Mobile Broadband and the UK Economy

30 April 2012

CAPITAL ECONOMICS

Rolling out 4G LTE mobile broadband

Improving connectivity — stimulating the economy

- Mobile now the dominant telephone technology.
- New tech puts mobile broadband on par with fixed.
- £5½bn investment when the economy needs it most.
- Superfast mobile broadband where fixed line can't go.
- Platform for innovation and m-commerce.
- Efficiencies created by 4G LTE could add ½% to GDP.

This report has been commissioned by Everything Everywhere however the views expressed remain those of Capital Economics and are not necessarily shared by Everything Everywhere. The report is based on analysis by Capital Economics of information available in the public domain. Where additional information has been provided by Everything Everywhere it is clearly stated in the report.

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Contents

1 Introduction and key findings

Capital Economics has been commissioned by Everything Everywhere to provide an independent, realistic and hard-headed assessment of the potential economic benefits of investment in '4G Long Term Evolution (LTE)' mobile broadband technology to the United Kingdom.

Once a 'yuppie' fashion accessory, **mobile has grown to be the dominant telephone technology**, and especially important for business. It has also become a significant industry in its own right. The network operators employ around 35,000 people directly, which is more than the pharmaceutical sector. This rises to 56,000 when taking into account the jobs supported in their supply chains. They turn over annual revenues of nearly £20 billion and contribute £4 billion per annum to national economic output. (See section 2.)

Subject to the acquisition and licensing of appropriate spectrum, the network operators are planning to invest substantially to improve mobile broadband provision.

Current mobile broadband services are not competitive on quality with their fixed line alternatives and, in some respects, resemble something closer to 'dial up' than broadband. By upgrading to 4G LTE, which is the successor to currently deployed 3G and 3.5G technologies, the **mobile network operators will have the potential to provide internet connectivity on a par with fibre optic broadband** offered by their fixed line competitors. (See section 4.)

We estimate that an **investment of around £5½ billion will be made by the mobile telephone network operators to deploy 4G LTE** (excluding the cost of acquiring the spectrum) and full national roll out will be phased over the next 3-4 years provided that the allocation of spectrum can be expedited. (See section 3.)

This is a substantial capital expenditure programme by any standard — which could support over 125,000 jobs for one year. It is equivalent to almost five per cent of the total amount invested by all private sector businesses in 2010, and is not far off the £7.3 billion being spent by the Olympic Delivery Authority on venues and infrastructure for the 2012 games. **The timing of this spending is opportune for the wider economy.** Investment slumped during the recession and has recovered little of its losses since. A capital expenditure programme of this size will register as a meaningful boost to business investment nationally, and will come at a time when the economy is operating below full capacity. (See section 3.)

Once deployed, 4G LTE coverage will extend beyond that which will be connected to BT's fixed line fibre optic network. **Up to a fifth of the population may get access to superfast broadband through mobile who wouldn't otherwise have had access via fixed line.** Indeed, it is likely that 4G LTE will also cover some communities that are either outside BT's standard ADSL broadband network or who receive poor speeds from ADSL. **Up to five per cent of the population may be able to access broadband via mobile who would otherwise have had no or poor broadband facilities.** (See section 5.)

The improvement in speed, reliability and performance of the new technology will be valued by consumers. Willingness to pay research conducted in the United States suggests that the net benefits to consumers of internet access rise by between 33 and 200 per cent as they move from dial up to broadband speeds; moving from broadband to superfast technology adds at least a further 30 per cent. As such, our calculations suggest that **4G LTE in the United Kingdom will increase consumer and producer surpluses by something in the order of £0.9-1.4 billion annually** — for existing users alone. (See section 4.)

In this report, we focus on the impact of 4G LTE technology alone, which provides only enhancements to data transfer. Aside from 'Voice over Internet Protocol' (VoIP), 4G LTE itself does not improve the traditional voice services. However, given the scale of investment involved and the extent of works to be conducted across the network of base stations, it is likely that the **mobile network operators will use the opportunity to repair, maintain and upgrade their existing voice equipment — thus providing benefits to telephony as well as data users.** (See section 7.)

The use of the new data technology will have an impact on macroeconomic performance through productivity improvements. (See section 2.)

First, 4G LTE make certain activities — such as communicating, finding information, comparing prices, getting directions, arranging diaries, making transactions, remotely monitoring — easier or cheaper to do. Second, new technologies, like mobile broadband, can be catalysts for further innovation elsewhere — stimulating new products, services and even business models. 4G LTE will be particularly important to future innovation and development of m-commerce and cloud computing, as well as the 'apps' industry. (See section 6.) Third, the nature of communications technologies means that their benefits accelerate as more people use them.

We have reviewed relevant academic and professional literature in order to **assess the potential macroeconomic benefits that may arise from the use of 4G LTE technology**.

There is a substantial body of research that attempts to evaluate the economic benefits of technology, including information and communication technology generally, and mobile telephony, the internet and broadband specifically — and there are also some researchers who have begun considering mobile broadband or superfast broadband. However, **it can be difficult to draw reliable conclusions from this material** because either: there are wide variations in the results from different studies; or the research identifies a correlation between the technology and economic performance, but fails to establish causality. We have avoided using such material in the computation of 4G LTE's impact as we believe the results would be unrealistically large. (See section 4.)

Instead, we have taken a more cautious approach to quantifying benefits and considered how 4G LTE might improve efficiency. For example, **with 4G LTE, employees that already use mobile broadband will save 37 million hours of time each year that might otherwise have been spent watching their devices download data over 2G, 3G or 3.5G technologies.**

On the basis of what appear to us to be conservative assumptions, **we anticipate that the eventual boost from 4G LTE to national GDP will be in the order of a ½ per cent — although it will take time to feed through entirely. In today's terms, that is equivalent to £75 billion over a decade.** The full impact will be felt once the technology is fully deployed, adopted by users and user behaviour has adapted to realise the potential opportunities. This could be expected to take until the end of the decade.

2 Importance of the mobile telephone industry

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

Our key findings are:

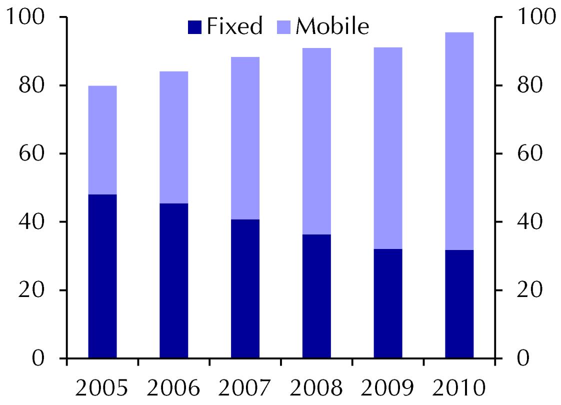
- **Mobile has grown to be the dominant telephone technology, and is especially important for businesses**
- **It is a significant industry in its own right with network operators alone employing directly around 35,000 people, turning over annual revenues of nearly £20 billion and contributing £4 billion per annum to national economic output**
- **In addition, the industry stimulates further activity in its supply chain so that, overall, 56,000 jobs are supported**
- **The industry creates value for consumers and businesses alike. It generates consumer and producer surpluses in the order of £850 per annum for every mobile telephone using adult**
- **The use of mobile telephones stimulates growth in the economy at large by increasing mobility, improving productivity and offering new opportunities for innovation**
- **Although some studies suggest an even higher figure, mobile telephony is said to have added around a half of a percentage point to GDP each year over the past two decades**

2.1 The growing role of mobile telephony

Seen commonly as a mere 'yuppie' fashion statement in the 1980s, the mobile telephone has become a vital part of everyday life for over 46 million adults in the United Kingdom[1] — and an essential tool for many businesses.

In the half-decade to 2010, the volume of voice calls originating from mobile telephones rose by an average of twelve per cent per annum.[2] Over the same period, the volume of calls made on the traditional 'fixed line' telephone networks fell by 4½ per cent annually. In 2010, 125 billion minutes of calls were made on mobile telephones — while over 2,000 text messages were sent for every man, woman and child in the country.[3] In that year, the fixed line network carried only four billion more minutes of calls than the mobile networks[4]; **by now it is likely that 'cellular' has overtaken fixed line to become the dominant telephone technology**.

FIGURE 1: BUSINESS VOICE CALL VOLUMES



Sources — Ofcom, Communications Market Report 2011 (Ofcom, London),2011.

The mobile telephone is now firmly established as a business tool. Over two thirds of the 95 billion minutes of calls made by businesses in 2010 were made on a mobile telephone; business voice usage of the cellular networks has grown by an annual average of fifteen per cent from 2005 to 2010. (See Figure 1.)

Moreover, almost one quarter of employees who use the internet for their work are now being provided with 3G mobile devices for internet access and data connectivity. (See Figure 2.)

FIGURE 2: EMPLOYEES USING COMPUTERS AND THE INTERNET FOR THEIR WORK AT LEAST ONCE A WEEK, BY SIZE OF BUSINESS

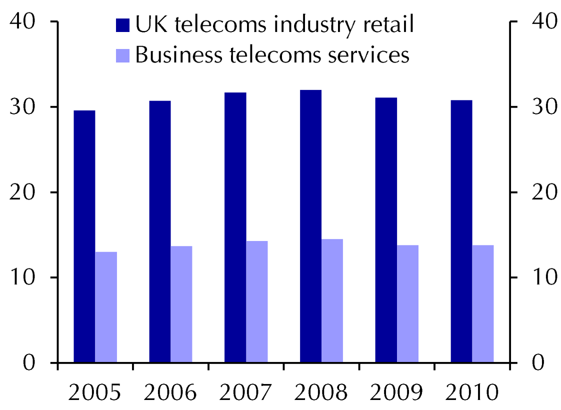
million employees, 2010	Businesses by number of employees				
	10-49	50-249	250-999	1000+	All
Used computers	1.5	1.5	1.2	3.3	7.5
Of those employees with computers:					
Used computers with Internet access	1.3	1.3	1.0	2.5	6.2
Used computers without Internet access	0.1	0.2	0.2	0.8	1.3
Provided with a 3G portable device for accessing the Internet	0.3	0.3	0.2	0.5	1.4
As proportion of employees using computer with Internet access	23%	23%	20%	20%	23%

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

2.2 Increasing significance of the mobile telephony industry

The industry behind the device has grown rapidly and is, today, one of the nation's largest and most vibrant economic sectors. According to the latest Ofcom data, retail revenues from mobile voice and data services account for almost half of the telecommunications industry's turnover — with mobile voice and access revenues outstripping their fixed line equivalents by over ten per cent. Looking at the industry's revenues from its business customers alone, the dominance of mobile is starker still — with cellular revenues double those of fixed line voice. (See Figure 3.)

FIGURE 3: REVENUES FROM THE TELECOMS INDUSTRY (£ BILLIONS)



Sources — Ofcom, *Communications Market Report 2011*, Ofcom, London. 2011.

Recognising the changing importance of the communication sector generally, and the mobile telephony industry especially, the government's statistical agency, the Office for National Statistics, now collates and reports economic information specifically relating to the sector. Part of a new telecommunications 'division' within the 2007 revision of their *Standard Industrial Classification*[5], 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 ONS recognise the industry in their classification, the data collected for it do not yet appear to be robust. Data for 2010 from the ONS's business register and employment survey suggest that the mobile telephone industry employed 11,000 people in Great Britain, compared with 5,000 in 'wired', 8,000 in 'satellite' and 180,000 in 'other' telecommunications activities.[6] Everything Everywhere alone has almost 15,000 employees, so these official data are suspicious. Likewise, data extracted from the official annual survey of businesses suggest that the total revenues generated by 'wireless telecommunications activities' was £1.2 billion in 2010[7]; Telefónica UK Limited, which trades under the O2 brand, turned over more than £6 billion alone then.

2.3 Economic activity and jobs

Given the lack of credible official data, we have developed our own measures of the scale of the industry.

We have estimated the current employment in and turnover of the mobile telephone industry based on the most recent published accounts of the four networks.[8] However, 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 we believe it to be conservative assumption.

Overall, we estimate that the mobile telephone industry employs directly around 35,000 people (or 0.13 per cent of all jobs nationally[9]), turns over annual revenues of nearly £20 billion and generates over £4 billion of gross value added, equivalent to 0.3 per cent of all economic activity[10].

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

In terms of employment, the industry is around the same size as the drinks manufacturing industry and the 'holiday and short stay accommodation' sector. It is bigger than ship and boat building (with 31,500 jobs), clothes manufacturing (31,700) and pharmaceutical manufacturing (34,200).[11] Its direct contribution to national gross value added is larger than the transport infrastructure construction, mainline rail and airline sectors — which added value of £2.6, 3.7 and 3.4 billion respectively to the national economy in 2010.[12]

We have also estimated the distribution of the mobile telephone industry's activity across the regions of the United Kingdom based upon the ONS's data[13] plus information from Everything Everywhere on their operations. (See Figure 4.) This shows that the industry employs substantial numbers in every region of the country.

FIGURE 4: MEASURES OF THE MOBILE TELEPHONE NETWORK OPERATOR'S ECONOMIC ACTIVITY

United Kingdom, 2010	Jobs	Turnover	GVA
	Number	(£ million)	(£ million)
North East	2,400	1,400	300
North West	3,300	1,900	400
Yorkshire and The Humber	2,700	1,500	300
East Midlands	1,600	900	200
West Midlands	2,200	1,200	300
East	2,300	1,300	300
London	6,400	3,600	700
South East	5,900	3,300	700
South West	3,100	1,700	400
Wales	1,100	600	100
Scotland	3,100	1,700	400
Northern Ireland	800	400	100
Total	**34,850**	**19,610**	**4,040**

Sources — Capital Economics estimates using a variety of sources as described.

Our estimates of the industry's overall scale appear comparable to or conservative against others produced in the past few years. CEBR, in their 2004 study for O2, estimated operators' service revenues at £13.8 billion and direct employment at 37,164 for 2003 — which is broadly consistent with our estimates given inflation, volumes growth and productivity improvements in the intervening six years.[14] Estimates made in 2006 by Europe Economics, on the other hand, are much higher. They reported total turnover for the 'cellular' sector at £37.5 billion in 2006 with employment at almost 80,000 (although presumably on a wider definition of the industry than ours, which considers the network operators only).[15]

2.4 Supply chain multiplier effects

In addition to the direct activities of the mobile telephone companies themselves, the industry also stimulates further economic activity in its supporting supply chain.

We have made estimates of the scale of activity upstream of the mobile telephone industry in the supply chain. Our estimates are based upon information we have received from Everything Everywhere about the scale and nature of their purchases from suppliers; from this we have generalised for the industry as a whole. In addition, we have used the ONS's 'Supply and Use Tables' to simulate how much the suppliers to the mobile telephone industry themselves will purchase from their suppliers, and so on.[16]

In total, we estimate that almost 56,000 jobs are either directly employed by the mobile telephone network operators or are supported by their purchases from their suppliers.[17]

Our estimates of the jobs multiplier for the industry lie between others' differing calculations. For example, 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[18] — whereas Europe Economics' estimate of 103,627 people employed directly in 2004 by the radio spectrum using industries[19] rises to 240,275 after multiplier effects.[20]

FIGURE 5: DIRECT AND INDIRECT IMPACTS OF THE MOBILE TELEPHONE INDUSTRY

United Kingdom, 2010	Direct	Supply chain	Total
Jobs	34,848	20,944	55,792
Turnover (£ m)	19,610	11,256	30,866

Sources — Capital Economics estimates using a variety of sources as described.

2.5 Consumer and producer surpluses

Behind the growth in revenues and the increasing economic importance of the mobile telephone industry is a product and service that is valued by its users.

Mobile telephony generates significant value for consumers and producers alike. In 2006, Ofcom commissioned Europe Economics to evaluate the use of radio spectrum in the United Kingdom, including use by the cellular networks.[21] 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[22], 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, which is the amount revenue received by the networks over and above the economic cost of the services they provided

We have not attempted to replicate this work using today's data. However, Ofcom have attempted to up-rate the Europe Economics numbers for 2006 to take into account the growth in connections and inflation. They believe the value of the consumer surplus is now £24 billion.[23]

This could be an overly cautious estimate and may not fully reflect the changing willingness to pay of users. As an alternative approach we have calculated an up-rated value that takes the Europe Economics numbers, puts them in 2011 prices and increases them to reflect the growth in the volume of mobile telephony usage. On this basis, **the combined value of the mobile telephone industry's consumer and producer surpluses could be around £40 billion today — which is equivalent to £850 per annum for every mobile telephone using adult.**

2.6 Productivity and growth

The use of mobile telephony has broader economic significance by:

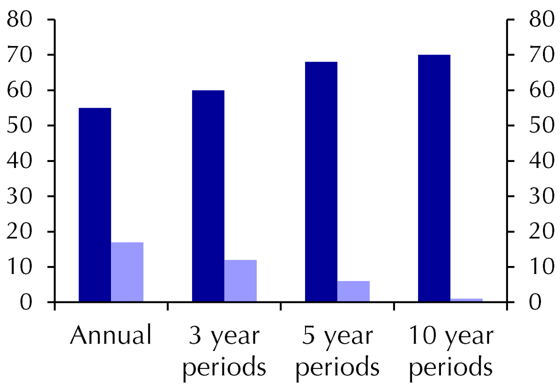
- permitting greater and easier communication between consumers, between consumers and businesses, and between businesses
- facilitating greater mobility for consumers and businesses alike
- improving the efficient use of time for consumers and businesses alike
- increasing rates of productivity
- stimulating 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, show 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 6)

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 organizational change that ICT makes possible.[24] Since 1995, ICT 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.[25]

FIGURE 6: RELATIONSHIP BETWEEN EMPLOYMENT AND PRODUCTIVITY LEVELS OVER TIME (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, 2011*

An academic study from 2001 found that around one-third of growth across 21 OECD countries over the period 1971–90 can be attributed directly or indirectly to voice telecommunications technology.[26]

There is also a developing literature on the macroeconomic significance of mobile telephony specifically (although much of it is focussed on the impact in developing countries).

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.[27] 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, the consultancy Ovum found that, in 2004, **mobile voice services generated productivity gains to the United States economy worth $157 billion per year.[28] This is the equivalent of around 1.3 per cent of gross domestic product.[29]**

3 4G mobile broadband technology and its rollout

In this section, we introduce the next generation of mobile broadband technology, 4G LTE, and consider the scale and impact of the proposed investment by the network operators in it.

Our key findings are:

- **4G LTE is the successor to currently deployed 3G and 3.5G technologies, and offers substantial improvements to mobile data services**
- **The roll out of 4G LTE will require investment by the mobile telephone network operators of around £5½ billion (excluding the cost of acquiring the spectrum)**
- **Depending on the level of imports required to service the roll out, the initial capital expenditure programme alone is expected to support in the United Kingdom at least the equivalent of 85,000 jobs for one year and, probably, more like 125,000**
- **A £5½ billion programme will register as a meaningful boost to business investment nationally, and will come at a time when the economy is operating well below full capacity and there is a dearth of private sector investment**

3.1 What is 4G LTE?

4G Long Term Evolution is the successor mobile data transmission technology to the 3G and 3.5G systems currently deployed by the cellular networks in the United Kingdom.

4G LTE offers significant improvements to mobile internet access: higher peak download speeds; greater overall capacity through more efficient use of the radio spectrum; and more rapid response times (or, what is described technically as, reduced latency). Such a technology should enhance the customer experience of mobile internet and provide a platform for greater bandwidth higher value online services — although it is unclear yet what precise services will be delivered through mobile and it is likely that the achievable speeds on mobile will be lower than the best available on fixed line fibre optic. (See Figure 7.)

According to research commissioned by Ofcom, 4G LTE could be delivering peak download rates that are as good if not better than fixed line services by 2013.[30] On neither system are users likely to achieve peak download speeds, but the Ofcom report suggests that real life rates on 4G should be significantly higher than those achieved on the networks today or after future improvements to 3.5G technologies.

FIGURE 7: 4G NETWORK CAPABILITIES COMPARED TO PREDECESSOR WIRELESS TECHNOLOGIES

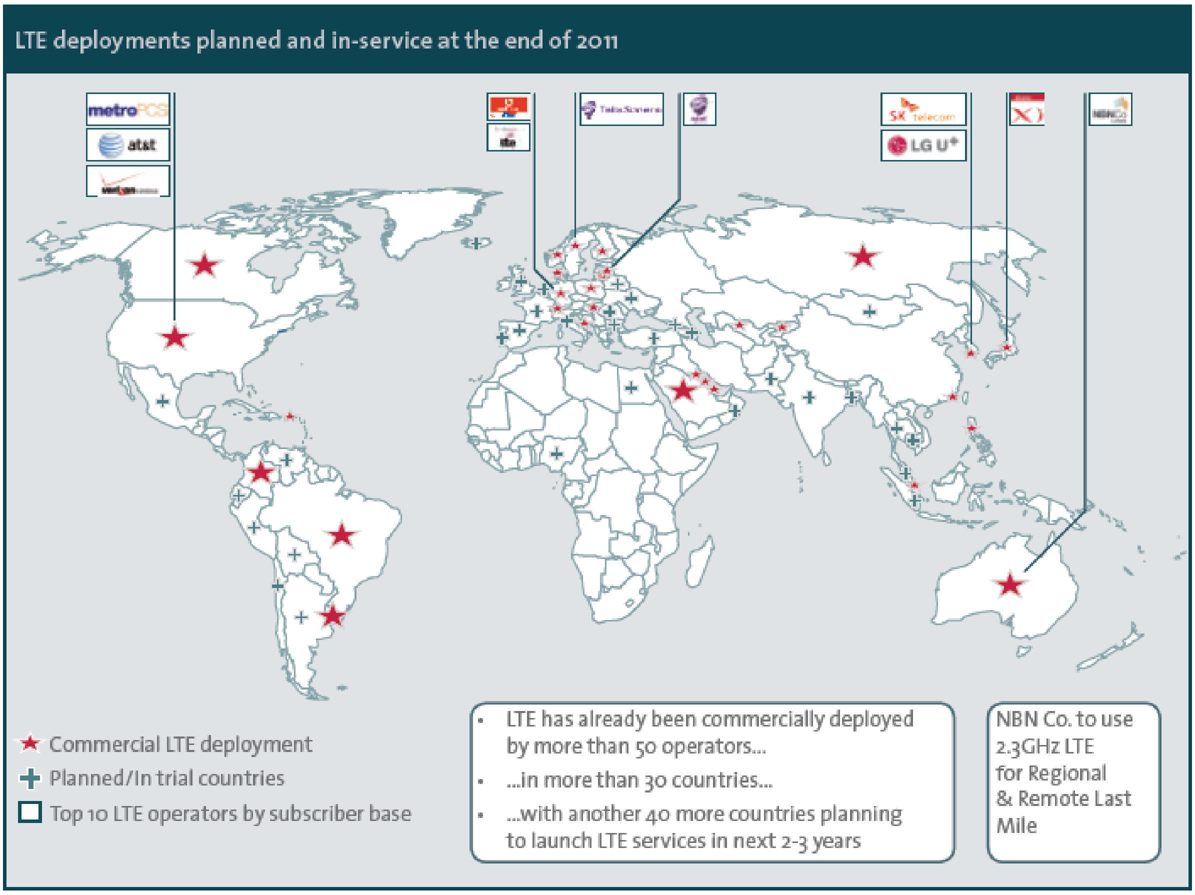
	2.5 - EDGE	3G - UMTS/HSPA	4G - LTE/WiMax
Device type	• Basic handset	• Smartphone/tablet • Air card •Some sensors, appliances, etc	• All personal electronics: phone, TV, tablet, camera, automobile • Widespread sensors, machines, kitchen appliances etc
Device computing and storage	• Limited physical memory	• 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*, 2011.

When it comes to roll out of LTE, the United Kingdom is somewhat off the international pace. The technology has already been deployed commercially by more than 50 operators in over 30 countries. (See Figure 8.)

Once rolled out, **the take up of 4G LTE among users shouldn't be limited by the availability of devices that can use the new technology**. There are already 42 commercially available devices, including chipsets, dongles, phones, tablets and routers, for the 800 MHz band; 36 of which also support other frequency bands including 1800 MHz and 2600 MHz.[31]

FIGURE 8: MAP OF LTE DEPLOYMENTS PLANNED AND IN-SERVICE AT THE END OF 2011



Source: Press reports, LTE Maps, operator websites.

Source — Dominic Arena, Cheryl Lim and Ishan Singhal, *LTE - Learnings from first movers* (Value Partners, Singapore), 2012.

3.2 Scale of investment

The deployment of 4G LTE by the mobile telephone networks will be one the most significant private sector investments in the coming few years.

Given understandable commercial sensitivities, there is little detailed information in the public domain about the network operators' investment plans. However, we have been given access to some of Everything Everywhere's data while partial costings can also be deduced from other reports.[32]

FIGURE 9: INVESTMENT NEEDED BY MOBILE NETWORKS TO ROLL OUT 4G LTE

	Capital expenditure
	(£ million)
Base station equipment	2,300
Installation	1,900
Software and network upgrades	1,400
Total	**5,600**

Sources — Capital Economics estimates using a variety of sources as described.

We estimate that the cost to deploy the equipment to support 4G LTE in the United Kingdom will be in the order of £5½ billion — most likely, spread over three or four years to roll out fully nationally. (See Figure 9.)

This covers the cost of equipment and its installation at base stations and at network facilities, and includes software.

This is a significant investment programme. To give some comparators with which to gauge the scale:

- The total budget for the organisation responsible for building the 2012 games' venues, infrastructure and the Olympic Park, the Olympic Delivery Authority, is £7.3 billion[33]
- 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[34]
- The cost of building a new nuclear power plant is in the order of £4-6 billion[35]
- Government's total procurement of capital items for the health service in 2009/10 was £6.1 billion; it was £6.6 billion for education and £4.1 billion for defence[36] (although, of course, these are values for a single year, whereas the 4G LTE investment is likely to be spread over three or four years)

Indeed, a £5½ billion investment programme will register as a meaningful boost to business investment nationally. Across the United Kingdom economy as a whole, including the public and private sectors, gross fixed capital formation totalled £217 billion in 2010 (in 2010 prices),[37] while total private sector business investment in 2010 was £117.8 billion. Of this, investment by manufacturing businesses accounted for £13.0 billion, while the entire 'information and communication' sector invested £12.8 billion (all in 2010 prices).[38]

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 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.

3.3 Jobs and multiplier effects

An investment of this scale will support a large number of jobs and generate knock-on economic activity through the supply chain.

There have been a number of studies attempting to estimate the so-called multiplier effects from investment in fixed line broadband infrastructure. For example, a team from the London School of Economics and the Information Technology and Innovation Foundation estimate that a £5 billion (2009 prices) investment in fixed line broadband in the United Kingdom could support 280,000 jobs, of which 94,000 would be in businesses with under 250 employees.[39] (See Figure 10)

Meanwhile, a joint commission of United Nations' agencies recently cited research from the Columbia Business School suggesting that, for each $1 billion (2009 prices) invested in fixed-line broadband network construction, 10,700 jobs have been created directly or in the supply chain in the United States, 11,000 in Switzerland, 8,500 in Germany, and 28,300 in the United Kingdom.[40] The study also calculates that for every job directly created by broadband investment in the United Kingdom, another 1.78 jobs are generated in the supply chain.

There are also now emerging studies that attempt to quantify the potential impact of investment in 4G mobile infrastructure.

A report by the accountancy-based consultancy, Deloitte, suggests that a 'baseline' investment of $25 billion in the United States' 4G infrastructure could boost GDP by $73 billion and employment by 371,000.[41]

We have simulated the impact of a £5½ billion investment in 4G LTE infrastructure using the ONS's input-output tables. The impact of investment on the United Kingdom will depend upon how much of the initial investment (and then how much of suppliers' procurement) is spent on supplies and services sourced from foreign companies, and hence will leak money out of this country through imports.

If we take the average leakage rate for the whole of the telecommunications industry as estimated by the Office for National Statistics for 2005 (latest available data), we find that **over 85,000 jobs would be supported in the United Kingdom for one year by the 4G LTE investment on this conservative assumption.**

However, we think there are good reasons to believe that, in the current economic climate, the network operators will be able to and will want to source more domestically. On a reasonable assumption of an increase in domestic purchases of twenty per cent against 2005 ratios, we estimate that the **investment required to roll out the new technology will more likely support 125,000 jobs in the country, and stimulate £8 billion of purchases in the upstream supply chain.**

It is often argued, rather acutely, that calculations of jobs created by investments, and their multiplier effects, are partial and potentially misleading analyses. The argument goes that an investment doesn't necessarily create jobs but, rather, diverts resource from whatever else it would have been doing into the newly funded activity. The net benefit of an investment then is its gross benefits minus that which has been foregone through the diversion of resources. Especially in times of low unemployment and when rates of output are close to full capacity, these net impacts can be small. Indeed, they can even be negative if, for example, government subsidies distort decisions or if market valuations fail to reflect underlying economic value.

FIGURE 10: ESTIMATE OF UK JOBS CREATED OR RETAINED FOR ONE YEAR BY A £5 BILLION INVESTMENT IN FIXED-LINE BROADBAND

	Total jobs	Small business jobs
Direct	76,500	22,500
Indirect and induced	134,500	37,000
Network effect	69,500	34,500
Total jobs	280,500	94,000

Source — Jonathan Liebenau *et al*, *The UK's Digital Road to Recovery* (LSE Enterprise ltd. and The Information Technology and Innovation Foundation, London), 2009.

FIGURE 11: INCREMENTAL IMPACT OF 4G INVESTMENT FOR THE PERIOD 2012-16

	Multiplier	Baseline: $25 billion 4G investment	Robust: $53 billion 4G investment
GDP	2.873	$73 billion	$151 billion
Jobs	14.67	371,000	771,000

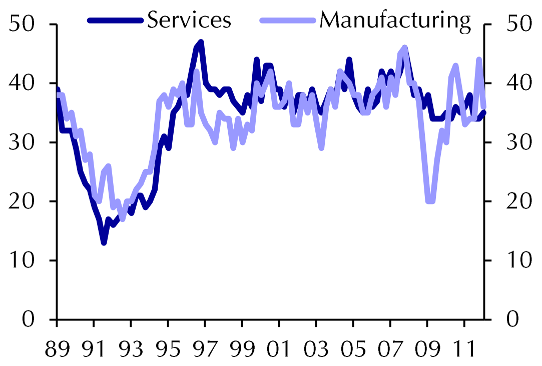
Deloitte Consulting, *The impact of 4G technology on commercial interactions, economic growth, and US competitiveness*, 2011.

But the current context of slow and fragile national economic growth gives the 4G LTE roll out wider macroeconomic significance — and means that more of the computed economic impact of the investment is likely to be realised as a net gain to the economy.

Although the output gap has reduced since the recession, the economy is still operating below its maximum potential. (See Figure 12.) Unemployment hasn't risen as far as many feared, but there remains slack in the labour market (although not necessarily always where it's needed) as demonstrated by weaker productivity and wage rates. Meanwhile, there is a dearth of private sector investment, resulting partly from low levels of bank lending.

Investment was particularly knocked back during the recession and, since then, recovery has been faltering. Real gross fixed capital formation fell 22 per cent from its pre-recession peak in the final quarter of 2007 to its low in Q2 2009.[42] It had only recovered three of the 22 percentage points by Q4 2011. So investment is recovering — but painfully slowly. Our latest forecasts are for fixed investment to grow only

FIGURE 12: PROPORTION OF FIRMS AT FULL CAPACITY



Source — BCC

1.0 per cent this year (2012) but starting to accelerate to 4.0 per cent next.[43]

In this context, **the investment in 4G LTE may be well timed to minimise its potential to crowd out other activity, as well as being a welcome private sector funded boost to an economy having to cope with fiscal austerity**.

FIGURE 13: IMPACT ON SUPPLY CHAIN OF £5½ BILLION IN 4G LTE INFRASTRUCTURE

	Jobs		Turnover	
	Base scenario	Reduced imports	Base scenario	Reduced imports
Region	(number)	(number)	(£ million)	(£ million)
North East	2,702	3,960	174	307
North West	6,946	10,178	448	897
Yorkshire and The Humber	4,464	6,542	288	665
East Midlands	5,422	7,946	350	569
West Midlands	6,872	10,071	444	698
East	9,495	13,914	613	717
London	12,850	18,831	829	1,262
South East	18,881	27,669	1,219	1,134
South West	7,459	10,932	482	690
Wales	3,147	4,612	203	351
Scotland	6,255	9,166	404	704
Northern Ireland	1,901	2,785	123	180
Sector				
Energy and primary	**191**	**280**	**56**	**82**
Construction	**132**	**193**	**15**	**22**
Manufacturing	**39,525**	**57,923**	**3,699**	**5,421**
Fabricated metal products	896	1,313	57	84
Computer and electricals	36,114	52,923	3,364	4,930
Other machinery &	251	368	27	40
Repair & maintenance	648	950	31	45
All other manufacturing	1,617	2,369	220	322
Services	**46,546**	**68,212**	**1,807**	**2,648**
Financial & business services	5,832	8,547	293	429
Mgmt consultancy & support	1,388	2,033	55	80
Employment Services	4,298	6,298	74	108
Administrative support	1,140	1,671	51	75
Communications	25,524	37,404	1,141	1,671
Property services	2,101	3,079	21	31
Transport and storage	1,062	1,556	53	77
Wholesale, retail & services	3,363	4,929	90	131
Public services	1,838	2,694	31	45
United Kingdom	**86,394**	**126,607**	**5,577**	**8,173**

Sources — Capital Economics estimates using a variety of sources as described.

4 Being online on the move

In this section, we consider the improvements that 4G LTE will make to mobile broadband, and assess how they might translate into benefits for both users and the economy as a whole.

Our key findings are:

- **The mobile broadband services currently offered are often slow and clunky, and do not feel like or perform as well as broadband provided by fixed line competitors**
- **4G LTE can deliver mobile broadband services of a quality on a par with their fixed line counterparts**
- **Customers are likely to value the improvements in speed and quality of connections, with a consequent increase in either or both consumer and producer surplus attainable that could be in the order of £0.9-1.4 billion annually**
- **There are also benefits for the economy at large through improved productivity, innovation and 'network economies of scale' — although we are cautious about reading too much into the results of some academic and professional studies that predict very large impacts**
- **On the basis of what appear to us to be cautious assumptions, we would not be surprised if 4G LTE gave a boost to GDP in the order of a half of one per cent eventually**

4.1 The current provision of mobile broadband

There is clear, substantial and growing demand for high speed data and internet connectivity on the move at remote locations — from both businesses and consumers.

Over a hundred million gigabytes of data were transferred over the existing 3G mobile telephone networks in 2011.[44] Meanwhile, almost five million people report using wifi hotspots, typically linked to the fixed line networks, to provide internet access when out-and-about. (See Figure 14.)

However, current mobile broadband services are not competitive on quality with their fixed-line alternatives and, in some respects, resemble something closer to 'dial-up' than broadband.

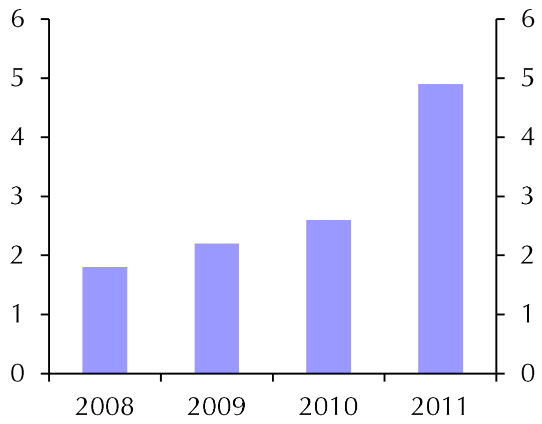
In 2011, Ofcom published a report on the performance of mobile broadband dongles and datacards using 3G and 3.5G HSPA connections.[45] They found that the average download speed was 2.1 Mbps — so a five megabyte music track would download in about twenty seconds and a 250 MB video file, which is the size of a standard definition 30 minutes television programme, would take about seventeen minutes. Domestic fixed line broadband customers, on the other hand, are receiving an average of 7.6 Mbps, and have access to much higher speeds.[46] (See Figure 15)

The average time to download pages from popular web sites in the United Kingdom across 3G and 3.5G networks was 2.2 seconds; over half of all pages (59 per cent) were downloaded in less than two seconds, but twelve per cent of requests took longer than four seconds.[47] This performance is beaten by the slowest of the fixed line broadband services. (See Figure 16.)

The measured responsiveness of mobile broadband also compares unfavourably with fixed line counterparts.

Ofcom report an average latency (which is the time it takes for the data to start to be received after a request) of 117 milliseconds on the cellular networks. With nearly two thirds of their tests taking more than 100 milliseconds, Ofcom concedes that mobile broadband connections may not be optimal for some online games. Basic fixed line broadband services have average latency of less than 40 milliseconds. (See Figure 17.)

FIGURE 14: PEOPLE USING WIRELESS HOTSPOTS IN GREAT BRITAIN, 2011 (MILLIONS)



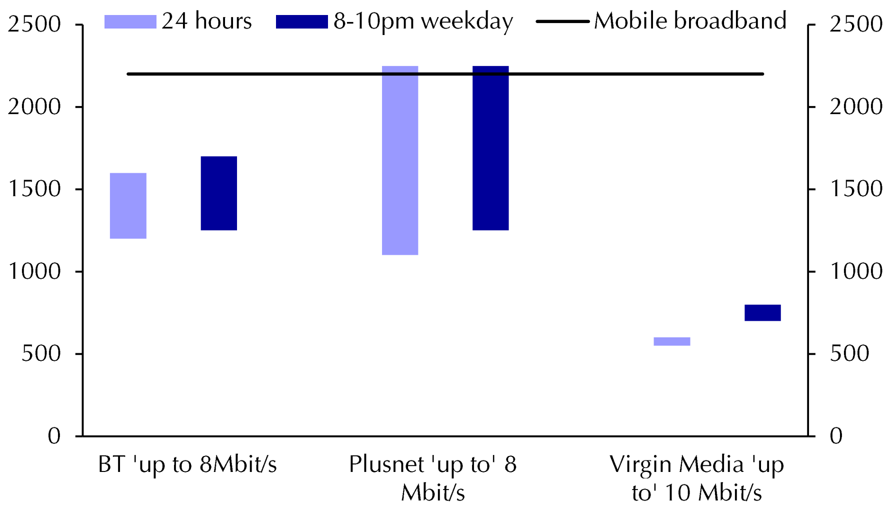
Source: Office for National Statistics, *Internet Access - Households and Individuals, 2011* (ONS, London), August 2011.

FIGURE 15: AVERAGE DOWNLOAD SPEEDS RECEIVED BY FIXED LINE BROADBAND CUSTOMERS (MBIT/S)

Current packages	10% receive more than (90th percentile)	50% receive more than (median speed)	Typical speed range (25th to 75th percentile)
ADSL 'up to' 8 Mbit/s	6	3	1 to 5
ADSL 'up to' 20/24 Mbit/s	14	5	3 to 10
Cable 'up to' 10 Mbit/s	10	10	9 to 10
Cable 'up to' 30 Mbit/s	32	32	31 to 32
Cable 'up to' 50 Mbit/s	51	49	47 to 50
FTTC 'up to' 40 Mbit/s	38	38	35 to 38

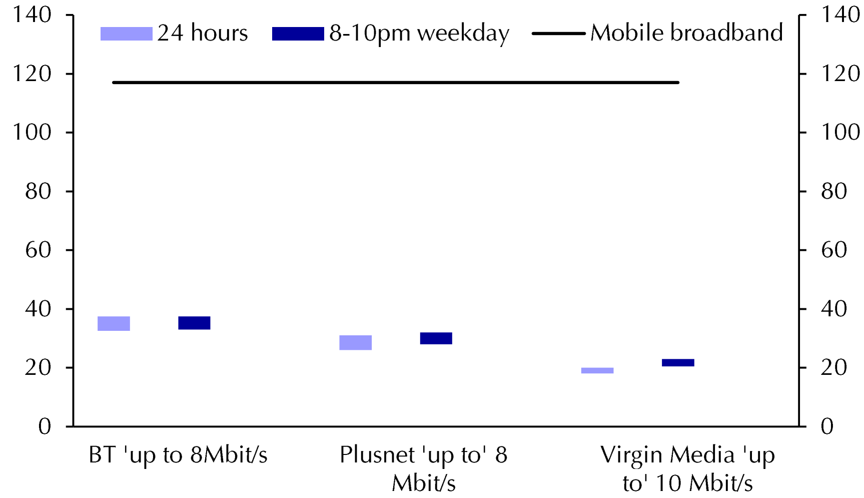
Source — Ofcom, *UK fixed-line broadband performance, November 2011: The performance of fixed-line broadband delivered to UK residential consumers* (Ofcom, London), 2012.

Figure 16: Average and peak time loading of web pages for basic fixed line broadband services, November 2011 (milliseconds)



Source — Ofcom, *UK fixed-line broadband performance, November 2011: The performance of fixed-line broadband delivered to UK residential consumers* (Ofcom, London), 2012.

Figure 17: Average and peak time latency for basic fixed line broadband services, November 2011 (milliseconds)



Source — Ofcom, UK fixed-line broadband performance, November 2011: The performance of fixed-line broadband delivered to UK residential consumers (Ofcom, London), 2012

The relatively poor technical performance of 3G and 3.5G broadband is reflected in consumers' responses to Ofcom surveys on satisfaction. Around one-third of mobile broadband users said they had a problem with the speed of connection while using the service away from home. (See Figure 18.)

The communications regulators conclude their research by saying: '[T]here is a significant difference in performance between fixed and mobile broadband services. Mobile broadband performs below fixed broadband service levels in technical metrics such as download speeds, latency and DNS resolution time. For applications including web browsing, file downloading, VoIP, video streaming and on-line game playing, mobile broadband services are likely to perform at a lower standard than fixed broadband service.'

Moreover, there can be considerable variability in the quality of mobile broadband service delivered; Ofcom testing shows that the availability and performance of 2G, 3G and HSPA networks 'vary significantly even within small geographic areas'.[48]

FIGURE 18: SATISFACTION WITH FIXED AND MOBILE BROADBAND SERVICES

Are there any problems using (X) to access the internet?	Fixed line (WiFi)	Fixed line (no WiFi)	MBB at home	MBB out of home
Speed of connection too slow	18%	24%	22%	34%
The internet is unreliable	7%	7%	12%	13%
Poor coverage - it's hard to get a connection	3%	2%	7%	9%

Source — Ofcom, *Mobile broadband research summary report* (Ofcom, London), November 2010

4.2 Consumer benefit from 4G LTE

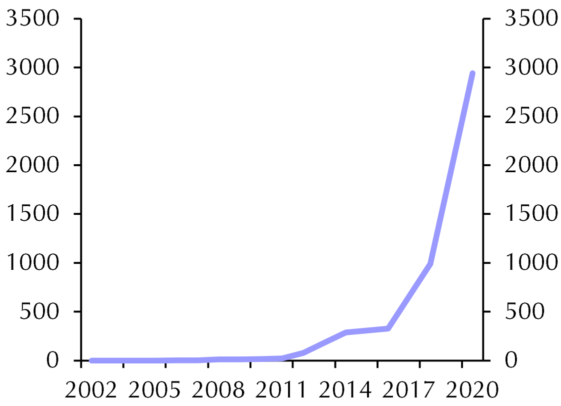
The deployment of 4G LTE will deliver mobile broadband services of a quality on a par with their fixed line counterparts.

According to Ofcom research, 4G LTE technology could deliver peak data rates of over 50 Mbps, while enhancements coming on stream by the end of the decade could theoretically permit up to 3 Gbps (although none of the operators are currently expecting to provide this level). (See Figure 19.) 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.[49]

In real world conditions, the networks are unlikely to 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 including decisions still to be made by network operators as to the products they intend to offer. It is therefore difficult to assess in advance the actual average rates obtained. Nevertheless it is realistic to expect significant improvements in achieved download speeds and even initial deployments of **4G LTE technology will enhance the day-to-day mobile broadband experience** in other ways[50]:

- Responsiveness will be as good as or better than the best that 3.5G can offer now or in future[51]
- 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[52]
- Connection times on 4G LTE will match or better the best that can be offered on 3.5G systems with devices feeling 'always on'[53]

FIGURE 19: EXPECTED TREND IN THEORETICAL MAXIMUM MOBILE BROADBAND PEAK DATA RATES WITH 4G ROLL OUT (MBPS)



Source — Real Wireless Ltd, *4G Capacity Gains: Final report — main body* (Ofcom, London), 2011. Note — These are theoretical maximum speeds; it is likely that both the peak data rates and speeds actually achieved will be much lower.

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.

The same three sources of consumer benefits that were identified by Plum Consulting for fixed line superfast broadband will be applicable to users of the next generation of mobile broadband:[54]

1. Doing what people do now, but in less time
2. Doing more of existing things where superfast broadband improves the experience most — particularly rich content sharing, viewing and forms of collaboration
3. Doing new things involving transformations of the way we live, work, and create and distribute content and data

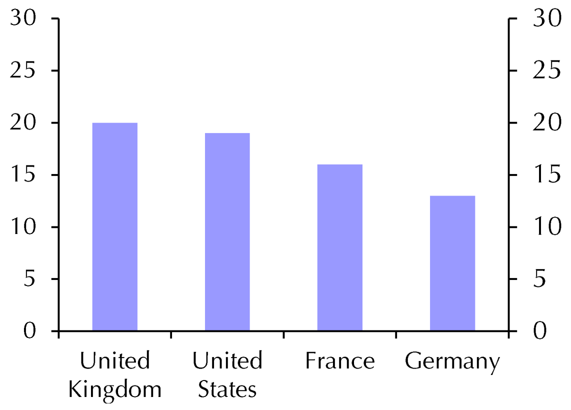
The tricky question to answer, though, is: how much added value?

There are (widely varying) estimates of the consumer surplus from the internet. For example, McKinsey estimate that the average internet user benefits from the service by an average of twenty euros per month over and above the price paid for it.[55] Meanwhile, two academics from Stanford University and University of Chicago estimate the surplus at more like two per cent of incomes given how much time people are willing to spend surfing.[56]

But there is little research in the public domain attempting to evaluate the consumer surplus from mobile broadband or, for that matter, broadband generally.

One rare example is the 2009 study of fixed line home broadband in the United States conducted by Compass Lexecon for the Internet Innovation Alliance.[57] In the absence of something from the United Kingdom, evidence from the United States may be the next best thing. A recent study by McKinsey suggests that consumers in this country gain the greatest value from the internet when compared to counterparts in other major economies; United States' consumers are close behind.[58] (See Figure 20.)

FIGURE 20: CONSUMER SURPLUS ACCRUING TO USERS OF THE INTERNET IN SELECTED COUNTRIES (€ PER USER)



Source — Matthieu Pélissié du Rausas et al, *Internet matters: The Net's sweeping impact on growth, jobs, and prosperity* (McKinsey Global Institute), 2011.

Compass Lexecon estimate that, for 2008, home broadband was providing a total consumer surplus of $31.9 billion. Their study used two methods for computing the surplus: econometric analysis of price and sales data; and a 'willingness to pay' survey. The econometrics, for 2008, indicated an average consumer surplus of $478 per annum per household with broadband (which is around £322 in today's sterling prices) against $359 for households with dial-up (£242). The survey yielded a lower valuation of $342 for broadband (£230) and a much lower $114 for dial-up (£77). These results suggest that **an improvement from dial up quality to current broadband standards increase the value of an internet connection by something like a further 33 to 200 per cent.**

The researchers also used their survey to assess consumers' willingness to pay for superfast broadband services. On average, households already with a broadband connection said they would be willing to pay an extra $31.40 per month (or just over £250 per annum in today's sterling prices) to improve their service from 5 Mbps, which is around 100 times the historical dial up speeds, to 50 Mbps. The willingness to pay for higher performance of households still using dial up was lower — at $21.93 per month (£177 per annum).

Overall, the researchers estimate **an extra $6 billion of consumer surplus could be obtained with superfast services in the US; 30 per cent more than with a 5 Mbps connection.** They also, quite rightly, suggest that their survey-based methodology is likely to understate the future value consumers will gain from the new technology because, without experience of it, respondents to the survey are unlikely to appreciate the full range of benefits that superfast broadband will bring.

The Lexecon estimates are lower than those in earlier reports by Criterion Economics, which put the projected rise in consumer surplus due to broadband adoption at $234-351 billion per year in 2003.[59] Their analysis is based on an assessment of potential benefits that might flow from the new services that households can obtain with faster Internet connections and more powerful home computing, as well as time savings and gains on commuting allowed by high speed broadband. They believed that the largest contribution would be made by shopping, followed by entertainment, telephone services, telemedicine and commuting.

Plum Consulting, on behalf of the Broadband Stakeholder Group in the United Kingdom, developed a framework for evaluating the benefits of superfast fixed line broadband, but concluded that much of the potential gain was difficult or impossible to quantify.[60] They did, however, suggest a value of £1 billion per annum gain from time savings for existing users conducting their current activities online.

The Brattle Group have made an assessment of the potential producer and consumer surpluses in United States for 'wireless broadband', like 4G (but also including wifi based systems). Assessing the potential value of allocating up to

294 MHz of spectrum to the cellular network operators, they estimate a potential producer surplus of $45-59 billion per annum, and a consumer surplus of $500-1,200 billion.[61] Their assessment of the consumers' value, however, is based only on a factoring up of their producer surplus number based on previous telecommunications experience. Adjusting for the different sizes of the countries, the equivalent values for the United Kingdom would be producer surpluses of £5.5-7.2 billion, and consumer surpluses of £61-147 billion. These are large numbers, and are probably best treated with caution. Moreover, the quality of existing mobile broadband in the United States is arguably of low quality which may overstate the benefits of improvements there.

Overall, the evidence on surpluses is patchy, variable and at times implausible. However, it is possible to make some tentative conclusions.

Above, we suggested that, depending on assumptions used, the combined value of consumer and producer surpluses from mobile telephony may be around £24-40 billion today based on research conducted for Ofcom. (See section 2.5.) If we assume that this surplus can be split between voice and data in proportion to the network operators' revenues for voice and data then around £3-5 billion per annum should be attributable to mobile broadband currently.[62] Meanwhile, 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 £0.9-1.4 billion annually**.

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 temptation to try to quantify them here given the paucity of evidence and data.

4.3 Macroeconomic benefits: Productivity, catalytic and network effects

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

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 be a ring tone industry — but, equally, 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 Blackberrys, iPhones or an 'apps industry', whose global worth was recently predicted to reach over $100 billion by 2017.[63] 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). Although scarcity may make jewellery valuable, it is abundance that determines the worth of ICT. These 'network effects' mean that productivity benefits and catalytic effects can all be expected to increase as penetration rates for a communications technology grow.[64]

There is a sizeable literature that attempts to quantify these macroeconomic benefits for a range of technologies. Above, we refer to some of the evidence relating to ICT generally and telephone technologies specifically. (See section 2.6.) There is also a literature, which is more relevant to our investigation of the potential impacts of 4G LTE, focussed on broadband and, to a limited extent, mobile internet — although there is almost no research into the impact of superfast broadband.

Although the body of relevant research is sizeable, it does have to be read with a degree of caution.

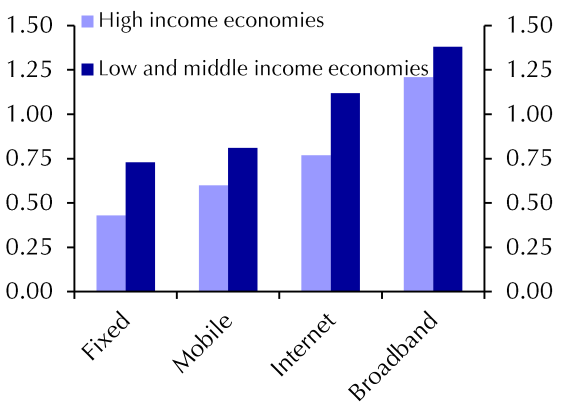
First, a remarkably large number of the studies all refer to a much smaller cohort of quantitative exercises. These are typically econometric models — which, themselves, need to carry health warnings. In particular, it is not always possible, through the use of econometric techniques, to distinguish the direction of causality — for example, does broadband penetration stimulate GDP, or does GDP growth stimulate the technology's take-up, or even both? A lot rests on the soundness of a few assumption-laden mathematical models, and the accuracy and completeness of their underlying data. Second, most of the studies are couched only in terms of the impact on GDP (or jobs) of an increase in the adoption of the technology being study. There is nothing wrong with this approach; however, it does conflate the various drivers of the value — i.e. productivity, catalytic and network effects — into a single metric and makes it difficult to interpret or corroborate.

Probably the most cited and best exemplar of the work in the field 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 ICT technologies could explain different rates of economic growth across 120 countries.[65] 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 21.)

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 21: GROWTH EFFECTS OF DIFFERENT ICT 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 other studies.

A recent paper in *The Economic Journal* reports that a ten percentage point increase in broadband penetration raised annual per capita growth by 0.9–1.5 percentage points.[66] A 2009 study by management consultants, Booz & Company, found that ten per cent higher broadband penetration in a specific year is 'correlated with 1.5 per cent greater labour productivity growth over the following five years'. It also suggests that 'countries in the top tier of broadband penetration have exhibited two per cent higher GDP growth than countries in the bottom tier'.[67] Another management consultancy, McKinsey & Company, is more cautious and gives the GDP impact as a range from 0.1 to 1.4 per cent.[68]

Earlier research for the US Department of Commerce measured the differences in economic performance of communities with broadband and those then without it.[69] This study found that communities with broadband had growth in jobs 1.0 to 1.4 percentage points higher than those without — although it may be difficult to determine whether this is entirely a net gain or, at least in part, the broadband areas capturing growth that would have otherwise gone to the non-broadband communities. (See Figure 22.)

In another study from the United States, the Brookings Institution found that, for every one percentage point increase achieved in broadband penetration, employment rises from 0.2 to 0.3 per cent[70] — while the National Bureau of Economic Research estimates that broadband deployments increased GDP by up to $10.6 billion from 1999 to 2006 with as much as an additional $6.7 billion in non-market consumer benefits.[71] More recent research in Australia estimates an impact from broadband on overall economic welfare of 3.5 per cent of GDP.[72]

FIGURE 22: IMPACTS OF BROADBAND OF ECONOMIC ACTIVITY IN US COMMUNITIES

Indicator	Results
Employment	Broadband added 1.0 to 1.4 percentage points to the growth rate in the number of jobs during 1998 to 2002
Number of businesses	Broadband added 0.5 to 1.2 percentage points to the growth rate in the number of firms during 1998 to 2002
Housing rental rates	Rates were more than 6 per cent higher in 2000 in zip codes where broadband was available by 1999
Industry mix	Broadband added 0.3 to 0.6 percentage points to new business creations in IT-intensive sectors in 1998 to 2002 Broadband reduced the share of small business by 1.3 to 1.6 percentage points in 1998 to 2002

Source — 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.

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.[73] 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.[74]

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. A recent ITU/Unesco report helpfully outlines a wide range of this research, which we reproduce below. (See Figure 23.)

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.[75] 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.

FIGURE 23: EXAMPLES OF RESEARCH INTO BROADBAND'S IMPACT ON JOBS (1 OF 2)

	Report Title	Institution	Key findings
Germany	The impact of Broadband on jobs and the German economy (2010)	Columbia Business School, Telecom Advisory Services LLC, Polynomics AG	An investment of €36 billion will return €22.3 billion
Thailand	Broadband Thailand 2015	Center for Ethics of Science and Technology, Digital Divide Institute, Thailand	In 2010 the Thai broadband penetration rate was only 3.4% of households and about 12% of individuals
Japan	Investment in broadband infrastructure: Impacts on economic development and network neutrality (2009)	Kyushu University, Japan	If the Japanese economy grows and the potential of ubiquitous networks is fully utilised, the real GDP growth rate will be about 1.0 to 1.1 points higher than otherwise
China	Broadband in China: Accelerate development to serve the public	Value Partners	The development of China's dial-up and broadband internet may contribute a combined 2.5% to GDP growth for each 10% rise in penetration
Global	What role should governments play in broadband development? (2009)	The World Bank/InfoDev	Broadband is a key driver of economic growth providing a boost of 1.38 pp in GDP growth in developing countries, for every 10pp rise in penetration
Latin America, Carribean	The impact of taxation on the development of the mobile broadband sector (2009)	Telecom Advisory Services LLC	In 24 Latin American and Carribbean countries (controlling for educational level and development starting point), a 1% rise in broadband penetration yields a 0.017 point rise in GDP growth between 2007 and 2008 (prorated average of 37%) contributed between $6.7 billion and $ 14.3 billion, including direct and indirect effects, and preservation of an economic growth rate
15 OECD nations, 14 European	Economic impact of broadband: An empirical study (2009)	LeGG ltd, for Nokia Siemens Networks	One more broadband line per 100 people in these 'medium or high ICT' countries raises productivity by 0.1%
Republic of Korea	Broadband as a platform for economic, social and cultural development: Lessons from Asia (2008)	The World Bank/InfoDev USA	The contribution of telecom services and broadband to GDP more than doubled between 1995 and 2005: the decade of broadband's expansion in the republic of Korea
United Kingdom	The economic impact of a competetive market for broadband (2003)	Centre for Economics and Business Research Ltd, The Broadband Industry Group	By 2015, the productivity benefits of broadband could result in the GDP of the UK rising by up to £21.9 billion

Source — Broadband Commission for Digital Development, *Broadband: A platform for progress*, (ITU/UNESCO, Geneva), 2011.

FIGURE 24: EXAMPLES OF RESEARCH INTO BROADBAND'S IMPACT ON JOBS (2 OF 2)

	Report Title	Institution	Key findings
Germany	The impact of Broadband on jobs and the German economy (2010)	Columbia Business School, Telecom Advisory Services LLC, Polynomics AG	Broadband network construction will create 304,000 jobs between 2010 and 2014, and 237,000 between 2015 and 2020. Also, it is estimated that an additional 427,000 jobs will be created: 103,000 in 2010 to 2014 and 324,000 in 2015 to 2020. The accumulated total jobs over a ten year peiod (2010 to 2020) will reach 968,000
Sudan	Economic impact of mobile communications in Sudan (2010)	Zain, Ericsson	In addition to providing over 40,000 jobs to the Sudanese economy, the mobile telecommunications sector is related to demand-side GDP growth rates of 0.12% for each 1% rise in market penetration
Brazil	Economic development and inclusion through local broadband access networks (2009)	The Multilateral Investment Fund, Inter-American Development Bank	Broadband has added about 1 to 1.4% to the employment growth rate
United Kingdom	The UK's digital road to recovery	LSE Enterprise Ltd, The Information Technology and Innovation Fund	An additional £5billion investment in broadband networks would create or retain an estimated 280,500 UK jobs for one year
USA	Economic impacts of broadband, information, and communications for development: Extending reach and increasing impact	The World Bank	Broadband added 10 to 14% to the growth rate in the number of jobs between 1998 and 2002
USA	The effects of broadband deployment on output and employment: A cross-sectional analysis of US data; Robert Crandall, William Lehr, Robert Litan (2007)	Issues in Economic Policy' July 2007 (The Brookings Institution)	For every one percentage point increase in fixed broadband penetration in a US state, employment is projected to increase by 0.2 to 0.3% per year

Source — Broadband Commission for Digital Development, *Broadband: A platform for progress*, (ITU/UNESCO, Geneva), 2011.

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

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).[76] 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

Through the use of case studies and analysis of official labour market statistics, identifying occupations where mobile technology enhance productivity, 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 GDP).** In that same year, they estimate that the productivity value of all mobile wireless services was worth $185 billion (1.5 per cent).

In the United Kingdom, the Open Digital Policy Organisation have estimated the cost of the time currently being spent by businesses downloading across the existing 2G and 3G networks that could be saved if 4G were deployed.[77]

By modelling data sourced largely from Ofcom, the group estimates that, with a 4G LTE system delivering an average speed of 6.6 Mbps 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.

4.4 Placing a value on 4G LTE mobile broadband macroeconomic impact

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 GDP, 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.

As such, there is merit to the logic and the transparency of Open Digital Policy Organisation's calculation. It is seemingly simple and, arguably, simplistic assessment — and it captures only one element of the potential benefits from 4G LTE, namely the direct time savings on only current activities for businesses using mobile data services today. But it is a good starting point.

We do not, however, want to risk overstating the value of 4G LTE — an accusation that may be levelled (often with apparent justification) at some of the research into benefits of ICT technologies elsewhere.

The potential danger with the Open Digital Policy Organisation's estimates is that they rely upon an implicit assumption that time spent downloading isn't being used in another productive activity. This clearly is not always true, and means that we can only treat their calculation as a 'maximum' value. But this assumption may not be as unrealistic as it first seems.

It can be difficult to reallocate idle time from activities that have short durations and, especially, if there is uncertainty around how long the idle time will be.

The person pressing the print button on the production of 100 copies of a 50 page report knows that they'll have plenty of time to check emails and make some telephone calls (although, if their experience of printers is anything like the author's, they will need to check it regularly!). The database operator can switch applications while a known and lengthy report run is processed. But can you really do anything else meaningful in the seconds that it takes to download most data and websites — especially if you don't know how long it will take?

In most cases, the answer is probably not.

Plum Consulting make similar points in relation to fixed line broadband: 'Whilst consumers may be able to do other things when data is uploading or downloading, there may be insufficient time to effectively switch tasks, access may be slow while a background task is performed and multi-tasking may interfere with other users utilising streamed services. It therefore seems reasonable to assume that data transfer limitations impose significant costs on users.'[78]

On the other hand, some of the original calculations by James Firth and Dominique Lazanski are, in our view, too conservative and also warrant reassessment.[79]

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 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.[80]

Of course, there is a lot of chicken-and-egg at play here; most predictions for growth of mobile data are predicated on 4G or similar improvements. But we believe there will still be strong (albeit lower) growth in mobile data regardless of whether 4G or, for that matter, further enhancements to HSPA come on stream. Partly fuelled by the popularity of 'smartphones' like the Blackberry and iPhone, 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.[81] 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. If roll-out is delayed by a further year to 2016, this increases to almost £5½ billion or 0.4 per cent.**

The Open Digital Policy Organisation's approach captures only one element of the potential benefits from 4G LTE. There are others. Probably the most important productivity gain for business from 4G LTE will be the ability to work differently — and to use mobile broadband for tasks that currently aren't reliably achieved over the existing services.

For example, gains may be achievable through more efficient management and documentation. Based on their case studies, Ovum suggest that mobile wireless applications 'will yield at least an additional 30 minutes per day that can be put to productive use'.[82] This would be an average 6.8 per cent increase in productive time for those benefitting. In reality, only certain professional and managerial occupations are likely to benefit — but these still account for over a quarter of the workforce.[83] Meanwhile, some of these benefits identified by Ovum have probably already been achieved through widespread use of 'smartphones' using 3G networks — and/or maybe delivered through wifi rather than mobile telephone technology. Nevertheless, even **a saving of just five minutes per day to the managerial and professional occupations alone would increase total productive hours by over 0.3 per cent** — and, taking account of the higher wages in these sectors, probably adds 0.4 per cent to potential national output.

As explained above, in addition to productivity benefits, there are also catalytic and network effects. (See section 4.2.) 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 impact of 4G LTE mobile broadband will be in the order of a half of a percentage point on GDP**.

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.

First, the new technology has to be fully deployed by the mobile network operators — which should take 3-4 years from now unless there are further delays to the spectrum allocation process. Second, new devices with 4G LTE capabilities need to be widely adopted by users; adoption of the technology is likely to follow the infrastructure roll-out with a lag of, say, six months, although it may be more like 18-24 months after roll-out is completed until maximum penetration rates are reached. Third, businesses, employees and consumers must adapt their behaviour and processes to optimise the efficiency benefits of the new technology; this is an ongoing process, but it is not unreasonable to assume that much of the benefit is realised within five years of the technology becoming available.

5 Broadband for the under- and un-provided

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

Our key findings are:

- **Around ten per cent of the population do not have access to fixed line broadband or, if they do, download speeds are less than 2 Mbps — while over twenty per cent are unlikely to benefit from BT's planned roll out of fibre optic superfast broadband**
- **Even if 4G LTE was only deployed across the current 3G network, it would still be the only source of superfast broadband for around fifteen per cent of the population**
- **On a more plausible scenario of roll out to at least 95 per cent coverage, 4G LTE will be the only superfast option for around a fifth of households**
- **4G LTE's reach may extend beyond BT's standard ADSL broadband provision giving some families fully fledged broadband for the first time**
- **4G LTE's ability to increase coverage will have a macroeconomic benefit — although predicting the scale is contentious. Nevertheless, our cautious estimate of an overall macroeconomic impact of 4G LTE in the order of a half of a percentage point of GDP is reasonable and realistic**

5.1 Fixed line broadband and superfast broadband provision

The fixed line networks do not — and probably never will — provide universal access to superfast, or even decently fast, broadband.

Although almost everyone can now obtain an ADSL broadband connection from BT, the quality of provision varies markedly — and **a significant proportion of the population are still unable to access the internet with an appropriately fast connection**.

Rural businesses report to Ofcom that, while the introduction of broadband in rural areas was a very welcome technology a few years ago, the bandwidth available is now insufficient to meet users' needs, and the lack of broadband coverage (or the low broadband speeds where available) in some rural areas prevents some employees from working from home and some local businesses, such as B&Bs, from promoting their services.[84] Meanwhile, consumers also experience problems where the actual broadband speeds received are well below what is advertised.

This is borne out by Ofcom data. Although average speeds received by fixed line broadband customers are around 7½ Mbps for the country as a whole, fourteen per cent of subscribers are receiving less than 2 Mbps — rising to nineteen per cent in Wales and 23 per cent in Northern Ireland.[85] Ofcom argue that a significant proportion of those receiving under 2 Mbps could improve their connection speeds by performing maintenance on their equipment or by changing supplier or product. So the BT network itself is probably only responsible for around eight percentage points of the twelve per cent with poor speeds. But given that take-up of broadband in poorer speed areas is likely to be lower than the national average, the eight per cent of ADSL subscribers probably translates into more like ten per cent of the population as a whole. So, **around one-in-ten of the population do not have access to a meaningful fixed line broadband service**.

In addition to ADSL, 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 Mbps. 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 40 Mbps now, rising to 80 Mbps from later this year.

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 concentration of Virgin assets in urban areas.

We have examined the BT Openreach's published roll-out programme of superfast broadband to exchanges in Great Britain — and have estimated the proportion of the population being served by an upgraded exchange. BT Openreach report that 918 exchanges have been upgraded already, and that this number will increase to 1,351 by September 2012 and 1,489 in the future (although with dates scheduled for sometime in calendar years 2012 or 2013).[86] (See Figure 25.)

However, as Ofcom point out, in practice some premises may not be able to receive superfast services even if they are within the catchment area of an Openreach FTTC enabled telephone exchange.[87] This is because some street cabinets within the exchange area may not be upgraded at the same time as the exchange. And, even where a cabinet has been upgraded, some lines may be too far from the fibre enabled cabinet to achieve high speeds. Ofcom conclude that, typically, '80 to 90 per cent of premises within an exchange area will be enabled in the initial deployment phase', although 'further coverage may be achieved in these areas at a later date as new technologies are developed and the commercial case for investment improves'.

As such, **the population that can actually receive superfast fixed line is around 54-61 per cent now, rising to 66-75 per cent later this year and 69-77 per cent by the end of BT's current investment programme**.[88]

FIGURE 25: POPULATION SERVED BY A BT EXCHANGE UPGRADED TO SUPERFAST BROADBAND

	Current situation	'Coming soon'	'Future'
		By September 2012	In 2012 or 2013
England and Wales	70%	84%	86%
Scotland	51%	70%	79%
Great Britain	68%	83%	86%
Number of upgraded exchanges (cumulative)	918	1,351	1,489

Source — Capital Economics calculations using information from http://www.superfast-openreach.co.uk/where-and-when/

5.2 Potential 4G LTE mobile broadband coverage

Although BT has now developed, published and started implementing a superfast broadband investment programme, delays to reallocating and relicensing spectrum means that the mobile network operators are several stages behind — and there is little in the public domain about the detail of their 4G LTE investment intentions.

However, as a minimum, it seems a reasonable assumption that areas currently served by 3G will be upgraded to 4G LTE over a three-to-four year roll out programme.

Coverage by cellular networks is already high on the existing technologies, including 3G. Although 6½ per cent of the country has no mobile telephone signal at all and 30 per cent lacks a 3G connection, the areas without a cellular service are mostly unpopulated.[89] According to Ofcom's research, less than 0.1 per cent of premises in the United Kingdom fail to receive any signal and only 1.2 per cent fail to receive any 3G signal. (See Figure 26.)

Individually, all the networks cover over 99 per cent of the population on 2G. Providers using Everything Everywhere's infrastructure, which is the country's largest 3G network, can offer 93 per cent coverage on 3G.

So, if Everything Everywhere deploy 4G LTE at their existing 3G base stations, all but seven per cent of premises should get a signal. In reality, some who get a signal to their premises may still have limited indoor reception or a connection that is too poor to facilitate meaningful data transfer — although this should improve with 4G LTE as signal range is expected to be boosted by around eleven per cent.[90]

In fact, it is likely that 4G LTE will be rolled out much further than the existing 3G coverage. Ofcom is considering including a licence requirement for 4G operators to cover a percentage of the population. They initially suggested 95 per cent although this has now gone up to 98 — while some are even mooting 99 or 100 per cent coverage criteria.

FIGURE 26: OFCOM ESTIMATES OF MOBILE TELEPHONE COVERAGE, 2011

	2G				3G			
Share of popn	Geographic coverage		Premises coverage		Geographic coverage		Premises coverage	
	no signal from any operator	signal from all operators	no signal from any operator	signal from all operators	no signal from any operator	signal from all operators	no signal from any operator	signal from all operators
England	1.4	83.8	<0.1	97.5	8.9	20.4	0.4	76.3
Scotland	15.5	37.9	0.2	94.5	60.6	3.1	3.9	63
Northern Ireland	2.2	73.4	0.4	93.2	51.7	5.7	13	51.7
Wales	5.8	59	0.2	91.6	31.5	6.8	3.5	49.9
UK	6.4	66.3	<0.1	96.8	29.9	12.8	1.2	73.1

Source — Ofcom, *UK Communications Infrastructure Report 2011* (Ofcom, London), 2011.

5.3 Potential impact of 4G LTE in areas where fixed line broadband can't reach

If 4G LTE is rolled out, it will expand the reach of superfast broadband (ie. services via 4G LTE or fibre optic fixed line) not only to areas that BT's fibre optic cables won't reach but also into territory currently poorly provided by standard speed ADSL.

Under plausible scenarios, 4G LTE will eventually be offering superfast broadband connectivity to more of the population than fixed line providers (although it is unclear yet what precise services will be delivered through mobile and it is likely that the achievable speeds on mobile will be lower than the best available on fixed line fibre optic). Even if the new mobile technology is only rolled out as far as the country's largest existing 3G network, it will still deliver a superfast connection to between six and 24 per cent of the population who would otherwise only have access via standard ADSL broadband or very slow dial up. If 4G is extended to '99 per cent coverage', around a fifth of the population, who will not get a BT fibre optic connection, could receive superfast broadband via mobile. (See Figure 27.)

FIGURE 27: COMPARISON OF EVENTUAL COVERAGE OF FIXED LINE AND MOBILE BROADBAND

Proportion of population covered	Mobile		Fixed line		Difference		
	(min)	(max)	(min)	(max)	(min)	(max)	(Average)
BT fibre optic versus 4G LTE							
Roll out to UK's largest 3G network	84%	93%	69%	77%	6%	24%	15%
'95% coverage'	86%	95%	69%	77%	8%	26%	17%
'97% coverage'	88%	97%	69%	77%	10%	28%	19%
'99% coverage'	89%	99%	69%	77%	12%	30%	21%
ADSL (>2 Mbps) versus 4G LTE							
Roll out to UK's largest 3G network	84%	93%	86%	92%	-8%	7%	-1%
'95% coverage'	86%	95%	86%	92%	-7%	9%	1%
'97% coverage'	88%	97%	86%	92%	-5%	11%	3%
'99% coverage'	89%	99%	86%	92%	-3%	13%	5%

Source — Capital Economics calculations using various sources as described. Notes — (1) For mobile: maximum coverage assumes all premises in a signal receiving area have an adequate mobile broadband connection; to account for cell edge speed fading, minimum assumes that ten per cent of premises in a signal receiving area do not have an adequate mobile broadband connection. (2) For fixed line fibre optic: maximum is 90 per cent of the proportion of population estimated to be within six kilometres of an upgraded exchange at the end of the currently published investment programme; minimum is 80 per cent. (3) For ADSL: maximum is only eight per cent of premises receive below 2 Mbps; maximum is fourteen per cent as per results of Ofcom research. See text for background. (4) For differences, the minimum and maximum are taken from the four combinations of differences between both minima and maxima.

Moreover, 4G LTE's superfast coverage may even extend beyond where BT can deliver standard ADSL broadband to a reasonable quality.

If 4G LTE is rolled out to '95 per cent coverage', there are likely to be communities who currently cannot receive more than 2 Mbps from BT who will be able to have superfast broadband via the mobile networks. **If there's '99 per cent' roll out, an estimated one-in-twenty people could have superfast connectivity who would otherwise have little or no broadband at all**.

Extending the reach of broadband will have a positive macroeconomic impact, as well as localised benefits to the communities newly served.

We have outlined above the body of academic and professional research that examines and attempts to quantify the links between broadband and prosperity — although we remain sceptical about some of it. (See section 4.) Using examples of this work, we have made estimates of the impact on GDP of the potential increase in penetration of broadband permitted through the roll out of 4G LTE. (See Figure 28.)

In addition, we have made further estimates of the impact on GDP of the expansion of superfast broadband achievable with the new generation of mobile technology. (See Figure 29.)

FIGURE 28: ESTIMATES OF THE EVENTUAL IMPACT ON UNITED KINGDOM GDP OF 4G LTE PROVIDING BROADBAND SERVICES TO HOUSEHOLDS WITHOUT ACCESS TO ADSL GREATER THAN 2 MBPS

Different 4G LTE roll out scenarios	**3G network**		**95% coverage**		**99% coverage**	
	(min)	(max)	(min)	(max)	(min)	(max)
Impact of 4G LTE						
Increase in coverage beyond ADSL	-8%	7%	-7%	9%	-3%	13%
Increase broadband penetration	0%	5%	0%	6%	0%	8%
Impact on national GDP						
Christine Zhen-Wei Qiang		0.55%		0.71%		1.02%
Nina Czernich et al (max)		0.68%		0.88%		1.27%
Nina Czernich et al (min)		0.41%		0.53%		0.76%
Booze & Company		0.68%		0.88%		1.27%
McKinsey & Company (max)		0.64%		0.82%		1.18%
McKinsey & Company (min)		0.05%		0.06%		0.08%
CEBR (max)		0.02%		0.02%		0.03%
CEBR (min)		0.00%		0.00%		0.01%

Source — Capital Economics calculations using various sources as described. Notes — (1) A take up rate of 65 per cent is assumed in estimating the increase in penetration in response to greater coverage. (2) Studies used here are cited and discussed in section 0. (3) All estimates are based upon Capital Economics' interpretation of each study and calculations based thereon.

The results show a massive range in the potential macroeconomic benefit of extending broadband and superfast broadband via 4G LTE to currently unserved or under-served communities. **If one believes some of the more bullish studies then the extra coverage of 4G LTE could stimulate additional take-up of broadband sufficient to deliver an extra one per cent or more of GDP. Others yield results in the hundredths of a percentage point.**

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 cautious estimate of a macroeconomic impact of 4G LTE in the order of a half of a percentage point of GDP is reasonable and realistic. (See section 4.4.)

Figure 29: Estimates of the eventual impact on United Kingdom GDP of 4G LTE providing superfast broadband services to households that have access to ADSL but not fibre

Different 4G LTE roll out scenarios	3G network		95% coverage		99% coverage	
	(min)	(max)	(min)	(max)	(min)	(max)
Impact of 4G LTE						
Increase in coverage beyond fibre	6%	24%	8%	26%	12%	30%
Of which, already had access to ADSL	6%	23%	8%	23%	9%	23%
Increase in the penetration of superfast broadband among households with access to standard ADSL	3%	9%	3%	9%	4%	9%
Impact on national GDP						
Christine Zhen-Wei Qiang	0.03%	0.11%	0.04%	0.11%	0.04%	0.11%
Nina Czernich et al (max)	0.04%	0.14%	0.05%	0.14%	0.05%	0.14%
Nina Czernich et al (min)	0.02%	0.08%	0.03%	0.08%	0.03%	0.08%
Booze & Company	0.04%	0.14%	0.05%	0.14%	0.05%	0.14%
McKinsey & Company (max)	0.04%	0.13%	0.05%	0.13%	0.05%	0.13%
McKinsey & Company (min)	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
CEBR (max)	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
CEBR (min)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source — Capital Economics calculations using various sources as described. Notes — (1) A take up rate of 40 per cent is assumed in estimating the increase in penetration in response to greater coverage of superfast where ADSL broadband already exists. (2) For illustrative purposes only, these calculations assume that superfast broadband yields an additional benefit to GDP equivalent to ten per cent of the initial boost from standard broadband.

6 A catalyst for emerging and new technologies and business models

In this section, we consider future innovations that may be assisted by 4G LTE.

Our key findings are:

- **There is significant potential for m-commerce in the United Kingdom. 4G LTE can play a catalytic role by ensuring that some of the barriers to growth, such as slow speeds and poor connection reliability, are overcome**
- **Machine-to-machine communication, and parallel technologies such as the Internet of Things, can deliver substantial efficiency savings and productivity gains. Mobile telephone is the best suited technology for many M2M uses, and 4G LTE offers scope for development of the most innovative of applications**
- **Cloud computing can deliver sizeable improvements in computing efficiency. 4G LTE will allow robust connection of remote and mobile devices to cloud networks**

6.1 m-commerce

4G LTE can assist the United Kingdom, which is already a leading nation for e-commerce, grow and benefit from mobile trade and transactions.

The internet is already a significant or the primary channel for the sale of many good and services — and especially so in the United Kingdom. According to the latest Office for National Statistics data, e-commerce sales represented 16.9 per cent of total sales in 2010, with website sales contributing 4.2 percentage points.[91] Meanwhile, a recent McKinsey study estimates that the internet and e-commerce contributes 2.9 per cent of total world GDP.[92]

But, with every online buyer purchasing, on average, $2,535 worth of goods and services in 2009, McKinsey's argue that **the United Kingdom is one of the countries where e-commerce is the most developed.** They estimate that the internet contributed eleven per cent of the growth of United Kingdom GDP between 1995 and 2009, and 23 per cent of growth between 2004 and 2009.

Mobile broadband offers greater opportunities — for businesses and consumers alike — for e-commerce activity on the move or when a computer isn't convenient to use.

So-called 'm-commerce' has already established itself as a significant channel to market. According to research carried out by the retail consultants Verdict Research, around £1.35 billion of sales were transacted using m-commerce in 2011.[93] However, it is still in its infancy and faces constraints to wider acceptance and growth on a number of fronts — including mobile broadband performance.

On behalf of eBay UK, Verdict Research undertook an investigation into the views of consumers regarding mobile shopping and the barriers which deter them from using their mobile telephones more for purchases.[94] The most frequently cited barriers cannot be addressed by 4G LTE technology: over two-thirds (69 per cent) of respondents said the screen size of current mobile devices was a 'significant barrier' to m-commerce — followed by 65 per cent each citing security concerns and poor website optimisation for m-commerce. However, the speed of mobile broadband (64 per cent) and connection reliability (63 per cent) will be substantially improved through the introduction of the new system.

6.2 Machine to machine communication

4G LTE is likely to play a catalytic role in the development of so-called 'machine to machine' technologies and systems — and their deployment beyond either public or private wifi networks.

Machine to machine communication (or 'M2M') is a term covering devices that are connected to the internet using a variety of fixed and wireless networks which communicate with each other and the wider world. The devises may be used for a host of activities, including: real-time monitoring and the relaying of information to a central control; remote command and control of equipment; and embedded data connectivity. It is closely associated with the 'internet of things', although this term is more often refers to associated with applications that involve radio frequency identification (i.e. tiny chips with antennae that start to transmit data when they come in contact with an electromagnetic field).

M2M can deliver substantial efficiency savings and productivity gains by replacing the need for onsite manual inspection with automated remote monitoring, sensing and real-time updates. Indeed, the potential for M2M technology to permit widespread automated continuous tracking will generate more information on processes and behaviours, which can lead to greater insight into how to improve products and systems.

In addition, M2M opens the opportunity for future new business models. A recent OECD report cites some potential examples:[95]

- Pay as you drive insurance with insurers able to track in real-time distance driven, location, time of day and driving style
- Digital content distribution is already being conducted M2M through eBook and tablet devices with 3G embedded although can be taken much further with 4G
- Products as services such as delivering light as a service (charging by the lumen) or making energy-saving a service with payment based on the savings realised

As the OECD report explains, **mobile telephone technology 'is, in many ways, the technology best suited to many M2M applications**. ... [It] offers both the possibility to be used in a dispersed as well as highly mobile set of configurations.'[96] Not only do the cellular networks offer near ubiquitous global availability anywhere where people live, mobile telephone technology can be centrally controlled through the use of SIM-cards which have instant activation without user interaction; it supports for roaming between networks; and it provides reasonable coverage indoors.

Many current M2M applications do not need the bandwith and reliability of 4G LTE, but 2G networks are scheduled to be decommissioned and replaced in the coming years. Building an M2M solution that only functions on 2G may not be future proof.

For many potential M2M applications, the greater speeds, enhanced responsiveness and improved reliability of 4G over its predecessor technologies may be a distinct advantage and may permit much more sophisticated innovations. However, M2M device developers need clarity over future available communications platforms like 4G, especially their speed of rollout and their geographic coverage, before innovating and investing in new products.

6.3 Cloud computing

4G LTE can underpin the development of cloud computing with mobile devices.

Cloud computing is an evolving technology that consolidates and pools computer resources (such as servers, processors, storage and software applications) across a public, private or community networks to provide users with on-demand, pay-as-you-go access to rapidly scalable computing 'services'.[97] **It has the potential to deliver sizable improvements in computing efficiency, which one study estimates could improve labour productivity by an average of 2.1 per cent, as well as reducing the amount of investment tied up in underutilised IT capacity.**[98]

4G LTE will facilitate mobile broadband attached devices both being used to access cloud resources remotely and enabling remote resources to contribute to the cloud — with greater reliability and capacity than 3.5G.

7 Postscript: 4G investment and mobile voice telephony

In this report, we have focussed on the impact of 4G LTE technology, which provides only enhancements to data transfer. Aside from 'Voice over Internet Protocol' (VoIP), 4G LTE itself does not improve the traditional voice services.

However, given the scale of investment involved and the extent of works to be conducted across the network of base stations, it is likely that the **mobile network operators will use the opportunity to repair, maintain and upgrade their existing voice equipment — thus providing benefits to telephony as well as data users.**

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This document has been prepared, under commission from Everything Everywhere, by:

Andy Evans

Mark Pragnell

For enquiries about further copies, or other matters, please contact your local office:

North America
2 Bloor Street West, Suite 1740
Toronto, ON, M4W 3E2
Canada
Telephone: **+1 416 413 0428**
Facsimile: **+1 416 413 1342**

Europe
150 Buckingham Palace Road
London SW1W 9TR
United Kingdom
Telephone: **+44 (0)20 7823 5000**
Facsimile: **+44 (0)20 7823 6666**

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16 Collyer Quay
Singapore 049318
Telephone: **+65 65 95 5190**
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