomes more valuable as other people adopt the technology and you have greater opportunities for communication with them (and they with you, and they with each other). These 'network effects' mean that productivity benefits and catalytic effects can all be expected to increase as penetration rates for a communications technology grow.

A recent econometric study by researchers at the European Investment Bank and Imperial College London, for example, found that the United Kingdom economy has especially benefitted from mobile telephony.[38] It suggests that annual growth was 0.40 percentage points higher over the period 1990 to 2008 because of the growth in use of cellular telephones. This is a higher impact than for the likes of Germany, France and the United States, where the effect was estimated to be 0.39, 0.39 and 0.38 percentage points respectively. The study also suggests that the United Kingdom has benefitted from an annual 0.27 per cent improvement in productivity resulting from the communications technology. Meanwhile, in a 2004 study the consultancy Ovum found that mobile voice services generated productivity gains to the United States

[37] Global Industry Analysts, *Smartphone Apps — Global Strategic Business Report* (Electronics.ca Publications), 2011.
[38] Harald Gruber and Pantelis Koutroumpis, *Mobile Telecommunications and the Impact on Economic Development*, Paper to Economic Policy Fifty-Second Panel Meeting hosted by EIEF, 22-23 October 2010.

economy worth $157 billion per year.[39] This is the equivalent of around 1.3 per cent of gross domestic product.[40]

5.3 The emerging benefits of 4G LTE and mobile broadband

Innovation in mobile technology and investment by the operators will ensure that both consumer and economic benefits will continue to grow in the future.

Today, the most significant advance in cellular is 4G LTE. It offers dramatic improvements in mobile internet access: higher peak download speeds; greater overall capacity through more efficient use of the radio spectrum; and more rapid response times. Such a technology should enhance the customer experience of mobile internet and provide a platform for greater bandwidth higher value online services. (See Figure 18.)

According to research commissioned by Ofcom, 4G LTE will be able to deliver peak download rates that are as good if not better than fixed line services.[41] A recent study by Ofcom found that average 4G download speeds were more than twice as fast as 3G speeds at 15.1Mbit/s.[42] Meanwhile 4G download speeds on the EE network specifically averaged 18.4Mbit/s compared to an average fixed line download speed of 18.7 Mbit/s.

[39] Roger Entner, *The Increasingly Important Impact of Wireless Broadband Technology and Services on the U.S. Economy: A Study for CTIA-The Wireless Association*, Ovum, 2008.
[40] United States GDP was around $12,000 billion in 2004. Data downloaded from the Bureau of Economic Analysis website on 15 April 2012. www.bea.gov.
[41] Real Wireless Ltd, *The timing of the consumer and operator features available from HSPA and LTE* (Ofcom, London), 2012.
[42] Ofcom, *Measuring mobile broadband performance in the UK* (Ofcom, London), 2014.

Figure 18: 4G network capabilities compared to predecessor wireless technologies

	2.5 - EDGE	3G - UMTS/HSPA	4G - LTE/WiMax
Device type	• Basic handset	• Smartphone/tablet • Air card • Some sensors, appliances, etc	• All personal electronics: phone, TV, tablet, camera, automobile • Widespread sensors, machines, kitchen appliances etc
Device computing and storage	• Limited physical memory	• Limited access to cloud storage	• Input/output client with cloud computing and multi-device access
Communications media	• Voice, SMS, instant messaging	• Over-the-top applications • Social networking	• Video calls • Collaboration via cloud
Applications	• Carrier walled garden with basic UI • Limited M2M	• Phone functionalities • Downloadable apps • MP3 player, camera, etc	• Monitoring, automation and smart systems • HDTV streaming and conferencing
Application examples			
Security and monitoring	•Emergency response	• Vehicle security • RFID identification	• Streaming video surveillance • Vehicle tracking
Transportation	• Basic voice	• Automatic crash notification • Public transportation navigation	• Smart traffic flow/infrastructure • Real time vehicle monitoring and control
Location based services	• Maps and basic GPS navigation • 911 functionality	• Localised, personalised recommendations near location • Mobile check-in	• High definition, location based video advertisements • Augmented reality for field technicians
Video/music/gaming	• Ringtone downloads	• Video streaming onto smartphone or tablet	• Multi-device mobile HDTV streaming from cloud based content locker
Education	• Collection and transmission of student data	• eBooks • Game based learning	• Immersive gaming • Enhanced immersive interaction education

Source — Deloitte Consulting LLP, The impact of 4G technology on commercial interactions, economic growth, and US competitiveness (Deloitte, London), 2011.

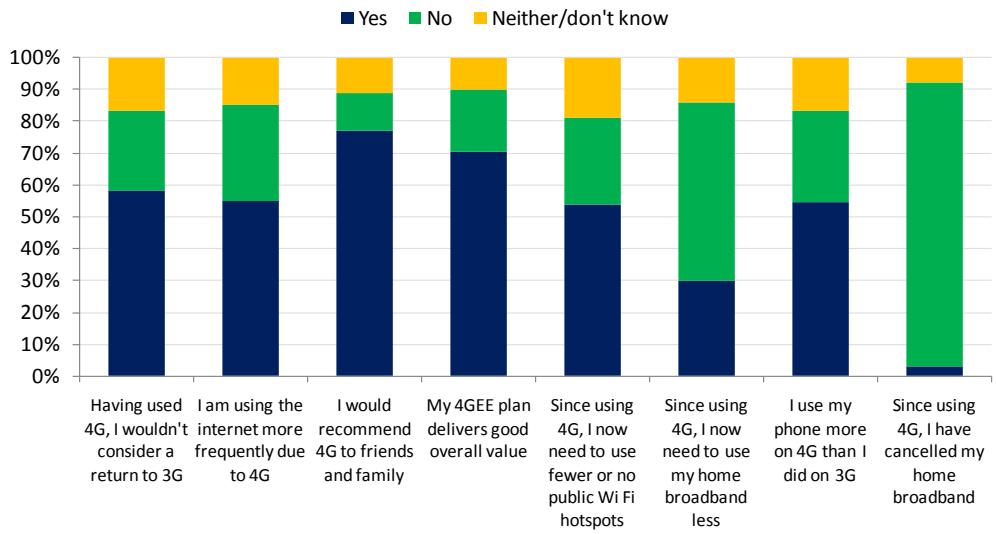
In 2012, the government sold off a combination of 800 MHz and 2.6GHz frequency spectrum which is suitable for the rollout of 4G LTE. A total of £2.2 billion was spent by the four network operators who are now at varying stages of delivering their 4G LTE networks. EE was the first to utilise suitable spectrum. This was thanks in part to it holding suitable spectrum that it reassigned before the general auction; EE has already rolled out a network covering 75 per cent of the population. Meanwhile, O2 have committed to rollout 4G LTE covering 98 per cent of the United Kingdom population by 2017, with the other operators planning to match this by 2017 or earlier.

4G LTE mobile services have only been available in the United Kingdom for eighteen months, but have already delivered tangible benefits to both users and the wider economy. Although it is too early for empirical studies to assess the eventual impact of full adoption of the new technology, EE has conducted a survey of its current 4G LTE users to gather original data which gives us an idea of the benefits that have already been felt and an interesting steer on the potential future impacts of mobile 4G LTE technology.[43]

[43] Survey conducted by TNS in May 2014. Survey covered a sample of 1,000 of EE's 4G subscribers.

It is clear that consumers already value the new technology. Over 70 per cent of users feel that their 4G LTE plan represents good value for money and three quarters would recommend it to friends and family. The survey results also indicate that people are using their mobile devices more because of the improved service on 4G LTE; over 50 per cent of respondents are using their phone more on 4G LTE than they did on 3G. (See Figure 19.)

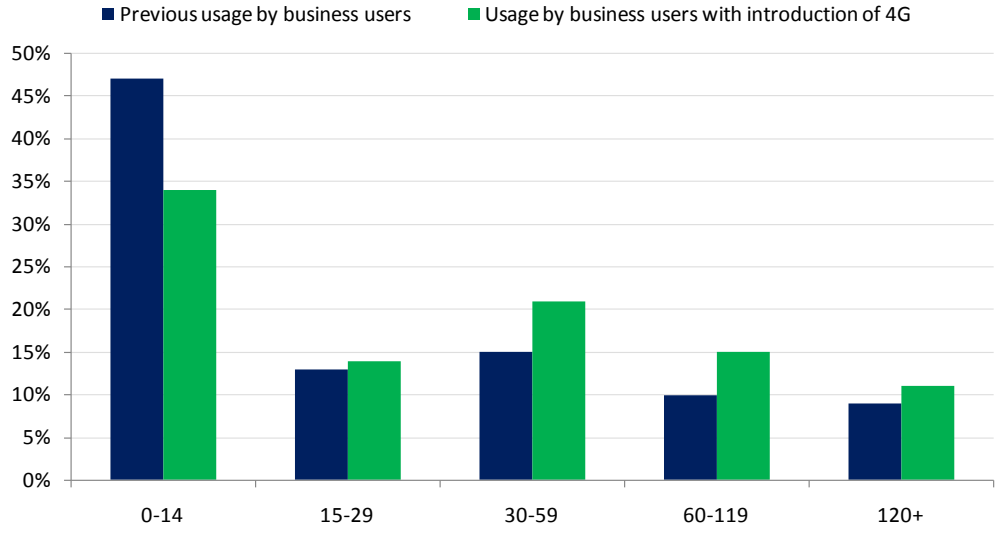
Figure 19: Customer satisfaction responses from EE survey



Source: EE survey conducted May 2014. Note: Approximately two per cent of respondents responded 'don't know' and have been excluded from this analysis.

Much of the productivity benefit of faster and more reliable mobile internet will come from its use for conducting business. EE's survey of its 4G LTE customers demonstrates that, only eighteen months since the launch, it is having an effect on the ways business customers use mobile data services. Almost one fifth of business users that were surveyed indicated that they had been able to alter their working practices after switching to 4G LTE services on their mobile. They are also using their mobile for work activities significantly more than they were on the 3G network. Business users' responses suggest that, on average, each user spends a minimum of nearly nine minutes per day more time on mobile broadband for work activities. (See Figure 20.)

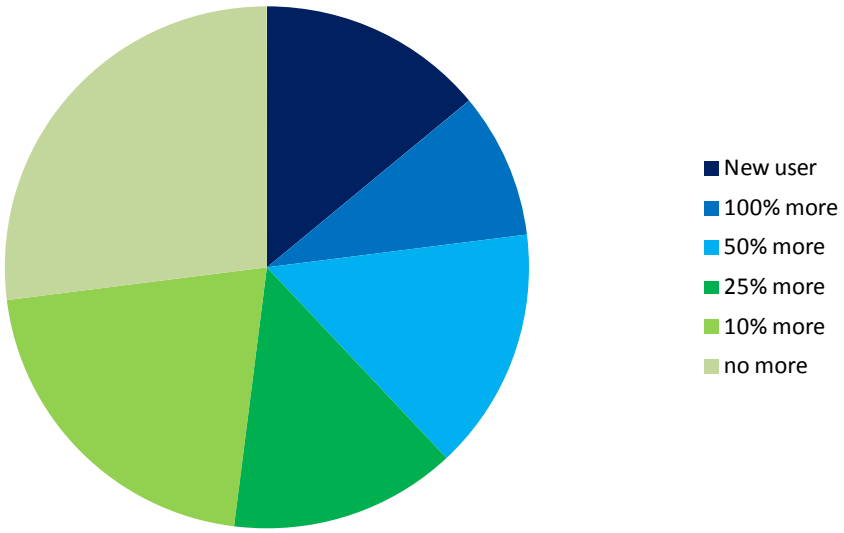
Figure 20: Number of minutes per day using mobile broadband for before and after the introduction of 4G LTE



Source: EE survey conducted May 2014.

Not only does 4G LTE encourage users to work on their mobile device more frequently, but it also increases the productivity of that time. EE's survey suggests that almost fifteen per cent of business users did not previously use mobile broadband for work at all before 4G LTE. Meanwhile, one quarter of users get over 50 per cent more work done on the new technology than they did on 3G, and a further 35 per cent of users experienced at least some identifiable improvement in the efficiency of their work now compared to 3G previously. (See Figure 21.)

Figure 21: Percentage increase in work done in time spent using 4G LTE compared to previously



Source: EE survey conducted May 2014.

Business users' responses indicate that they save an estimated thirteen minutes per day by using 4G LTE. (See Figure 22.) Applying this to the current number of EE's 4GEE subscribers, and using average wages to place a value on the time saved, would translate into an annual saving of £1.4 billion or 0.1 per cent of national output.

According to Ofcom, 43 per cent of adults in employment used data services on their mobile phones in 2013.[44] If there was full penetration of 4G LTE to these users, the time savings already experienced on 4G LTE would equate to £11½ billion per annum or 0.7 per cent of national output.

Figure 22: Minutes per day saved by business users using 4G LTE, share of total business users by occupation

	Senior managerial/administrative /professional	Intermediate managerial/administrative /professional	Supervisor/clerical/junior managerial/administrative /professional	Skilled manual worker	Semi-skilled or unskilled manual worker	Student	All in work
0	45%	36%	30%	41%	31%	22%	38%
1-5	11%	14%	21%	14%	11%	20%	15%
6-10	11%	16%	14%	9%	23%	16%	12%
11-20	7%	14%	9%	9%	6%	13%	9%
21-30	14%	5%	9%	12%	14%	11%	10%
31-60	4%	7%	6%	4%	-	7%	5%
60+	9%	8%	11%	10%	14%	11%	10%
Average time saved per day	13.0	13.1	14.8	13.4	15.1	16.5	13.6

Source: EE survey conducted May 2014.

5.4 Potential macroeconomic of impact of 4G LTE

Once rolled out fully, the improved performance of mobile broadband due to the new 4G LTE technology will deliver even greater benefits to consumers, businesses and the economy at large.

First, we consider the likely scale of benefits that consumers may derive from the introduction of the new technology.

[44] Ofcom, *Measuring mobile voice and data quality of experience* (Ofcom, London), 2013.

In 2012 Ofcom research envisaged that 4G LTE technology could deliver peak data rates of over 50 megabits per second. This has already been surpassed in some areas with the introduction of LTE-Advanced 4G technology, which can deliver peak speeds of up to 150 megabits per second.[45] Enhancements coming on stream by the end of the decade could theoretically permit up to three gigabits per second (although none of the operators are currently expecting to provide this level). This places the mobile service in the realm of superfast broadband and, on this headline measure, would be in line with or ahead of the performance of BT Openreach's fixed line fibre optic service.[46]

In real world conditions, the networks are unlikely to be set up to deliver these theoretical maximum speeds — and even their lower peak data rates will probably never be achieved by users. A variety of factors will determine the actual speeds achieved.

Research by Ofcom found that 4G download speeds averaged 15.1megabits per second in the second quarter of 2014.[47] This is already being enhanced further though by the introduction of an upgraded service known as 'double speed' on EE's network, which is available in twenty cities and should deliver average download speed of 24 to 30 megabits per second and maximum speed of up to 60 megabits per second.[48] Even if the average speeds are disputed, initial deployments of 4G LTE technology will enhance the day-to-day mobile broadband experience in other ways[49]:

- Responsiveness is as good as or better than the best that 3.5G can offer now or in future[50]

- 4G LTE makes more efficient use of spectrum and hence will have greater capacity than 3G and 3.5G systems and improve the quality of service[51]

[45] See http://ee.co.uk/our-company/newsroom/2014/10/30/ee-switches-on-next-generation-of-4g-worlds-fastest-mobile-speeds-now-available-in-london [accessed 24 November 2014].
[46] See http://www.superfast-openreach.co.uk/ [accessed 24 November 2014].
[47] Ofcom, *Measuring mobile broadband performance in the UK* (Ofcom, London), 2014.
[48] See http://www.4g.co.uk/ee-4g-network-summary/ [accessed 24 November 2014].
[49] Real Wireless Ltd, *The timing of the consumer and operator features available from HSPA and LTE* (Ofcom, London), 2012.
[50] 'Latency' on initial 4G LTE deployments should be less than 25 ms, and should improve with later releases. This compares with 3G networks using HSPA operating at around 100 ms, and the latest HSPA+ at under 25 ms also.
[51] 'Cell spectral efficiency' on early deployments of 4G LTE is expected to be 1.5 bps/Hz rising to 2.4 bps/Hz towards the end of the decade. HSPA operates at 0.54 bps/Hz, and HSPA+ at 1.28 bps/Hz.

- Connection times on 4G LTE will match or better the best that can be offered on 3.5G systems with devices feeling 'always on'[52]

The deployment and use of the new generation of technology will, therefore, deliver a mobile broadband platform that will provide more value for users — which will accrue as additional 'consumer surplus', additional 'producer surplus' or both.

Analysys Mason suggests that the consumer surplus of mobile data services was £5.1 billion in 2011. (See section 5.1.) Using their forecasts, this is expected to increase and was probably somewhere around £7½ billion in 2013; equivalent to £120 for every man, woman and child in the United Kingdom. In reality, this is likely to be even higher if the willingness to pay for new 4G LTE services was captured fully. Compass Lexecon's analysis indicates a 30 per cent increase in benefit from a tenfold improvement in fixed line broadband speeds. If this reads across to mobile broadband, and we have no reason to believe it shouldn't, then existing users of mobile data services should benefit in the order of an additional £2 billion annually.[53]

In addition to this, we would expect further consumer surpluses to derive from: (i) existing users benefitting from new products and services becoming available that would have not occurred without 4G LTE; and (ii) new users being attracted to mobile data because of the enhancements that the new technology brings. These could be sizeable additions to the surplus — although we avoid the temptation to try to quantify them here given the paucity of evidence and data.

Second, we consider the wider economic benefits that 4G LTE will bring by increasing productivity.

In section 5.1, we refer to some of the evidence relating to the overall benefits of mobile telephone technologies. In this section we consider literature which is more relevant to the potential impacts of 4G LTE. There is a body of research that is focussed on broadband and, to a limited extent, mobile internet — although research into the impact of superfast broadband is limited.

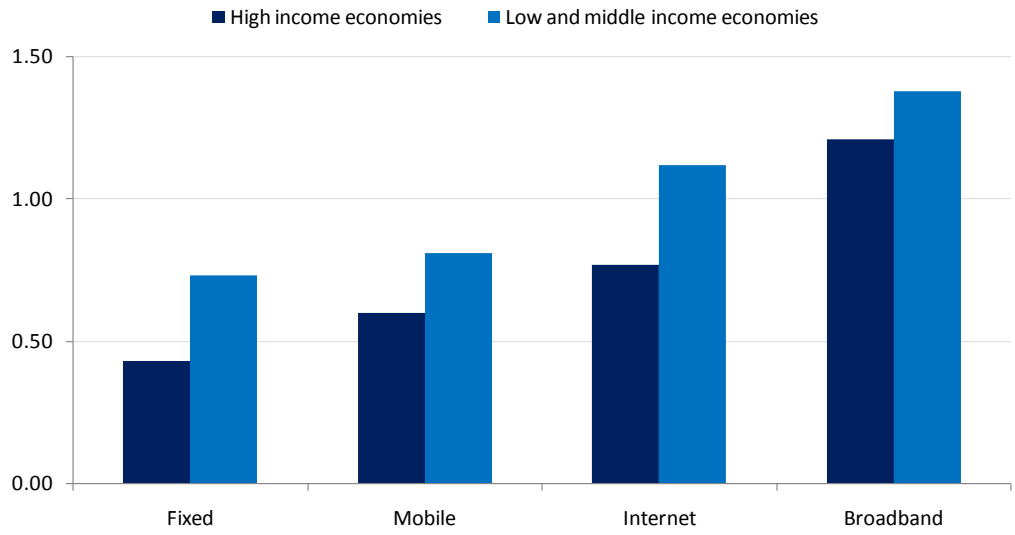
[52] 'Connection setup times' on 4G LTE will be less than 100 ms for initial deployments and will improve to less than 50 ms by 2020. HSPA+ is also currently under 100 ms, but HSPA systems take around one second.
[53] Mark Dutz, Jonathan Orszag and Robert Willig, *The substantial consumer benefits of broadband connectivity for US households* (Compass Lexecon LLC for Internet Innovation Alliance), 2009.

Probably the most cited and best exemplar of work in the field of broadband generally was conducted by Christine Zhen-Wei Qiang at the World Bank in 2008/9.

She used econometric techniques to assess the extent to which different rates of adoption of information and communication technologies could explain different rates of economic growth across 120 countries.[54] Broadband was found to be the technology with the greatest leverage — with every ten percentage point increase in broadband penetration adding 1.21 percentage points to annual growth rates in developed countries. This compares to 0.77 percentage points for the internet, 0.60 for mobile and 0.43 for fixed line telephony. (See Figure 23.)

Such a potential impact on growth is substantial given that the average growth rate of developed economies was just 2.1 per cent between 1980 and 2006. But, of course, we need to be careful about assuming that a statistical relationship is also a causal one.

Figure 23: Growth effects of different information and communication technologies



Source — Christine Zhen-Wei Qiang and Carlo M. Rossotto with Kaoru Kimura, 'Economic Impacts of Broadband' in *Information and Communications for Development: Extending reach and increasing impact* (World Bank, Washington DC), 2009.

Similar findings are made in a range of other studies.[55]

[54] Christine Zhen-Wei Qiang, *Telecommunications and economic growth*, unpublished paper (World Bank, Washington DC), 2008.

[55] See: Nina Czernich, Oliver Falck, Tobias Kretschmer and Ludger Woessmann, 'Broadband Infrastructure and Economic Growth', *The Economic Journal*, 121 (May), 505–532. 2011. Booz & Company "Digital Highways: The Role of Governments in 21st Century Infrastructure (2009)

Research has also been conducted in this country. In a 2003 study, for example, economics consultancy CEBR predicted that broadband would increase United Kingdom productivity, as measured in output per hour worked, by 0.04 per cent on a 'cautious' basis or 0.23 per cent under a more positive scenario.[56] Meanwhile, a team from the London School of Economics and the Information Technology and Innovation Foundation expect to see a 'network effect multiplier' of at least 0.33 on any new investment in broadband infrastructure — because, they argue, broadband itself increases business productivity, spurs upstream investment (e.g., of higher speed computer equipment), and contributes to the creation of new industries.[57]

There are, of course, many more studies: some producing similar results; others more positive; and some more conservative — but they are mostly in the same ballpark.[58]

Turning to the impact of superfast broadband, the Broadband Stakeholder Group in the United Kingdom commissioned research into the potential costs and benefits of moving from ADSL to a fibre based fixed line service.[59] The report, by Plum Consulting, focuses more on developing a framework for evaluation, but does give a qualitative assessment of 'wider economic' benefits — such as 'spill-over and virtual agglomeration benefits', reduced traffic congestion and competition.

There has been less research focussed on mobile internet or mobile broadband.

McKinsey & Company, *Mobile Broadband for the Masses* (McKinsey, London), 2009.
Sharon E. Gillett, William H. Lehr, Carlos A. Osorio and Marin A Sirbu, *Measuring the Impact of Broadband Deployment* (U.S. Department of Commerce, Economic Development Administration, Washington, DC.), 2006.
Robert Crandall, William Lehr, and Robert Litan, "The Effects of Broadband Deployment on Output and Employment: A Cross-Sectional Analysis of U.S. Data," *Issues in Economic Policy*, No. 6, (Brookings Institution, Washington, DC), July 2007.
Shane Greenstein and Ryan C. McDevitt, *The broadband bonus: Accounting for broadband Internet's.* PricewaterhouseCoopers, *Economic Impacts of Broadband for Australia and Globally: Possibilities and opportunities in a digital world* (Communication Alliance), February 2009.
[56] CEBR, *The economic impact of a competitive market for broadband* (Broadband Industry Group), 2003.
[57] Jonathan Liebenau, Robert Atkinson, Patrik Kärrberg, Daniel Castro and Stephen Ezell, *The UK's Digital Road to Recovery* (LSE Enterprise ltd. & The Information Technology and Innovation Foundation), 2009.
[58] For a summary of a wide range of research in this area please see: Broadband Commission for Digital Development, *Broadband: A platform for progress* (ITU/UNESCO, Geneva), 2011.
[59] Brian Williamson and Phillipa Marks of Plum Consulting, *A Framework for Evaluating the Value of Next Generation Broadband* (Broadband Stakeholder Group, London), 2008.

In 2008, technology consultancy Ovum made estimates and predictions of the productivity gains in the United States from 'mobile wireless broadband' (which probably includes wifi as well as mobile telephone technologies).[60] They identify six situations in which deployment and use of such technologies was 'undoubtedly providing tangible economic benefits':

- Resource and inventory management and documentation
- Health care efficiency enhancements
- Field service automation
- Inventory loss reduction
- Sales force automation
- Replacement of desk phones with mobile wireless devices

The consultants estimate that mobile wireless broadband services generated productivity gains to the United States economy worth $28 billion per year in 2005 (or 0.2 per cent of total gross domestic product). In that same year, they estimate that the productivity value of all mobile wireless services was worth $185 billion (1.5 per cent).

A 2012 study by GSMA and Deloitte investigated the economic impact of increasing penetration of mobile data use and the move from 2G to 3G connections. Looking at a sample of fourteen countries, they found that doubling of mobile data use leads to an increase of 0.5 percentage points in the gross domestic product per capita growth rate, while countries with a higher level of data usage per 3G connection have seen an increase in their gross domestic product per capita growth of up to 1.4 percentage points.

When they considered the move from 2G to 3G connections they found that across 96 developed and developing economies a ten per cent increase in 3G penetration increases gross domestic product per capita growth by 0.15 percentage points.

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[60] Roger Entner, *The Increasingly Important Impact of Wireless Broadband Technology and Services on the U.S. Economy: A Follow up to the 2005 Ovum Report on the Impact of the US Wireless Telecom Industry on the US Economy: A Study for CTIA-The Wireless Association* (Ovum, London), 2008.

Much of the most relevant evidence on the macroeconomic benefits comes from analysis of the introduction of fixed line broadband or mobile voice services.

However, we can only expect the impact of the enhancement of mobile broadband to be of a second order against these comparators — as the scale of change in the technologies aren't the same. Moreover, we have reservations about using much of the existing literature, especially relating to broadband. Too many of the studies appear to be quoting a handful of papers that prove a correlation between broadband penetration and gross domestic product, but do not robustly establish a causal link from the former to the latter. Rather than rely on these over-generalised correlations, we prefer an approach that considers how the new technology might benefit the economy, and attempts to quantify each of these processes individually.

This approach was taken by the Open Digital Policy Organisation who estimated the cost of the time currently being spent by businesses in the United Kingdom downloading across the existing 2G and 3G networks that could be saved if 4G LTE were deployed.[61]

By modelling data sourced largely from Ofcom, the group estimates that, with a 4G LTE system delivering an average speed of 6.6 megabits per second across 95 per cent of the population, businesses will save over 37 million hours of time that would otherwise be spent watching their devices download data. Using an average cost to employers of £19.60 per hour, they value this saved time at over £730 million per annum.

However, some of the calculations by James Firth and Dominique Lazanski are, in our view, too conservative and also warrant reassessment.[62]

First, their valuation of time understates the value of labour to the national economy. Rather than consider the financial cost to the employer of the time lost, it is more appropriate to focus on the potential output foregone by the economy. Using a measure of gross value added per hour, rather than remuneration rates, turns a total annual cost to employers of £730 million into £1.1 billion per annum of potential output lost. This is equivalent to just under 0.1 per cent of national gross value added.

Second, their estimates are based upon 2011 levels of mobile data demand — and do not take account of its likely future growth. Predictions of stellar rates of growth are abound. One analyst in the United States forecasting overall

[61] James Firth and Dominique Lazanski, *Estimating the cost to UK businesses of slow mobile broadband* (Open Digital Policy Organisation, Frensham), 2011.
[62] The paper also includes an assumption about current 3G speeds averaging being 2.0 Mbps which we have revised up to 2.1 Mbps (at the detriment of the valuation of 4G's benefit).

demand for mobile data there to grow at an annual rate of 125 per cent over the next few years and at rates 100 times greater than voice traffic over the next decade.[63] Ofcom report that mobile data volumes in this country grew almost 40-fold between 2007 and 2010 — although the rate of growth had slowed to around 55-65 per cent per annum by the end of this period.[64] Given that smartphone penetration rates will slow, a cautious and reasonable assumption would be to use an annual rate of, say, 35 per cent growth in mobile data volumes for the next few years. On this basis, by 2015 — a reasonable target date for full 4G LTE roll-out, the value of business time saving would be almost £4 billion per annum (2011 prices), which is almost 0.3 per cent of national output.

We have made similar estimates based on a survey of EE's 4G LTE users (See Section 5.3.). This suggests that full penetration of 4G LTE to existing business users that use mobile data would generate a time saving worth £11½ billion each year, or 0.7 per cent of national output; and this doesn't account for any new users.

Furthermore, these calculations only capture one element of the potential benefits from 4G LTE. There are others. Probably the most important productivity gain for business from will be the ability to work differently — and to use mobile broadband for tasks that currently aren't reliably achieved over the existing services.

In addition to productivity benefits, there are also catalytic and network effects. These are difficult — if not impossible — to quantify with any reliability, but that does not mean they should be ignored.

Overall, we believe there is sufficient evidence to suggest that a reasonable and cautious estimate of the eventual impact of 4G LTE mobile broadband will be in the order of 0.5-0.7 per cent of gross domestic product; we take the mid-point of 0.6 per cent as our central estimate. This benefit will build up over time, and only accrue fully once the technology is rolled out and its potential is being realised by current and new users.

5.5 Expanding superfast broadband coverage

In this section, we consider the potential for 4G LTE to serve communities who would otherwise be unable to access superfast broadband or even standard broadband.

[63] Coleman Bazelon, *The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations* (The Brattle Group, Washington DC), 2009.
[64] Ofcom, *Communications Market Report 2011* (Ofcom, London), 2011.

BT is currently rolling out its fibre optic superfast broadband network. In the rare instances where a 'fibre to the premises' connection is achievable, the new technology will initially deliver download speeds of 100 megabits per second. The more likely scenario is 'fibre to the cabinet', where BT's investment provides a fibre optic path between roadside cabinets and the local exchange. However, the final leg uses the existing copper network between the premises and the green box on the pavement; this system will deliver speeds of up to 80 megabits per second.

In addition, Virgin Media is rolling out a superfast fibre optic service across its network. For the purposes of this study, we have not examined their future coverage as it is unlikely to match the eventual spread of BT's fibre network — given the cable operator's concentration of Virgin assets in urban areas.

BT's current rollout programme has already reached around two thirds of premises nationally. The last third of households, however, are predominantly in harder to reach rural areas, which are often not commercially viable. Through Broadband Delivery UK, the government has provided funding of £530 million to support the delivery of superfast broadband to all areas of Great Britain. A further £250 million of support was provided under the superfast extension programme in June 2013.[65]

The target of the current programme is to provide 90 per cent coverage by the end of 2015. However, the coverage targets and timelines vary significantly for different areas. Individual contracts were awarded for each county with combined funding from the government, local authorities and the private sector.[66] For example, Surrey is set to have 99.7 per cent coverage by the end of 2014 while Suffolk's target is for 80 per cent coverage by the end of 2015.[67] The superfast extension programme sets out a target of 95 per cent coverage by 2017, although it is unclear yet whether either target will be met.

By comparison, as part of Ofcom's 4G LTE spectrum auction, the mobile network operators committed to provide coverage to 98 per cent of premises by 2017. Given that it is easier to provide outdoor coverage, this probably equates to more than 99 per cent of the population when outdoors.[68] As the leading provider, EE is on course to deliver 98 per cent coverage by 2014; and this will be delivered solely at the cost of the network operators with no public funding.

[65] Information from: https://www.gov.uk/government/policies/transforming-uk-broadband/supporting-pages/rural-broadband-programme [accessed 29 May 2014].
[66] All contracts were awarded to BT.
[67] Information from: http://www.superfast-openreach.co.uk/rural-broadband/ [Accessed 03 June 2014].
[68] Information from http://consumers.ofcom.org.uk/what-is-4g/ [accessed 03 June 2014].

This means that, on average, between four and nine per cent of the population will have access to superfast broadband through 4G LTE who will not be served by superfast fixed line broadband (at least in the foreseeable future). This will provide a huge boost to rural communities across the country and in particular those that are the most remote and difficult to reach.

This is demonstrated by EE's rollout of 4G LTE to 2,000 residents and businesses in rural Cumbria. This is an area where fixed line fibre networks are not commercially viable. The Northern Fells Broadband Group estimated that the cost of delivering superfast broadband to this area of Cumbria using fibre would be around £10 million. The cost of delivering superfast broadband wirelessly using 4G LTE is approximately ten per cent of this.

The rollout follows EE's 4G LTE commercial trial in the area of Threlkeld, where users experienced average speeds of 24 megabits per second and demonstrates the potential of mobile broadband to reach the final ten per cent of the population that it is difficult for a fixed line network to reach. The network has now been extended to cover more than 100 square miles, spanning from Wigton in the north to Threlkeld in the south.

Extending the reach of broadband will have a positive macroeconomic impact, as well as localised benefits to the communities newly served. Using the available literature on the impact of broadband penetration on economic growth, we have estimated the potential impact that 4G LTE will have by providing superfast broadband access to those who do not have access to fixed line alternatives.

Ofcom estimate that as of June 2013, eight per cent of households did not have access to broadband of a reasonable standard (more than 2 megabits per second), although five per cent of those could have a superfast connection if they chose to upgrade. This leaves three per cent of the population with no access to standard broadband. On the cautious assumption that the areas not covered are the same on the mobile and fixed line networks, 4G LTE will provide broadband to at least two per cent of the population for the first time, and could result in a boost to gross domestic product of up to 0.25 per cent. What's more, even if fixed line superfast broadband is extended to the optimistic target of 95 per cent of the population, 4G LTE will deliver economic benefits by providing a comparable internet access to those in the most remote areas. (See Figure 24.)

The results show a massive range in the potential macroeconomic benefit of extending broadband and superfast broadbrand via 4G LTE to currently unserved or under-served communities. The breadth of these estimates reinforces an impression that the existing literature is far from coherent. However, it is clear that meaningful economic benefits will derive from 4G LTE expansion beyond BT's catchments, and this gives us greater confidence

that our estimate of a macroeconomic impact of 4G LTE in the order of 0.5-0.7 per cent of gross domestic is reasonable and realistic. (See section 5.4.)

Figure 24: Estimates of the eventual impact on United Kingdom GDP of 4G LTE providing superfast broadband services to households not served by fixed line alternatives

Different fixed line roll out scenarios	Current premises with no access to broadband above 2 M/bit/s	Current coverage of fixed line superfast broadband	90% coverage of fixed line superfast	95% coverage of fixed line superfast
Impact of 4G LTE				
Increase in coverage	2%	25%	9%	4%
Increase broadband penetration	1.4%	10.0%	3.6%	1.6%
Impact on national GDP				
Christine Zhen-Wei Qiang	0.17%	0.12%	0.04%	0.02%
Nina Czernich et al (max)	0.22%	0.15%	0.05%	0.02%
Nina Czernich et al (min)	0.13%	0.09%	0.03%	0.01%
Booze & Company	0.22%	0.15%	0.05%	0.02%
McKinsey & Company (max)	0.20%	0.14%	0.05%	0.02%
McKinsey & Company (min)	0.01%	0.01%	0.00%	0.00%
CEBR (max)	0.00%	0.00%	0.00%	0.00%

Sources: As described in section 4.4.

6 SECURING FUTURE GROWTH AND INVESTMENT

In this section we examine whether profit levels are large enough to secure investment for future growth in the sector. Our key findings are:

- **Mobile network operators in the United Kingdom are less profitable than European and North American peers for a variety of reasons, including the after-effects of the 3G auction, the competitive nature of the market and the increasing impact of regulation**

- **Cost increases would threaten the industry's investment rate, for example Ofcom's proposed increase in annual licence fees could reduce capital expenditure and delay the rollout of 4G LTE**

- **A fall in investment equivalent to the proposed increase in annual licence fees and the associated reduction in the capital stock could reduce gross domestic product by around 0.1 per cent**

- **Cost increases such as the proposed increase in annual licence fees may result in enforced costs savings elsewhere in the business, such as moving staff offshore, or may be passed through to consumers in the form of higher prices**

6.1 Comparing profitability with international peers

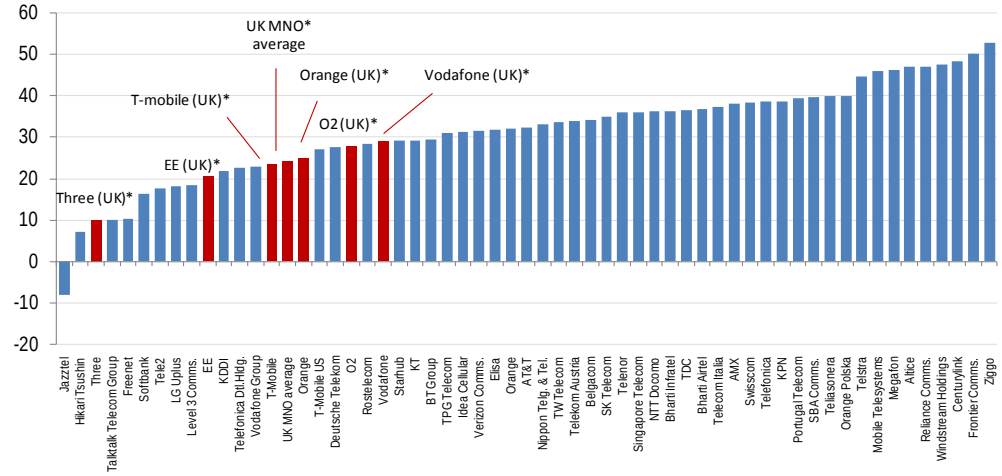
As large investment intensive businesses, mobile network operators require access to the international capital markets. As such, they need to deliver adequate returns to satisfy their past investors, and ensure future funding from institutions able to pick and choose between competing investments globally. Indeed, the operators in the United Kingdom are all now subsidiaries of larger international groups, which operate at a scale greater than any national market.[69]

[69] The specific subsidiaries that we have analysed are EE Limited (2382161), T-Mobile (UK) Limited (2382161), Orange Personal Communications Services Limited (2178917), Telefonica UK Limited (1743099), Vodafone Limited (01471587) and Hutchison 3G UK Limited (3885486). Note: The United Kingdom operations of Vodafone are part of Vodafone plc, which is listed and headquartered in the United Kingdom but has significant global presence.

However, mobile network operators in the United Kingdom deliver low returns to their investors compared with their peers in the telecommunications industry elsewhere. Operating profits, as measured by earnings before interest, tax, depreciation and amortisation ('EBITDA'), have been used as the benchmark metric of earnings in the telecommunications industry since the 1980s.[70] And, as a proportion of revenue, they show that mobile network operators in the United Kingdom have been at the lower end of profitability of telecommunications firms over the past decade. (See Figure 25 and Figure 26.)

What's more, the margins of mobile network operators in the United Kingdom have fallen by over 30 per cent since 2003. (See Figure 27.)

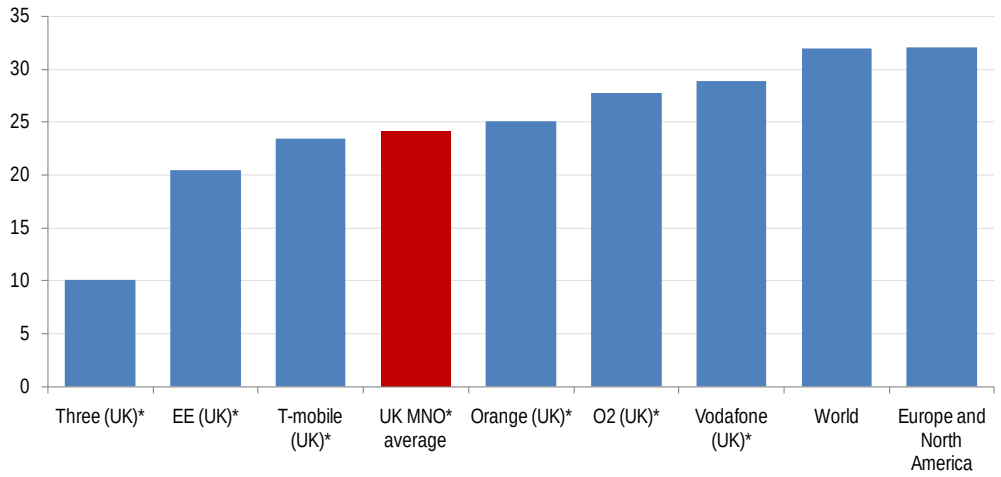
Figure 25: Average ratio of EBITDA to revenue for telecommunications firms globally, 2003-12



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-2012, data for Orange is for 2003-2009, data for T-Mobile is for 2003-2009 and data for Three is for 2011-2012. * United Kingdom operations.

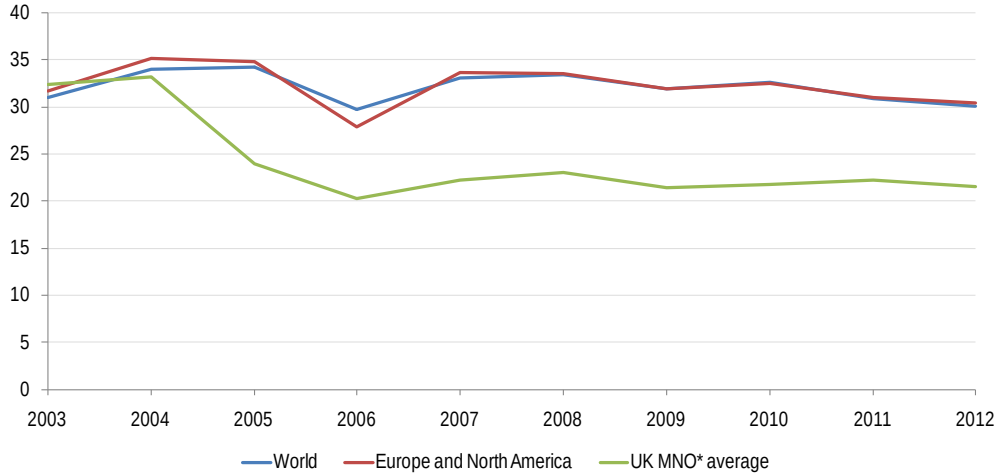
[70] Ernst & Young, *Metrics transformation in telecommunications* (Ernst & Young, London), 2013.

Figure 26: Average ratio of EBITDA to revenue in the mobile telecommunications sector, 2003-12



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-2012, data for Orange is for 2003-2009, data for T-Mobile is for 2003-2009 and data for Three is for 2011-2012. * United Kingdom operations.

Figure 27: Ratio of EBITDA to revenue for telecommunications firms globally since 2003



Source: Capital Economics, Datastream, Worldscope, annual accounts. * United Kingdom operations.

It is not just on this measure of profitability that returns in the United Kingdom are low. The country's four mobile network operators also currently earn low profits on alternative measures, such as earnings before interest and tax ('EBIT') and return on capital employed. (See Figure 28.)

Figure 28: EBIT margin and return on capital employed for United Kingdom mobile network operators

	EE		O2		Vodafone		Three	
£ millions	**FY 2013**	**FY 2012**	**FY 2012**	**FY 2011**	**FY 2012/13**	**FY 2011/12**	**FY 2013**	**FY 2012**
Revenue	6,482	6,657	5,609	5,968	5,063	5,364	2,042	1,970
Operating profit	6	(165)	395	728	135	243	195	93
EBIT	267	259	402	720	135	243	195	83
EBITDA	1,574	1,429	1,040	1,345	945	1,085	391	252
EBIT margin (EBIT / revenue)	**4.1%**	**2.4%**	**7.2%**	**12.1%**	**2.7%**	**4.5%**	**9.5%**	**4.2%**
Total assets	14,612	15,183	14,260	14,194	14,034	11,068	7,008	6,470
Current liabilities	(2,368)	(2,322)	(3,088)	(2,810)	(4,576)	(4,137)	(5,715)	(5,525)
Total assets less current liabilities	12,244	12,861	11,172	11,384	9,458	6,930	1,293	945
Long-term assets	12,735	12,842	7,411	8,019	7,601	5,665	5,452	5,183
Working capital	(920)	(855)	(914)	(856)	(541)	(111)	(588)	(502)
Capital employed	11,815	11,987	6,497	7,163	7,060	5,555	4,864	4,681
Return on capital employed (EBIT / capital employed)	**2.3%**	**1.3%**	**6.2%**	**10.1%**	**1.9%**	**4.4%**	**4.0%**	**1.8%**

Source: Capital Economics and annual accounts. Note: data for EE is for 'EE Limited', data for O2 is for 'Telefonica UK Limited', data for Vodafone is for 'Vodafone Limited' and data for Three is for 'Hutchison 3G UK Limited'. Working capital for O2 excludes amounts due by Group undertakings (2012 net book value of £5,098 million) and excludes amounts owed to Group undertakings (2012 net book value of £680 million). Working capital for Vodafone excludes amounts due by Group undertakings (2013 net book value of £3,730 million) and excludes amounts due to Group undertakings (2013 net book value of £2,719 million). Working capital for Three excludes amounts due to Group undertakings classified as loans (2013 net book value of £4,590 million). EBIT is equal to operating profit with management and brand fees and restructuring costs added back.

Returns using these measures have been lower than elsewhere over the period from 2003 to 2012.[71] Part of the reason for this is because of the comparatively large 3G licence contributions made by the industry to the exchequer compared to those paid by operators in other countries to their governments. The competitive nature of the market in the United Kingdom, with four large mobile network operators and a host of mobile virtual network operators, also has an impact.

What's more the market is becoming increasingly regulated. The Consumer Rights Directive is costing the industry an estimated £71 million a year,[72] whilst proposals to lower mobile termination rates will only worsen their profitability.[73] Although Ofcom may have assumed that operators would react to lower termination charges by increasing consumer prices in other areas, the so-called 'waterbed effect', there is now evidence from Valletti and Genakos

[71] For simplicity, to compare ten years of history for the four United Kingdom mobile network operators with that of international operators or firms in different industries, we use total assets less current liabilities as our measure of capital employed. We also use operating profit as an approximation for EBIT for the four United Kingdom mobile network operators.

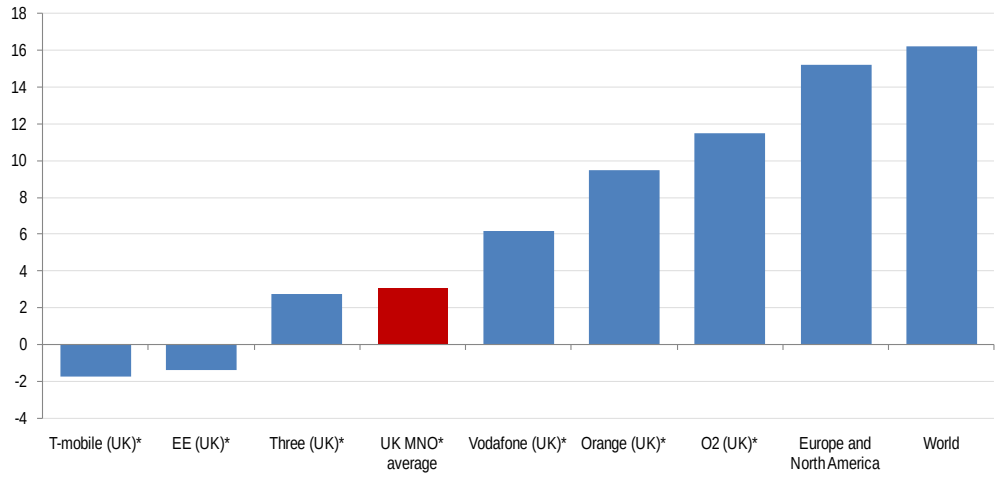
[72] Estimates based on data sourced from EE and scaled up for industry in relation to market share.

[73] Ofcom, *Mobile call termination market review 2015-18* (Ofcom, London), 2014.

(the original authors of the 'waterbed effect' theory) that suggests that this is not occurring.[74]

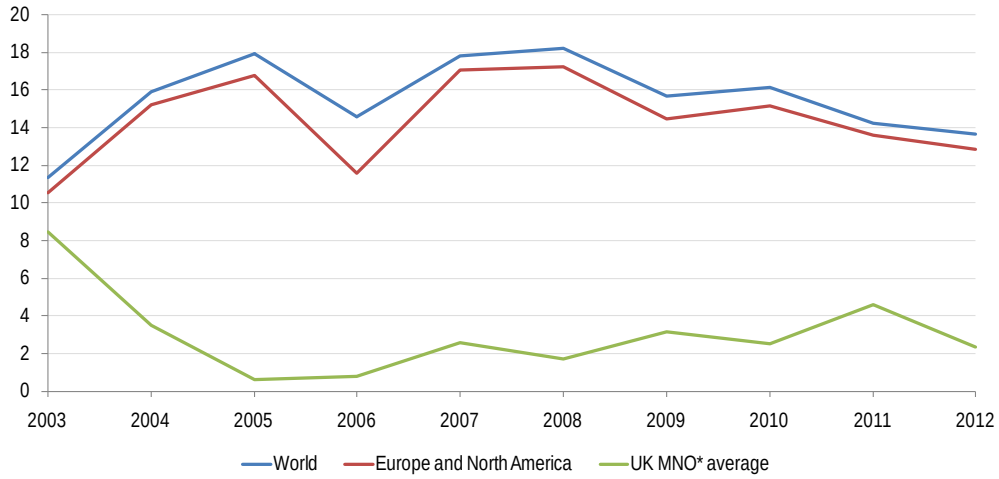
Accordingly, an international investor might easily view the United Kingdom as unattractive especially when compared with higher returns elsewhere in the world. (See Figure 29 to Figure 32.)

Figure 29: Average ratio of EBIT to revenue for mobile telecommunications firms, 2003-12



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-2012, data for Orange is for 2003-2009, data for T-Mobile is for 2003-2009 and data for Three is for 2011-2012. * United Kingdom operations.

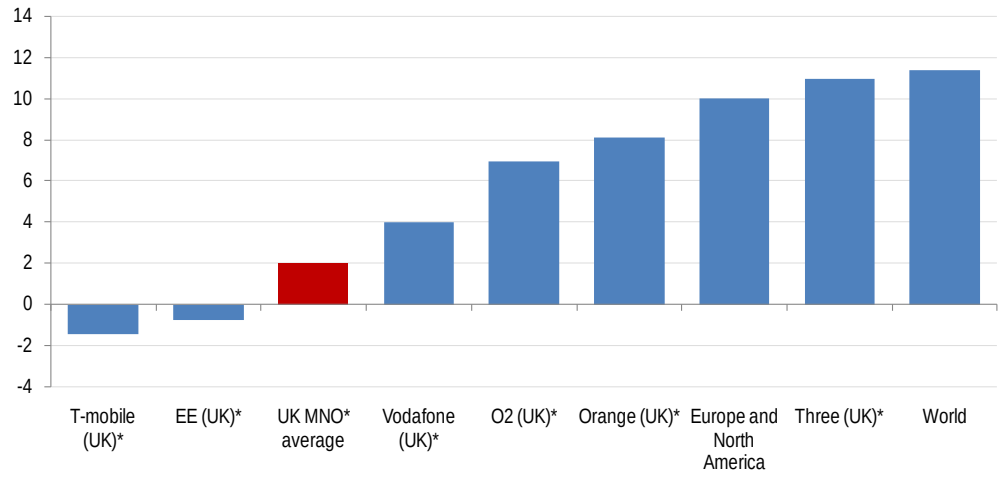
Figure 30: Ratio of EBIT to revenue for mobile telecommunications firms since 2003



Source: Capital Economics, Datastream, Worldscope, annual accounts. * United Kingdom operations.

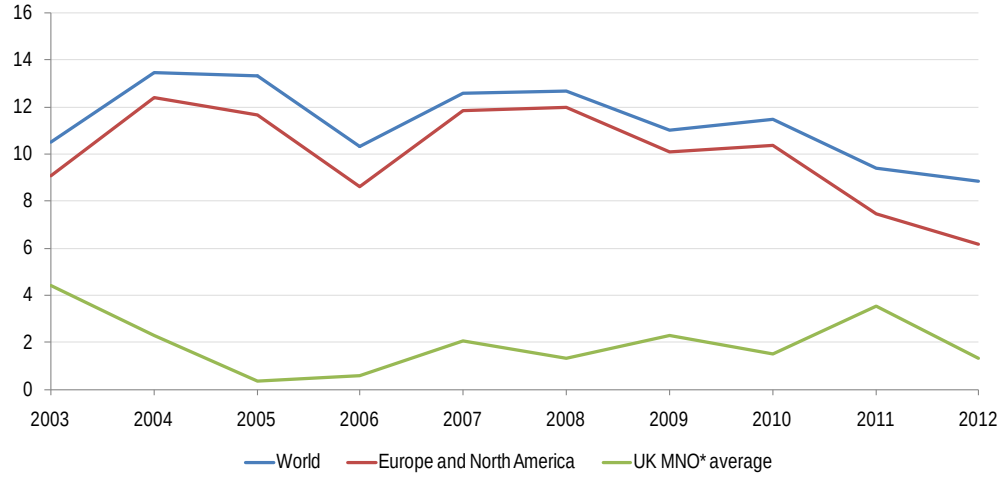
[74] Christos Genakos and Tommaso Valletti, 'Evaluating a decade of mobile termination rate regulation', *Centre for Economic and International Studies research paper series*, vol.12, Issue 1, no.303, 201.

Figure 31: Average return on capital employed for mobile telecommunications firms, 2003-12



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-12, data for Orange is for 2003-2009 and data for T-Mobile is for 2003-2009.* United Kingdom operations.

Figure 32: Return on capital employed for mobile telecommunications firms since 2003

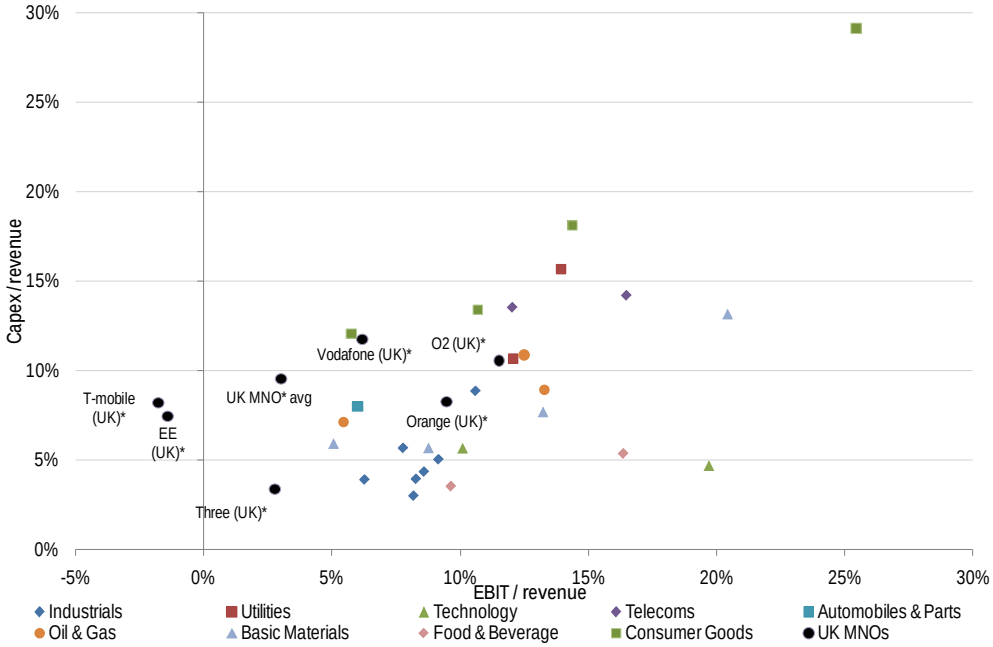


Source: Capital Economics, Datastream, Worldscope, annual accounts. * United Kingdom operations.

British mobile telephony not only delivers below par returns compared with others in their sector globally, they also make only modest or even negative earnings relative to their rates of capital expenditure compared with other industries.[75] (See Figure 33.)

[75] There are a number of financial ratios that investors consider as they assess the capacity of firms to earn profits and pay dividends. However the use of the EBITDA measure to compare operating profits with those of other industries of differing capital intensities is not particularly meaningful.
Instead, we look at earnings as a proportion of revenues once this depreciation has been taken into account.

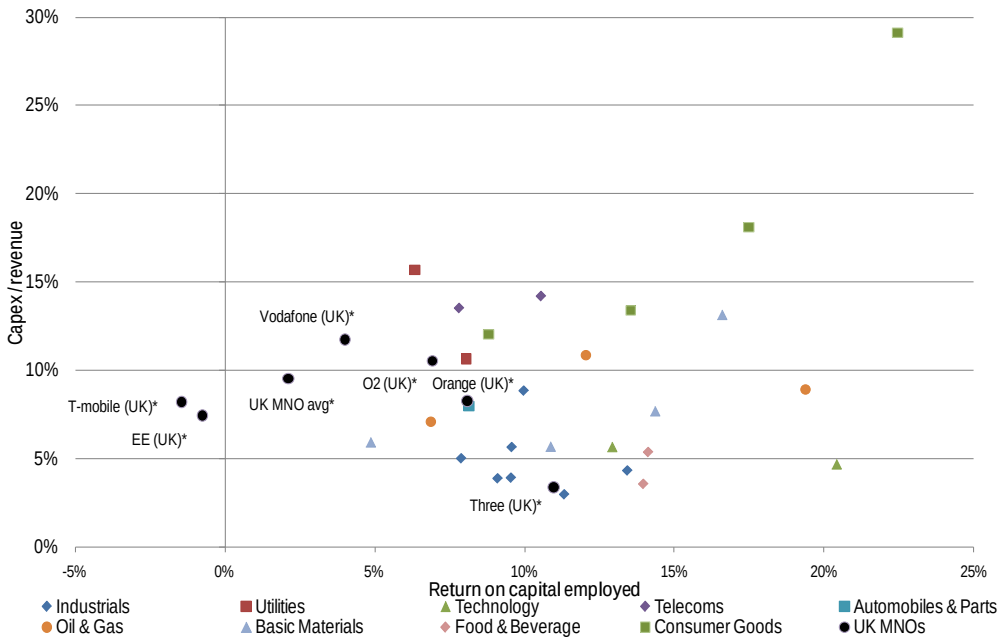
Figure 33: EBIT and capital expenditure as proportions of revenue for United Kingdom mobile network operators and global sectors, ten year weighted averages, 2003-2012



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-2012, data for Orange is for 2003-2009, data for T-Mobile is for 2003-2009 and data for Three is for 2011-2012. Multiple markers for each industry represent different sub-sectors. * United Kingdom operations.

One final measure of profitability, the return on capital employed, suggests that mobile network operators in the United Kingdom make a poor return on the amount of capital required to run the business. Indeed, they perform worse than utilities, a sector that also requires significant amounts of capital. (See Figure 34.)

Figure 34: Return on capital employed against capital expenditure as a proportion of revenue for United Kingdom mobile network operators and global sectors, ten year weighted averages, 2003-2012



Source: Capital Economics, Datastream, Worldscope, annual accounts. Note: data for EE is for 2010-2012, data for Orange is for 2003-2009 and data for T-Mobile is for 2003-2009. Multiple markers for each industry represent different sub-sectors. * United Kingdom operations.

Mobile network operators earn below European and global par rates of return. Studies suggest that cash flow is an important determinant of business investment decisions.[76] Firms that are more profitable are able to spend more on capital expenditure and firms that invest more generate greater profits. So, if mobile network operators in the United Kingdom were able to reach rates of return equivalent to their international peers, there should be a substantial increase in investment as markets permit firms to increase their capital budget allocations in that country.

It is not just rates of return being less than other sectors or industries that should be a concern for anyone wanting to see a vibrant industry, and future innovation and growth; analysis suggests that up to one-third of current mobile operators consistently fail to earn their cost of capital.[77] Indeed, a strategy firm, BCG, suggests that the minimum sustainable cost of capital is a 25 per cent EBITDA margin. In the United Kingdom, the industry operated at

[76] Cherian Samuel, *The Investment Decision: A Re-examination of competing theories using panel data* (The World Bank, Washington), 1996
Warwick University, *Financial systems, financing constraints, and investment: empirical analysis of OECD countries* (Warwick University, Warwick), 2005.
[77] The Boston Consulting Group, *Reforming Europe's telecoms regulation to enable the digital single market* (European Telecommunications Network Operators' Association, Brussels), 2013.

an average EBITDA margin of 24.2 per cent across the period from 2003 to 2012; in eight of those years, it was less than 25 per cent.

The business model for mobile operators in the United Kingdom is already stretching reasonable limits.

6.2 The impact of an increase in costs on the business model

With the business model for mobile network operators in the United Kingdom already looking stretched, we examine how material cost increases to the industry could affect investment, employment and consumers.

One such increase in costs could come from Ofcom's proposed rise in annual licence fees for spectrum originally granted in the 1980s and 1990s and used for 2G services. Under the initial proposals published in October 2013, annual payments by operators would rise by £244 million from £65 million currently to £309 million.[78] A revised consultation released in August 2014 reduced the proposed increase by twenty per cent to a total of £246.7 million — nearly four times its current level.[79] This gives us a benchmark figure for a potential cost increase to analyse.

The industry could meet these increased costs by changing how it spends elsewhere within the business, through delaying or cutting investment, reducing labour costs with outsourcing, or by raising prices to earn more revenue.

First we examine how capital expenditure could be affected. The increase in costs would likely reduce the profitability of firms in the industry, and further weaken the operators' attractiveness to investors.

A report by Plum Consulting, *Annual licence fees — you cannot have your cake and eat it*, provides evidence supporting the notion that an increase in costs, such as a rise in annual licence fees, is likely to result in a fall in investment.[80]

Firms face difficult decisions over where to assign their finite amount of capital. Although the net present value of investments in the United Kingdom could still be greater than zero, in reality investors base their decisions on a

[78] Ofcom, *Annual licence fees for 900 MHz and 1800 MHz spectrum Consultation* (Ofcom, London), 2013.
[79] Ofcom, *Annual licence fees for 900 MHz and 1800 MHz spectrum Further Consultation* (Ofcom, London), 2014.
[80] Brian Williamson, Phillipa Marks and Yi Shen Chan, *Annual licence fees — you cannot have your cake and eat it* (Plum Consulting, London), 2014.

range of metrics not necessarily directly linked to the net present value, including financial ratios such as net debt to profits.

What's more, investment decisions of mobile network operators are typically constrained by a capital expenditure limit that is agreed with shareholders. An 'agency' problem arises when shareholders perceive that their dividend may be reduced as a result of costs increases that are not reflected in investment decisions by the operators. As such, this is likely to result in a reduction in the capital expenditure limit agreed to by the shareholders.[81]

There is also an internal issue for mobile network operator companies that are part of a wider international group, which could face pressure to meet minimum dividend targets from the parent company. In meeting these commercial realities firms could choose to reduce capital expenditure budgets. And given the international nature of the companies, projects in other regions could now offer greater returns as a result of the cost increase and firms could allocate capital away to these accordingly.

On top of this, there is also a risk that investment will be deterred by the increased risk of expropriation of sunk investments, whereby the government retrospectively extracts value from investments that have already been made. The mobile network operators have spent large sums on spectrum in the 3G and 4G auctions which they cannot get back and the increase in annual licence fees may reduce the value of these assets. Expropriation risk is a significant deterrent to investment and innovation.[82]

Overall, there is strong evidence that reduced cash flows result in lower investment; an increase in costs, for example annual licence fees, could threaten investment in mobile coverage and capacity.

We consider the impact of a fall in investment by the mobile network operators in line with the revised proposal for the increase in annual licence fees. Using 2012 industry totals as a benchmark, reducing capital expenditure by £182 million would see it fall by ten per cent from £1.80 billion to £1.62 billion. Assuming that revenue remained constant, the share of revenue allocated to capital investment would be 0.9 percentage points lower. (See Figure 35.)

[81] *ibid.*

[82] Brian Williamson, Phillipa Marks and Yi Shen Chan, *Annual licence fees — you cannot have your cake and eat it* (Plum Consulting, London), 2014.

Figure 35: The impact of proposed annual licence fee increases on capital expenditure

Industry totals* (£ millions)	2012	Cost increase effect	After cost increase
Revenue	19,386	0	19,386
Capital expenditure	1,804	-182	1,622
Capital expenditure / revenue	9.3%	-0.9 (percentage points)	8.4%

Source: Capital Economics' calculations, annual accounts. * United Kingdom operations.

The industry is in the initial process of rolling out 4G LTE in the United Kingdom. If it was faced with these additional costs now, it may offset the higher annual licence fees by cutting capital expenditure and delaying the investment timetable. A reduction in annual capital expenditure of £182 million would be equivalent to a delay in completing the rollout and subsequent densification of 4G LTE services of up to six months.[83]

Clearly an increase in costs that led to reduced capital expenditure could create significant delays for major infrastructure projects, which will affect consumers, businesses and the wider economy.

Over time, the fall in investment will reduce the mobile telephony industry's capital stock. We have estimated that, after five years, the industry's net capital stock would be eight per cent lower if capital expenditure fell in line with Ofcom's revised proposals for an increase in annual licence fees. Based on the findings of studies which look at the value of mobile telephony (see section 5.2), we estimate that the introduction of higher annual licence fees could reduce gross domestic product by around 0.1 per cent.

Alternatively, the mobile network operators could decide to cut costs elsewhere in the business, putting jobs in the United Kingdom at risk. For example, domestically based call centres could be moved offshore. We estimate that the mobile network operators could save around £6½ million per annum for every 'typical' call centre that is moved offshore.[84]

Finally the industry could maintain its capital expenditure commitments and employment in the United Kingdom and simply meet the increased costs by raising revenues through higher prices. This though would mean consumers and businesses have to pay more in their bills. If we again use the proposed increase in the cost of annual licence fees of £182 million as our benchmark additional cost burden, and this was all passed directly to consumers, then

[83] We have assumed that the industry is only a third of the way through its current investment schedule for the rollout and subsequent improvements to indoor coverage, capacity increases and quality of 4G LTE services.
[84] Estimates based on data provided by EE on cost of 'typical' call centre with 1000 full time equivalent jobs.

bills could increase by 1.3 percentage points before value added tax.[85] At a time when wage growth has long been running behind inflation, this would be further unwelcome to household budgets.

6.3 Future investment

Mobile network operators' financial resources in Europe are becoming increasingly constrained, which could limit the rollout of investment in new infrastructure. Analysis by McKinsey shows that mobile prices have fallen at a greater rate in Europe than in the United States, and lower revenues are eating into profitability.[86] Moreover, these financial pressures are attributed to contributing to falling investment levels in Europe.[87] Within that context the environment for mobile network operators in the United Kingdom is even bleaker; they are less profitable than European and global peers and as a result have less capacity to invest. If they were able to achieve those benchmark rates of return, it would be possible for capital expenditure to be deployed faster and in greater quantities generating growth in the industry. Conversely the business model of mobile network operators in the United Kingdom is stretched such that already the industry is struggling to earn its cost of capital. Any cost increases would damage profitability to the extent that investment levels would be threatened as finite supplies of capital are allocated to regions or industries with higher rates of return. This could seriously damage the United Kingdom's standing in the mobile technology leader board globally.

[85] Proposed increase in annual licence as a share of 2012 United Kingdom mobile network operators total revenue was 1.3 per cent.
[86] McKinsey and Company, *A "New Deal": Driving investment in Europe's telecoms infrastructure* (McKinsey and Company), 2012.
[87] The Boston Consulting Group, *Mobile Economy Europe 2013* (GSMA), 2013.

7 NATIONAL ROAMING

In this section we examine whether the currently consulted upon option of national roaming would produce a net benefit to the economy. Our key findings are:

- **National roaming would likely increase 2G voice and messaging geographical coverage by just two to four percentage points, but at an estimated cost to the industry of almost £3 billion over a five year period**
- **Although consumer surplus could increase by £136 to £175 million, this could be wiped out by 'signal locking', when mobile devices unnecessarily connect to another network momentarily and remain attached to it for several minutes and can't access data services. It would only take one to two incidents each week per data user for this benefit to be completely lost**
- **The rollout of 4G could be delayed by eighteen to 24 months if mobile network operators' resources are diverted to implement national roaming**
- **The policy is likely to lead to perverse incentives and reduce rural coverage. Industry capital expenditure could be lowered by £360 to £440 million each year, reducing gross domestic product by 0.1 to 0.2 per cent. This is in addition to the negative 0.1 percentage point impact that a rise in annual licence fees would have**
- **National roaming, and the proposed increase in annual license fees, could serve to dramatically reduce the proceeds the government takes from future licence auctions, such as for 5G technologies**

7.1 The benefits of national roaming

The four mobile network operators in the United Kingdom collectively offer almost ubiquitous 2G mobile telephony coverage, with over 99 per cent of the population and 89 per cent of geographical area receiving coverage from at least one operator with strong enough signal to make a call in a car.[88] Mobile network operators compete in a private market and have historically invested in their networks in varying amounts and in different places. Accordingly,

[88] The 'Impact Assessment' for Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014.

areas called 'partial not-spots' exist where there is sometimes coverage from one, two or three, but not all operators;[89] for example Vodafone, the provider offering the widest 2G coverage, reaches 99 per cent of the population and 82 per cent of geographical area.[90] The Department for Culture, Media and Sport has launched a consultation on various options to further improve rural mobile coverage.[91] One of the options being consulted upon is 'national roaming', which would allow domestic users access to a competitor's 2G network if their own was unavailable.[92]

National roaming, in the form that is currently being consulted upon, would allow mobile phone users to connect to another mobile network provider's 2G signal in areas where their home network does not have coverage, but only if another network has coverage. This would enable the user to make and receive telephone calls or send and receive text messages, but not let them send or receive data, in some areas where they wouldn't have been able to previously.

It is unclear in what areas the technology behind national roaming will kick in giving consumers access to another provider's network, and so how much additional coverage consumers would receive under national roaming. In any one place in the United Kingdom, there is less likely to be coverage from all operators using a high quality signal level than on a low quality signal level. This means the measure of potential coverage gains are greatest if we look at a particularly high quality of signal, as Ofcom do. But we suspect that it is more appropriate to use a weaker signal, for example one which relates to a robust outdoor voice service, where national roaming would give smaller benefits. Indeed, the only way it would be possible to switch networks at a high quality of signal is if there is seamless national roaming;[93] but this is not technically feasible across all mobile networks in the United Kingdom.[94] We believe it is

[89] Note: a domestic user can still make calls to emergency services if they don't have coverage from their home network in a partial not-spot by drawing on another network's coverage.
[90] The 'Impact Assessment' for Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014.
[91] Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014.
[92] Another option being considered is establishing a 'multi-operator mobile virtual network operator'. This would give a user of the mobile virtual network operator the ability to roam across all networks. As such, the arguments for and against this option are much the same as for national roaming.
[93] Under seamless national roaming a phone would always search for the strongest signal and then connect to it, even if it was from another network provider. In transferring to a different network the user would not be disconnected.
[94] Analysys Mason, *Study on the technical issues associated with the introduction of national roaming* (Analysys Mason, London), 2010.

reasonable to assume that national roaming will only kick in on a device when the home network signal is lost altogether; this occurs at a signal strength well below what is needed for fully robust voice communication.

We analyse the implications of mobile devices switching to different network providers at this low level of signal quality. In addition, although technically unfeasible, as in the government's consultation, we provide results assuming roaming at a high level of signal quality.

Ofcom assess mobile network operator coverage with a signal quality that allows customers to make or receive calls in cars. If this was a true reflection of the areas in which basic national roaming was possible (which we do not believe to be the case), and users could switch to a different network provider at this high level of signal quality, the Department for Culture, Media and Sport's consultation suggests that geographical coverage would be extended by an additional thirteen percentage points of the United Kingdom's land mass.[95]

But this isn't a realistic picture of how national roaming would work. Mobile devices will attempt as priority to connect to their home network regardless of signal strength rather than move onto a network that has better signal. In doing so, they will likely retain a connection to the home network until a low signal level that might not be usable to make a call. EE estimate that between 92 and 94 per cent of all United Kingdom geography is likely to receive robust outdoor voice coverage from at least one operator. For EE customers this could give an additional coverage gain under national roaming of up to 4.0 percentage points of United Kingdom area.[96]

What's more, it does not seem appropriate to analyse national roaming by looking at calls that are made in cars when, in its currently feasible form, there would not be a seamless handover between radio masts of different operators when in-call. This means that calls would still drop if a user moved beyond the edge of a home operator's coverage even if there was available coverage from another operator.

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[95] The 'Impact Assessment' for Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014. Note this is Ofcom's estimate for partial not-spots following the completion of project Beacon (O2 and Vodafone's passive network infrastructure sharing plan). This is likely to be an over-estimate of coverage gains under national roaming for any one particular customer. What matters for an individual customer's coverage is the difference between coverage from all operators and coverage from their own network provider. The measure here is for the difference between coverage from all operators and coverage from at least one operator.

[96] Note there is a degree of uncertainty over this and EE estimate the additional coverage could extend from between 2.0 and 4.0 percentage points. We cautiously take the top end estimate for our analysis.

We assess the benefits of national roaming by calculating the number of masts that are likely to be used by customers from different networks and then the number of additional minutes of calls these masts would likely handle.

Partial not-spots are most likely to occur in rural areas where there is less possibility of coverage in an operator's network because of terrain effects, deployment constraints or economic viability. Masts in rural areas are more spread out than in urban areas, so while just 11.7 per cent of the country is classified as urban and developed land by the Office for National Statistics, rural masts make up less than half of the country's total.[97] We estimate that an additional 1,251 masts would effectively be made available to customers through national roaming across all networks. (If basic national roaming was effective in covering the partial not spots as defined by Ofcom's measure of coverage based on high signal quality, 4,071 masts would effectively be made available.)[98] (See Figure 36.)

Figure 36: Number of new masts reached by customers under national roaming

	Partial not spots based on any signal	Partial not spots based on in car signal quality*
Additional area of United Kingdom geography covered for customers on one network (percentage points)	4.0	13.0 **
Additional area covered for customers on one network (square kilometres)	6,857	31,834
Density of rural masts (number per square kilometre)	0.045	0.045
Number of additional masts available to customers on all networks	1,251	4,071

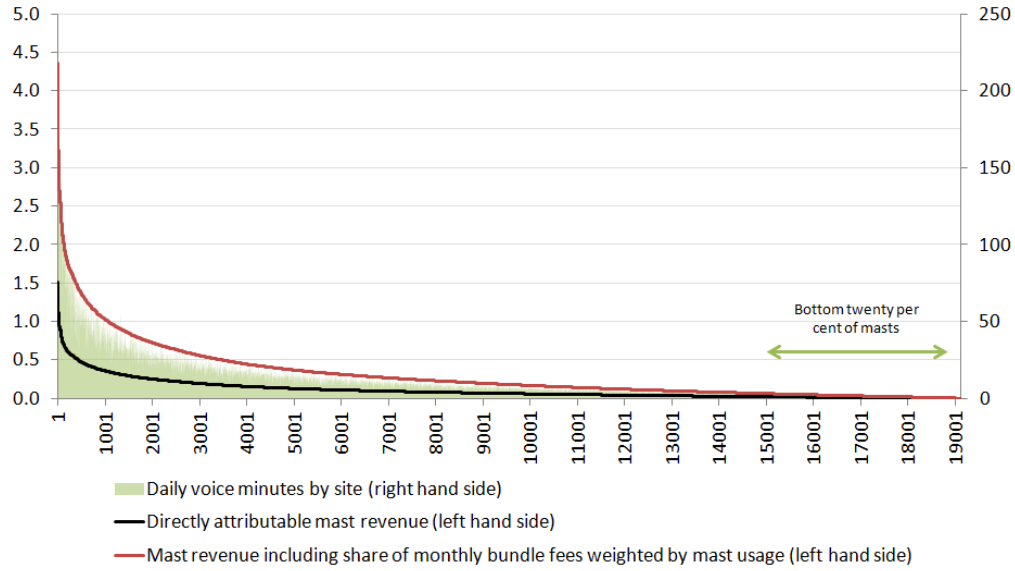
Source: Office for National Statistics, EE and Capital Economics. Notes: * It is not technically possible to implement seamless roaming and eliminate partial not spots as measured at this high level of signal quality. ** The 'Impact Assessment' for Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014.

We assess the benefit that access to these masts will give by estimating the additional minutes of calls that would have taken place if customers had the extended coverage. These marginal masts are likely to be in areas with low population densities, otherwise it would make economic sense for the mobile network operators to already provide service here. As such the mast that would see additional traffic is likely to be one that has low use.

[97] Office for National Statistics, *UK Environmental Accounts, 2014* (Office for National Statistics, London), 2014. Analysis of masts conducted using data from EE.
[98] Analysis conducted using data from EE about their network and we scale this up to give a figure for the industry. Seamless national roaming is implied if roaming at this high level of signal quality.

Figure 37 shows the implied annual revenue that is attributable to each mast in EE's portfolio and the voice minutes each site carries per day. We measure the implied revenue in two ways. First, we allocate total network revenues directly to charged for minutes, text messages and downloaded data (i.e. excluding revenues from inclusive bundles) to each mast (black line). Second, we include the fees customers pay for a monthly inclusive bundle and the network's revenues from roaming and mobile virtual network operators (red line). We allocate these additional revenues to each mast in proportion to its share of the network's total revenues directly charged for minutes, text messages and downloaded data.

Figure 37: Implied individual mast annual revenue (£ million, left hand side) and daily voice minutes per site (thousands, right hand side)



Sources: Capital Economics' calculations and estimates using EE data.

Although we estimate that only 2.3 per cent of masts would see additional minutes (or 7.5 per cent on Ofcom's measure of coverage at high signal quality), we cautiously assume that the marginal mast is represented by the average number of minutes for the bottom twenty per cent of EE's masts. We assume that, with users from all network providers, the mast's total voice traffic would increase in relation to market share. The additional minutes on a mast are then the difference between the voice traffic that already occurs and the newly calculated total. We estimate that voice traffic at a national level could increase by just 0.6 per cent or 72.5 million minutes each month.[99]

[99] This would be 235.9 million minutes each month if we use the high quality of signal measure that Ofcom looks at.

The consumer surplus of mobile voice services in the United Kingdom has been estimated at between £19 and £23 billion by Analysys Mason for 2011.[100] Using their forecasts, this is expected to increase and was probably between £21 and £27 billion for 2013. We assume that consumer surplus will increase directly in proportion to the additional minutes of calls made each year. This would lead to annual consumer surplus gains of between £136 and £175 million. (If basic national roaming was able to cover the partial not spots as defined by Ofcom's measure of coverage based on high signal quality, this would be between £443 and £570 million.) (See Figure 38.)

Figure 38: Consumer surplus gains from national roaming

	Partial not spots based on any signal	Partial not spots based on in car signal quality*
Number of additional sites	1,251	4,071
Additional annual minutes	0.9 billion	2.8 billion
Total annual United Kingdom mobile voice call minutes (2013)	134.1 billion	134.1 billion
Additional minutes as a proportion of existing call volume	0.6 per cent	2.1 per cent
Consumer surplus of mobile voice services (2013)	£21 to £27 billion	£21 to £27 billion
Additional consumer surplus	£136 to £175 million	£443 to £570 million

Source: Analysys Mason, EE, Ofcom and Capital Economics. Note: * It is not technically possible to implement seamless roaming and eliminate partial not spots as measured at this high level of signal quality.

It isn't just consumers that could benefit from the increased coverage. Mobile network operators themselves are likely to gain from offering an expanded geographical service through increased usage. Annual industry revenues could increase by up to £9.1 million.[101] The industry is unlikely to be able to capture all the additional minutes as revenue though; some of the extra voice traffic will fall within the inclusive allowances in consumers' monthly bundles.

7.2 What are the challenges and costs?

Introducing national roaming is not a small undertaking and isn't something that can just be 'switched on'. First, there are significant technical challenges to overcome that will take time to resolve. Executing seamless national roaming between Orange and T-mobile took approximately eighteen months,

[100] Kende, M, Bates, P, Stewart, J and Vroobel, M. *Impact of radio spectrum on the UK economy and factors influencing future spectrum demand* (Analysys Mason, London), 2012.

[101] We use a value of 1.05 pence per minute of voice call.

but it is not inconceivable that introducing non-seamless national roaming across all networks would take longer at eighteen to 24 months, or possibly more. Second, national roaming will require significant financial outlays for both capital and operating expenditure. Third, there will be costs to the consumer in the form of a worsened user experience and through delays to future projects, such as the rollout of 4G.

Based on data from EE, our estimates suggest that widespread implementation of national roaming would likely cost each mobile network operator in the region of £200 million of capital expenditure over a two year period, as well as £500 million of ongoing operating expenditure, over a five year period, to support it. (See Figure 39.)

Figure 39: Estimates of five year total cost for national roaming with three mobile network operators

Item	Type of expenditure	Cost per network operator (£ million)	Industry cost (£ million)	Timeframe
Information technology, network and software	Capital	50	200	Two years
Capacity for resilience	Capital	150	600	Two years
Customer service, support and security	Operating	50	200	Ongoing
Site rental	Operating	450	1,800	Ongoing
Total		700	2,800	

Source: EE and Capital Economics

Implementing national roaming would require significant information technology development costs and upgrades to capacity, provisioning and billing configuration changes, core network system capacity, and network system development and test programme. This would likely cost almost £50 million for one mobile network operator over a two year period.

There would need to be substantial investment in additional capacity to provide resilience in the event of a network outage by another operator. For example, the O2 network suffered from outages in July and October 2012.[102] Under national roaming those O2 customers affected by the outages would have been able to use 2G voice and text messaging services on the networks of the other providers. Without substantial investment to increase capacity, this would have overloaded these networks and potentially led to outages for the entire country. The cost of building out sufficient capacity has been estimated at £150 million for one mobile network operator over a two year period.

[102] See http://www.bbc.co.uk/news/technology-18816668 [accessed 29 October 2014] and http://www.bbc.co.uk/news/technology-19928507 [accessed 29 October 2014].

National roaming is likely to create several customer experience issues, which will lead to an increased level of customer service calls. EE estimate that these issues could lead to an additional four million calls per year and the cost for handling these calls and educating the customer base would need an additional £50 million over five years in operating expenditure for each mobile network operator. (See Figure 40.)

Figure 40: Customer experience issues caused by national roaming

Customer experience issue	
Inconsistent service experience	• Users only have access to a subset of home network services when nationally roaming: • No access to voicemail • Inability of home network to explain to a customer why they might have experienced a problem when nationally roaming, for example if a competitor's mast stops working • Customers could become confused if their mobile display shows the name of the visited network under national roaming
Signal locking	• No access to data services as mobile devices get stuck on the signal of a roaming network for at least 6 minutes
Reduced battery life	• Mobile devices rescan the networks more frequently to ensure they connect to their home network at the earliest opportunity
Reduced nationwide call performance	• Large scale network changes will create instability

Source: EE and Capital Economics

There would be significant additional operating expenditure costs due to the requirement to compensate site land owners for site sharing. This compensation could cost up to £450 million over five years for each mobile network operator.

Although the form of national roaming being consulted upon is designed to bring expanded voice and messaging coverage, it could lead to a diminished data service for consumers. Mobile devices periodically perform a search to make sure the device has the best connection to the network. Mobile network operators set how frequently these searches happen and the shortest this can currently be is six minutes. With national roaming it is possible that a consumer enters a small local partial not-spot and loses its home network signal and thus makes a connection with another provider, a process called 'signal locking'. Unless the consumer turns 'airplane' mode on and off or forces a manual search for the home network, the shortest period of time that the phone will currently begin to search again is six minutes. In this six minute window the consumer will be without access to data services.

The consumer surplus derived from data services has been estimated at £5.1 billion for 2011 by Analysys Mason.[103] Using their forecasts this was probably

[103] Kende, M, Bates, P, Stewart, J and Vroobel, M. *Impact of radio spectrum on the UK economy and factors influencing future spectrum demand* (Analysys Mason, London), 2012.

around £7½ billion in 2013. On average mobile phone users in the United Kingdom use the internet on their phones 5.6 times each day.[104] In 2013, some 44.5 million handsets connected to the internet using mobile data[105], which suggests there are approximately 91.3 billion instances a year where consumers use their phones for data services. The benefit of receiving these data varies across consumers. For some its importance would mean all consumer surplus could be lost if it isn't received instantly, but for others it might not matter at all if it takes six minutes longer. Without significant further research it is difficult to say how this breaks down. We take a cautious view and assume that half of users would lose the entirety of their consumer surplus and half won't lose any. On this basis consumer surplus would be lowered by 4.1 pence for each incident.

The addition to consumer surplus that national roaming could deliver through increased rural voice connectivity would be lost after 3.3 to 4.3 billion incidents where subscribers have failed to access their data services on time. Although this may seem a lot, it is only 1.4 to 1.8 incidents per week for each subscriber that uses data in the United Kingdom.

The scale of financial and technical resources required to implement national roaming is likely to affect the consumer experience beyond the issues already outlined. The policy will lead to delays in planned projects, affect business as usual activities and slow the rollout of 4G.

The introduction of national roaming could displace around 30 per cent of project resources for eighteen to 24 months.[106] Business as usual activities, such as capacity upgrades, coverage expansions, software upgrades and patches, and other essential 'maintenance' activities which use shared project resources with projects may be affected by the policy. Resources would be stretched to sustain this basic workload required to maintain an agreed level of service in line with the growing customer base and traffic load.

The rollout of 4G is likely to be delayed as well. The substantial costs of implementing national roaming need to be met somewhere and it is likely that scarce technical resources and network investment would have to be diverted away from 4G. The estimated annualised cost of implementing national roaming is £560 million over five years. Assuming that these costs would have to be met from mobile network operators' investment, the initial rollout and subsequent densification of 4G could be delayed by eighteen to 24 months.[107]

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[104] Ofcom, *Measuring mobile voice and data quality of experience* (Ofcom, London), 2013.
[105] Ofcom, *The Communications Market Report*, (Ofcom, London), 2014.
[106] Analysis conducted by EE.
[107] We have assumed that the industry is only a third of the way through its current investment schedule for the rollout and subsequent improvements to indoor coverage, capacity increases and quality of 4G LTE services.

Furthermore core network capacity would not be able to keep pace with the increased traffic under national roaming, which would likely cause existing 4G services to suffer. It is unlikely the industry would be able to keep investing at the same rate as today given the additional estimated £400 million it would have to spend on operating expenditure each year.

Assuming that investment is cut by £400 million each year under national roaming, the industry's net capital stock would be seventeen per cent lower after five years than without it. In line with findings from studies which look at the value of mobile telephony (see section 5.2), we estimate that the introduction of national roaming could reduce gross domestic product by around 0.1 to 0.2 per cent. This is on top of the negative 0.1 percentage point impact an increase in annual license fees could have (see section 6.2).

7.3 Implications for future investment decisions

Currently, a mobile network operator can stop its competitors' customers accessing its network and services. Any reward for investing in infrastructure accrues solely to the network provider that does the investing.

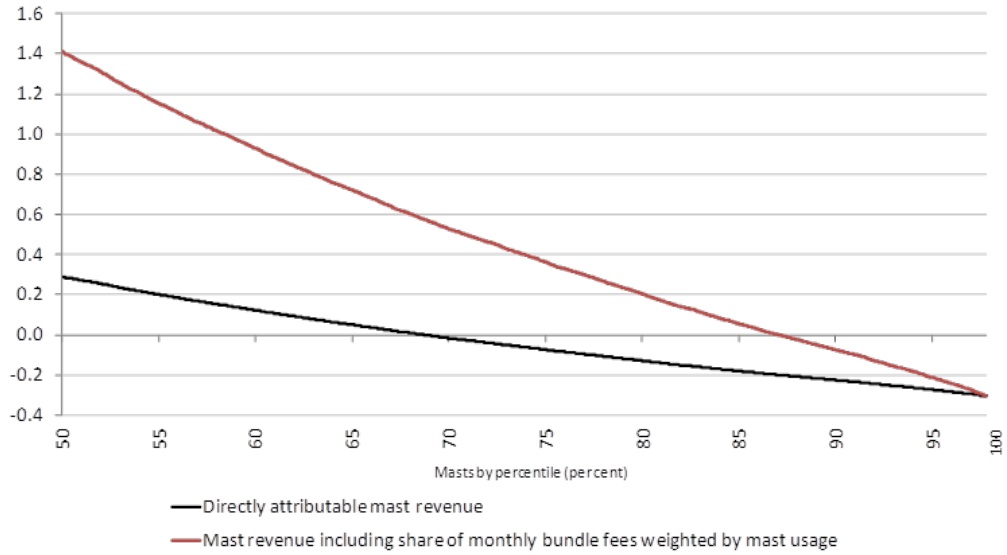
National roaming would change this. Mobile network operators deciding whether or not to invest in a new mast would then know that national roaming would allow their customers to use the network infrastructure of whichever provider builds it. In order to ensure that infrastructure investment levels were maintained, mobile network operators would need to be able to charge the other networks for the access to their infrastructure.

The decision to invest or not under national roaming is more marginal in the areas with minimal or zero coverage that the options being consulted upon are intended to help the most.

Using our implied revenues shown in Figure 37, we calculate the net present value for investing in a mast that would receive those revenues.[108] Approximately 30 per cent of masts would be 'loss-making' if they were allocated revenues according to their usage. This doesn't account for all of the revenues that a mobile network operator receives though. We allocate revenues from inclusive monthly bundles and roaming charges according to a mast's relative usage (the red line). (See Figure 41.)

[108] Analysis conducted using data provided by EE.

Figure 41: Net present value of investing in a mast (£ millions)



Sources: Capital Economics and EE

But these 'loss-making' marginal masts do exist. Although these masts are unprofitable themselves on this measure, their existence suggests they offer wider benefits to a mobile network operator. Customers are more likely to want a mobile service or will have greater willingness to pay for it if they know that it can be used in as many places as possible, even if they are unlikely to ever need to use it there themselves. Furthermore, there are likely to be benefits to the mobile network operator's brand if they can create a competitive advantage by offering the greatest coverage area. The full benefits of a marginal mast to a mobile network operator are likely to lie somewhere above the red line and this creates an incentive for mobile network operators to invest, even if a competitor does not.

National roaming would, however, introduce the industry to the economics concept of 'free riding'.[109] Mobile network operators would be able to benefit from their competitors' capital expenditure on marginal masts, as they would now be able to offer extended coverage to their customers without needing to increase their own investment. This removes the competitive advantage of being the network with the widest coverage, and the decision to invest in a mast would dissolve down to the red line in Figure 41. Approximately 11.5 per cent of masts would now be economically unviable, vastly diminishing the incentive to invest in areas of partial not spots.

The free riding problem could become apparent in the near future. BT Business launched its 4G network in August 2014, and will likely extend this

[109] See the appendix for a more detailed explanation.

coverage to all of its customers in the future.[110] It is unclear from the Department for Culture, Media and Sport's consultation whether or not BT would get access to the other providers' 2G networks under national roaming. If it did, it would be given a competitive advantage as its offering would not reflect its prior investments.

If a mobile network operator can sell access to their network under national roaming, as they do with mobile virtual network operators currently, then investment might not be diminished to the same degree. But access charges would have to reflect the actual costs to the investing mobile network operator for national roaming to not restrain investment. If they did not, it is probable that national roaming would have exactly the opposite effect to that the government intends.[111]

We assess different access charge rates and their implications for mast viability and population coverage in two ways. First, we consider the rate required if mobile industry investors were able to retrieve a fair return under national roaming on their sunk network investments; we do this by accounting for a mast's initial capital expenditure costs. Second, we examine what would happen if the government allowed mobile network operators to recover just a mast's operating costs under national roaming. This would not fairly compensate investors for their prior network investments, and could threaten future capital expenditure, but it may make sense for the mobile network operator to keep running existing masts in such circumstances.

Keeping the least used mast viable, in a world where investors are compensated for their sunk investments, would mean charging a competitor a vast £200 per minute to use it. The required rate falls if only operating costs are recovered, but only to £132 per minute. This is clearly an unfeasibly high access charge, so it is likely that mobile network operators will shut down multiple unprofitable masts.

Coverage obligations on the mobile network operators may restrict the number of masts that would be closed. Although there are no longer 2G

[110] See: http://www.btplc.com/news/Articles/ShowArticle.cfm?ArticleID=D4CF5838-C8C2-4374-BAB7-4F8A9FC4C183 [accessed 18 November 2014].

[111] Nijkamp and Rienstra explain how between 1830 and 1860 private companies expanded the Dutch railway network. However, the Dutch government obliged these companies to allow third parties to use their infrastructure for a fee and it capped the maximum tariffs which companies could charge. As a result, only the most profitable lines were built and coverage was restricted. In the case of mobile telephony these would be those in exactly the areas which the government currently identifies as suffering from unacceptably poor service; Peter Nijkamp and Sytze Rienstra, 'Lessons from private financing of transport infrastructure: Dutch infrastructure in the 19th century and European projects in the 20th century', *Revue economicque*, Volume 48, Number 2, 1997. pp231-246.

coverage obligations, there are coverage obligations for 3G and 4G technology.[112] It would not make sense for mobile network operators to offer either 3G or 4G coverage but not 2G, since the additional operating costs would be minimal. As such, we believe that they would choose to offer coverage to 98.0 per cent of the population in the United Kingdom. At this level of coverage 3.8 per cent of masts would not be covering their operating costs under national roaming unless mobile network operators could charge competitors 4.4 pence per minute to use it. (This would be 8.3 per cent of masts and would require charging 8.8 pence per minute if investors were able to recover capital costs.) To put some context around this, the required access charge is over sixteen times larger than the rate network operators effectively 'pay' for access to their own network.[113] This suggests that a policy of national roaming would place great stress on the industry. (See Figure 42.)

[112] Emma Downing, 'Subject: UK Broadband – Policy and Coverage', *House of Commons Library*, Standard Note: SN05970, 2011. O2 has to provide 4G coverage to 98 per cent of the population by 2017. The remaining mobile network operators have volunteered to match that commitment.

[113] We estimate this at 0.27 pence per minute based on our analysis of data provided by EE.

Figure 42: Rate of access charge required to keep masts viable

Proportion of masts that are viable (per cent)	Access charge to cover mast operating costs (pence per minute)	Access charge to cover capital and operating costs (per minute)	Estimated United Kingdom population coverage (per cent)
100.0	19,977.8	13,187.3	98.8
99.5	64.5	41.3	98.7
99.0	31.5	19.4	98.6
98.5	20.0	11.8	98.4
98.0	15.0	8.5	98.3
97.5	11.5	6.2	98.2
97.0	9.0	4.6	98.0
96.8	8.8	4.4	98.0
96.5	8.4	3.5	97.9
96.0	6.0	2.6	97.8
95.5	5.0	1.9	97.6
95.0	4.7	1.6	97.5
94.5	4.3	1.2	97.4
94.0	3.9	0.8	97.2
93.5	3.5	0.4	97.1
93.0	3.0	0.0	97.0
92.5	2.7	0.0	96.8
92.0	2.4	0.0	96.7
91.5	2.0	0.0	96.5
91.0	1.6	0.0	96.4
90.5	1.3	0.0	96.2
90.0	0.9	0.0	96.1
89.5	0.5	0.0	95.9
89.0	0.2	0.0	95.8
88.5	0.0	0.0	95.6

Source: Capital Economics and EE. Note: highlighted in green is the 98.0 per cent coverage obligation for 4G. We assume that it take the same number of masts to provide 98.0 per cent population coverage on both 2G and 4G technologies.

Implementing national roaming and enforcing the shared use of one mobile network operator's prior investments may have the unintended consequence of deterring future capital expenditure by the industry. A firm's decision as to whether or not to invest in infrastructure will depend on the return on that investment. As this return is only known after it has been completed or *ex-post*, a prior or *ex-ante* assessment of the expected return has to be made based on its likely rate and certainty. It is only if investors believe it will pay off that they choose to invest and policy decisions that affect that belief will affect investment.[114]

The expectation that government policy effecting an investment can change after that investment is made is known as 'regulatory uncertainty' or

[114] Federal Communications Commission, *The Broadband Availability Gap,* (FCC Omnibus Broadband Initiative (OBI) Technical Paper No. 1), 2010; Perloff, *Microeconomics*, pp592-595; Katz & Rosen, *Microeconomics*, pp361-362; Pindyck & Rubinfeld, *Microeconomics*, pp554-557.

'regulatory opportunism'.[115] By depressing these *ex-ante* assessments, it lowers expected returns on investment for the mobile network operators and reduces capital expenditure.[116] For example, research has found that regulatory uncertainty in the renewable energy industry in the United States has retarded investment and defeated policy goals.[117] Other research has found that uncertainty over whether the future regulatory regime will be 'strong' or 'relaxed' has reduced investment on broadband infrastructure in the United States relative to the European Union.[118]

Although the 2G networks have been around since 1992 and the network operators are likely to have recovered the costs of their investment, this repeated regulating and reregulating is a threat to future investment and the rollout of 4G in particular. Together with the proposal to increase annual license fees, mobile network operators have no certainty that the proceeds from investments they make will accrue to them and not be shared with their rivals or that they won't be taken away by government. Not only does this threaten future capital expenditure but it could also serve to dramatically reduce the proceeds the government takes from future licence auctions, such as for 5G technologies.

In today's competitive environment, there are strong incentives to invest in a marginal mast even if its own incremental finances do not stack up. With the current facility-based competition, mobile network providers must construct their own network facilities if they want to expand their reach. Under national roaming there would be no logic for a mobile network operator to invest in marginal masts. Mobile network operators would have to be incentivised through an access fee payment to continue operating these masts or invest in

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[115] Organisation for Economic Cooperation and Development, *OECD Communication outlook 2013* (Organisation for Economic Cooperation and Development, Paris) 2013. p9.

[116] Kim *et al,* for example, have examined the effect of allowing or requiring mobile network operators to allow mobile operators which do not possess their own frequency spectrum and infrastructure, which they term 'MVNOs', to access theirs.[116] Using firm level data for 58 mobile network operators in 21 Organisation for Economic Cooperation and Development countries for 2000 to 2008, they find that "mandated provision of access is related to lower investment intensity of MNOs, while voluntary access provision has no effect."; Jihwan Kim, Yunhee Kim, Noel Gaston, Romain Lestage, Yeonbae Kim, and David Flacher, 'Access regulation and infrastructure investment in the mobile telecommunications industry', *Telecommunications Policy*, Volume 35, 2011. pp907-919.

[117] Kira Fabrizio, 'The effect of regulatory certainty on investment: evidence from renewable energy generation', *Journal of Law, Economics, and Organization*, Volume 29, Number 4, 2012. pp765-798.

[118] George S. Ford and Lawrence J. Spiwak, *What is the effect of regulation on broadband investment? Regulatory certainty and the expectation of returns* (Phoenix Center for Advanced Legal & Economic Public Policy Studies, Washington DC), 2012.

new ones. However, just to meet existing coverage obligations, the access charge must be set at an unrealistically high level of at least 4.4 pence per minute under national roaming, and this is just to break even.

7.4 The overall impact

At face value national roaming appears to offer a simple solution to further improving rural mobile coverage. We estimate that expanded coverage could lead to an additional 72.5 million minutes or 0.6 per cent of voice traffic each month, with annual consumer surplus gains of between £136 and £175 million. Nevertheless, achieving this is not without significant costs to consumers, the industry and the wider economy: the potential loss of data services 1.4 to 1.8 times a week per data user could wipe out the consumer surplus benefits; the industry would have to commit almost £3 billion over a five year period, which could delay the rollout of 4G by eighteen to 24 months; and ongoing support for national roaming could reduce capital expenditure by £400 million each year, lowering United Kingdom gross domestic product by 0.1 to 0.2 per cent. The Department for Culture, Media and Sport's own cost benefit analysis suggest that this policy will yield a disbenefit.[119]

[119] The 'Impact Assessment' for Department for Culture, Media and Sport, *Tackling Partial Not-Spots in Mobile Phone Coverage* (Department for Culture, Media and Sport, London), 2014.

APPENDIX: THE CONCEPT OF 'FREE RIDING'

'Free riding' is a concept in economics that describes a situation where someone can receive the benefits of something without paying any of the costs of providing it. National roaming would allow users of networks which haven't invested in mobile telephony infrastructure to use the infrastructure of those which have. By reducing the return to the investor, this free riding in mobile telephony infrastructure could lead to reduced investment.

We use 'game theory' to illustrate this concept with a stylised example. Game theory allows us to analyse different investment strategies where the outcome of a participant's strategy depends on the strategy of another participant. Our participants in this 'game' are two mobile network operators. We examine the payoffs available to them from following given strategies as they decide to invest or not in new infrastructure.

Figure 43 illustrates the benefits to operators from investing or not investing in a marginal mast. It is a matrix depicting the stylised payoffs to two mobile network operators, 'A' and 'B', considering two strategies, 'invest' or 'don't invest'. The payoffs to network 'A' are the numbers on the left hand side in each box and the payoffs to network 'B' are the numbers on the right hand side of each box.

Figure 43: Current investment payoff matrix for two mobile network operators in a marginally unprofitable area

		Mobile network operator 'B'	
		Invests	Doesn't invest
Mobile network operator 'A'	Invests	0.4,0.4	>2,2
	Doesn't invest	2,>2	2,2

Source: Capital Economics. Notes: dominant strategy is shaded in green. The costs of building the infrastructure are assumed to be 1 and the payoff from operating the mast is 2.8. The payoff for investing when the other network doesn't is italicised to reflect that it is a notional value depending on the network's adoption of coverage as a unique selling point.

Both mobile network operators know that if they do not invest in the infrastructure they can earn a risk free return on a different investment (bottom right). Each knows that if they both invest then they split the payoff equally between them (top left). However, 'A' knows that if it invests and 'B' doesn't then all the benefits of investment will accrue to it (top right). Conversely, 'B' knows that if it invests and 'A' doesn't that all the benefits of investment will accrue to it (bottom left). While, in terms of the individual mast, there is no payoff for an infrastructure investor which is higher than the return offered by a risk free investment, there is some value in terms of the network which makes the payoff greater than not investing. Sequentially,

once a network has invested there is no incentive for the other to follow. Once in either the top right or bottom left boxes, a decision to invest by the other network would move the payoff to the top left making both networks worse off.

National roaming would, however, remove the competitive advantage of offering extra coverage and would remove the incentive for a mobile network operator to invest in unprofitable areas. (See Figure 44.)

Figure 44: Investment payoff matrix for two mobile network operators in a marginally unprofitable area under national roaming

		Mobile network operator 'B'	
		Invests	Doesn't invest
Mobile network operator 'A'	Invests	0.4,0.4	0.4,3.4
	Doesn't invest	3.4,0.4	2,2

Source: Capital Economics. Note: dominant strategy shaded in green.

As before, both mobile network operators know that if they do not invest in the infrastructure they can earn a lower but risk free return on a different investment (bottom right). Again, both providers know that if they both invest then they split the payoff equally between them (top left).

But under national roaming 'A' now knows that if it invests in infrastructure and 'B' doesn't (top right) the users from 'B' will be able to 'free ride' on its infrastructure. The payoff will be split between 'A' and 'B' but the cost will be borne solely by 'A'. Conversely, 'B' knows the same will happen if it invests and 'A's users 'free ride' (bottom left). In the expectation of free-riding of the other network's investment each network could hold off from investing itself, leading to the outcome where neither network invests (bottom right).

If a mobile network operator can sell access to their network under national roaming, as they do with mobile virtual network operators currently, then investment might not be diminished to the same degree. But access charges would have to reflect the actual costs to the investing mobile network operator for national roaming to not restrain investment. If they did not, it is probable that national roaming would have exactly the opposite effect to that the government intends.[120] Access charges would need to exist such that the

[120] Nijkamp and Rienstra explain how between 1830 and 1860 private companies expanded the Dutch railway network. However, the Dutch government obliged these companies to allow third parties to use their infrastructure for a fee and it capped the maximum tariffs which companies could charge. As a result, only the most profitable lines were built and coverage was restricted. In the case of mobile telephony these would be those in exactly the areas which the government currently identifies as suffering from unacceptably poor service; Peter Nijkamp and Sytze Rienstra, 'Lessons from private financing of transport infrastructure: Dutch infrastructure in the 19th

payoff matrix in Figure 44 was altered to the payoff matrix in Figure 45. Here a mobile network operator receives a larger payoff from investing than not investing.

Figure 45: Investment payoff matrix for two mobile network operators in a marginally unprofitable area under national roaming with access charges

		Mobile network operator 'B'	
		Invests	Doesn't invest
Mobile network operator 'A'	Invests	0.4,0.4	2.1,1.7
	Doesn't invest	1.7,2.1	2,2

Source: Capital Economics. Note: dominant strategy shaded in green.

century and European projects in the 20th century', *Revue economicque*, Volume 48, Number 2, 1997. pp231-246.

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