The benefits of 4G:
Sweden and E

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The benefits of 4G: Sweden and Estonia – European leaders in 4G

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Foreword

This is the sixteenth TeliaSonera Institute Discussion Paper. The Institute, located at the Stockholm School of Economics in Riga and generously supported by TeliaSonera, aims to promote applied economic research in the field of entrepreneurship and telecommunication.

The current report addresses an emerging and hitherto relatively unresearched topic, namely the economic impact of the 4G mobile network. A first version of this report was presented in Stockholm at the TeliaSonera and Ericsson seminar celebrating five years of 4G in December 2014.

This, as well as previous TeliaSonera Institute Discussion Papers, can be downloaded from the SSE Riga website, *www.sseriga.edu*. Hard copies can be ordered from *office@sseriga.edu*.

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Executive summary

The Swedish market for electronic communications in 2013 was just over SEK 52.3 billion which represented 1.39% of 2013 GDP of which nearly 55% was generated in mobile call and data services while in Estonia the market was EUR 675 million representing about 3.6% of GDP with mobile telephony generating just over 37% of total revenues.

Thus mobile services represent a significant sector in both economies with 4G leading a surge forward and Sweden and Estonia are the clear European leaders in the deployment of 4G although Europe in general is behind Asia and the United States.

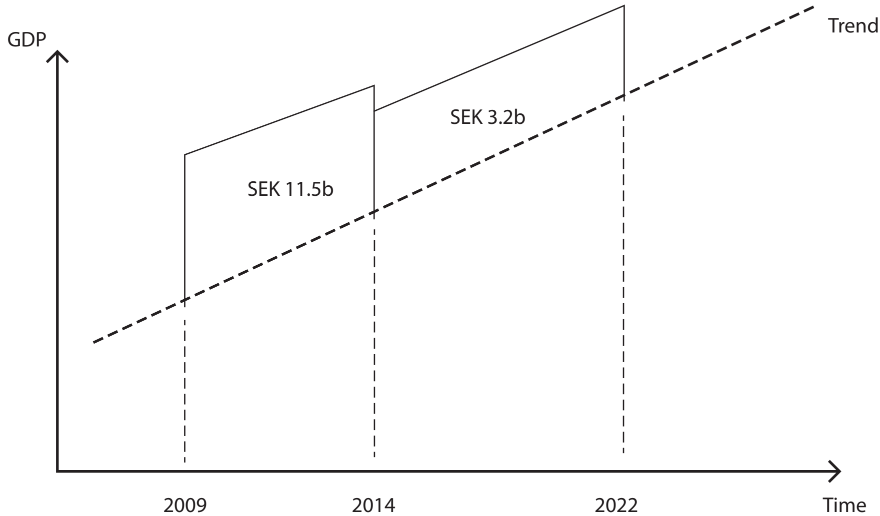
In Sweden roll-out of 4G started in 2009 and in Estonia a year later. In Sweden there have been SEK 5 billion cumulative investments into 4G infrastructure over 2009-2014 and a further SEK 1.4 billion are expected in the coming years. In Estonia 4G investments have amounted to EUR 38.7million with a further EUR 19.3 expected in the future. As a result of these investments 4G population coverage is 99% in both Sweden and Estonia and area coverage is 95% in Estonia and is expected to be 90% in Sweden in 2015.

The development of 4G in Sweden and Estonia generates benefits to the economy and society in a number of ways:

- The macroeconomic and employment gains of 4G roll-out investments.
- Long run productivity gains.
- Wider social impacts.

4G investments have had a non-negligible macro-economic impact in both Sweden and Estonia at a time when European economies including Sweden and Estonia have been in recession. Figure ES1 illustrates.

Figure ES1: The cumulative GDP effects of 4G investments in Sweden



Thus, taking into account multiplier and supply chain effects the cumulative GDP impact has been

- In Sweden between SEK 11.b billion and SEK 14.4 billion over 2009-2014 and a further cumulative gain of SEK 3.2 billion is expected over 2014-2022.
- In Estonia the cumulative GDP impact over 2010-2014 is estimated at EUR 63 million and EUR 31 million over 2015-2022.

Parallel with the GDP gain of rollout investments are the employment effects which for Sweden are likely to have been between 640 and 1280 jobs a year depending on how investments are distributed between computer equipment and construction.

In addition to transitory macroeconomic effects 4G generates permanent benefits through long-run growth, productivity and social effects. Here, we are too early in the full development of 4G to have reliable quantitative evidence. However, what people can do today with smart phones, tablets etc. has been greatly expanded with the availability of 4G which has removed many of the constraints imposed by the physical memory of devices. The result is significant potential for productivity gain. Additionally, because 4G is a 'general purpose technology' any narrow definition of impact is likely to understate the full gain.

More broadly the availability of 4G technology is contributing to radically changing behaviour – the mobile has become a universal device that serves almost all possible ways of communication, engagement and entertainment. Consumers use around three times more data on 4G networks than on 3G networks. At the social level, mobile technologies have increased interpersonal communication that allows contacting anyone from anywhere at low or no costs. Some of these benefits can be captured in money terms, but mostly they are likely to remain elusive and unmeasured (even unmeasurable) in monetary terms.

Quantifiable productivity and social effects which can be captured in monetary terms include:

- The time saved by the faster download speed available with 4G could be worth annually between SEK 1.8 billion and SEK 15.1 billion for Sweden and EUR 9 million and EUR 75 million for Estonia.
- Consumer surplus gains: estimated at SEK 2.24 billion to SEK3.5 billion annually for Sweden and between EUR 11.1 million and EUR 17.3 million for Estonia.
- Long run efficiency gains: estimated at 0.5% of GDP or SEK 18.9 billion for Sweden and EUR 93.7 million for Estonia.

These effects are the tip of the iceberg. The evidence is that while the growth of fixed broadband is slowing mobile broadband is rocketing in areas where 3G or 4G is available. Arguably, we are today only at the beginning of a revolution in which fast mobile broadband is in the process of overtaking if not replacing fixed broadband in the way that mobile voice telephony has been crowding out fixed line.

1. Introduction

What is 4G? Sometimes referred to as 4G Long Term Evolution (4G LTE) it is the successor mobile technology to the 2G and 3G systems currently widely prevalent in Europe[1]. With higher download speeds, greater overall capacity and more rapid response than predecessor technologies 4G generates such improvements in mobile internet access that make it the equivalent of high speed fixed broadband in terms of most technical parameters. It is not inconceivable that a quiet revolution is on the way with fast mobile broadband overtaking if not replacing fixed broadband in the way that mobile voice telephony has been crowding out fixed line.

How to measure the economic and social impact of such a development? In 1987 Robert Solow commented, "we can see the computer age everywhere but in the productivity statistics"[2]. The same applies today with respect to the internet in general, as well as to broadband and mobile technology in particular. For example, in a recent study on the impact of the internet by the McKinsey Global Institute it is noted that "The Internet seems to be everywhere around us today. Yet the extent of its economic impact has been relatively unclear. Much of the impact of the internet and the way that it contributes to growth and raising standards of living have gone unmeasured."(McKinsey Global Institute 2011a p.7).

Identifying and measuring the economic and social impact of the emerging 4G technology represents the same kind of challenge. Rather little research has been done on the impact of 4G itself – partial exceptions here are the Capital Economics (2012) report for the UK and the report by Deloitte (2012) for the United States. However, these studies are essentially synthetic or derivative, with no direct empirical research, with the impact of 4G inferred from studies of the impact of the replacement of, say, dial-up by broadband. The evolution of 4G has been so fast and so recent that the data needed for a direct scientific evaluation of 4G is simply not yet available.

Because Sweden and Estonia are countries which are among the most advanced in Europe in terms of the adoption of 4G there is some direct evidence on impact especially on the macro-economic impact of roll-out investments. However, beyond that, appeal is made to indirect synthetic evidence from the literature.

1 However, it should be noted that according to Zuk (2013) "there is no universal standard for what counts as a 4G network. The G simply stands for "generation" and indicates that the technology is significantly superior to its predecessor".

2 *New York Times* 20th May 1987, p. A1.

The next section offers an overview and discussion of different theoretical approaches to estimating the economic impact of 4G. Section 3 provides an assessment of where Sweden and Estonia currently stand in terms of the roll-out of 4G while section 4 provides a discussion of how roll-out and the spin-offs from 4G roll-out can be expected to develop in Sweden and Estonia in the medium term while section 5 offers some estimates of the macro-economic impact of investments in the roll-out of 4G together with a discussion of the medium term impact on productivity and growth. Section 6 contains a concluding discussion.

2. Some theoretical considerations: characterisation and measurement of impact

A useful theoretical starting point is provided in OECD (2013) where three approaches to measuring the economic impact of the internet economy are identified. Applied to measuring the impact of 4G these can be interpreted as:

- The *direct approach*: which would measure the share of GDP that is or can be expected to be generated by 4G related activities.
- The *dynamic approach*: this aims to measure the *net share of additional* GDP generated by or attributable to 4G related activities.
- The *indirect impact*: this is the impact that goes beyond GDP and is related to the broader welfare gains that might be generated by 4G some of which can be captured by consumer surplus.

The direct approach

The direct impact of 4G may be defined as the value added generated by the economic activities that either directly support 4G or are based on 4G. In other words, this approach attempts to measure the direct contribution to GDP that can be attributed to 4G activities. These activities can be:

- Activities undertaken for the operation and use of 4G e.g. production of equipment to support 4G or the direct provision of 4G services.
- Activities purely based on 4G, e.g. search, e-commerce or digital content.

The direct approach may be thought of as a 'static' approach – it aims to measure the scale of value added (contribution to GDP) by 4G at a given time. Although simple enough to describe in theory, in practice it presents major challenges for measurement. The problem is that 4G (like the internet in general) is a 'general purpose technology' that is used and can potentially be used in nearly all sectors of the economy. In that sense it is rather like electricity whose impact on the economy goes well beyond the valued added by the production and distribution of electricity.

The dynamic approach

The dynamic approach to measuring the impact of 4G seeks to identify and quantify the net share of additional GDP that is generated by all 4G-related activities. These can be of two kinds:

- The short/medium run effect that results from the construction of 4G networks. This would include multiplier effects or the so called 'supply chain effects' i.e. the induced upstream activities that support 4G.
- The longer term effects on GDP that arise from: potential productivity gains, reduced search costs, better/faster access to information or improved search and matching processes, new products or services.

The dynamic approach aims to identify and measure the growth in GDP or in productivity associated with the deployment and use of 4G and in that sense it represents that part of the gain to society from 4G that in principle can be captured by GDP or other standard macro-economic data.

The indirect impact (or extra GDP impact)

This approach considers aspects of the economic and social impact of 4G not captured by GDP. These impact areas include:

- The impact of 4G on consumer surplus i.e. the impact on consumer well-being over and above what can be captured by revenues accruing to service providers.
- The broader welfare gains generated as a result of 4G (e.g. welfare gains derived from non-monetary transactions, impact on the environment, social capital formation etc.).

Perhaps 'indirect' is something of a misnomer here because some of the non-GDP gains are really quite direct e.g. the gain in consumer surplus, which can be thought of as the gain in consumer satisfaction from the use of 4G services and products over and above what is paid for them is a direct (but possibly difficult to measure) benefit associated with the availability and use the new technology. On the other hand possible effects on the environment or on the creation of social capital may indeed be regarded or characterised as indirect.

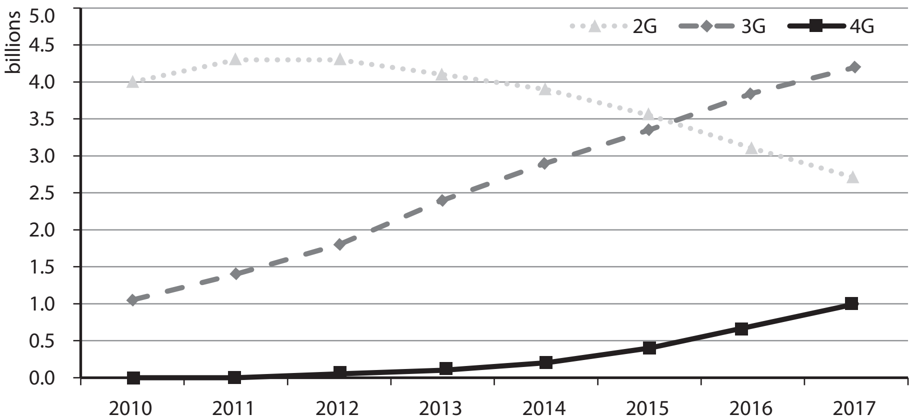
3. Where do we stand today?

Global market trends

Currently, there are 3 different wireless technologies available in the global mobile telephony market: 2G (EDGE), 3G (UMTS/HSPA) and 4G (LTE). While 2G has limited applicability, storage and communication capacity; 4G comes with a very broad capability for all personal electronic devices, cloud computing, multi-device accessibility, video calls and collaboration via cloud. If predecessor technologies have been mainly designed for mobile devices (incl. tablets and laptops) and their use is constrained by available device memory, then 4G significantly broadens the scope of devices by expanding the capacity to process and store information beyond the physical memory of installed devices.

At the end of 2013, fast broadband access (i.e. defined by 30Mbps or more) represented around 30% of the global broadband market (incl. fixed broadband) according to IDATE information (Chaillou (2014)). While the overall global market for faster broadband is growing everywhere, the growth of fixed broadband has slowed down, but mobile broadband has rocketed in regions where 3G or 4G is available. It is expected that the first billion mobile broadband users will be reached in 2017 (Digital Strategy Consulting (2013)). The uptake of 3G and 4G depends on the region and on the timing of when these technologies are made available by governments and communication service providers (CSPs).

Figure 1: Worldwide mobile connections by technology (2010-2017)



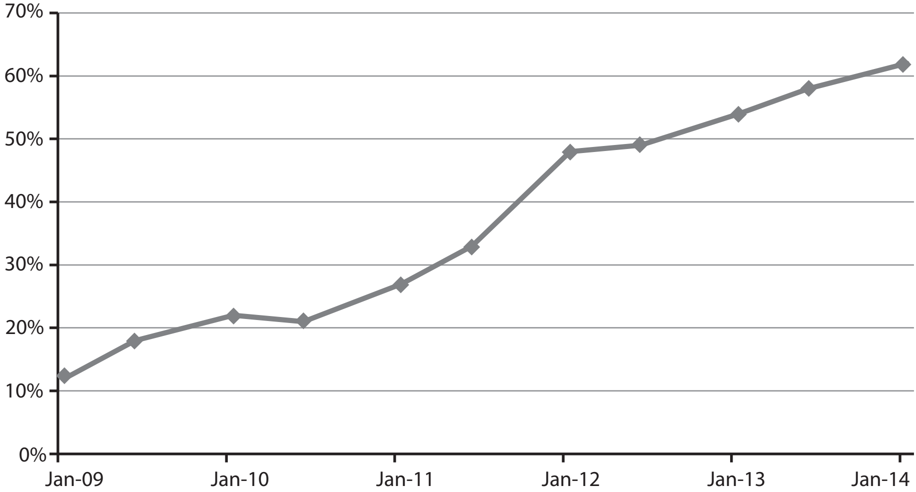
Source: Ekholm (2014)

According to Gartner predictions (Ekholm (2014)), the position of 2G networks will decline from 62% of the mobile market in 2013 to 35% in 2017 (Figure 1). Since 3G is still expanding in many countries, it will replace 2G and will grow from 35% in 2013 to 59% in 2017. Whereas, the uptake of 4G will depend on factors such as: the spectrum made available for CSPs, the level of concurrent rollout for 4G and the affordability and attractiveness of personal electronic devices that are available for end-users.

Sweden and Estonia in an EU context

Mobile broadband penetration in the EU has increased strongly in the last 5 years reaching 62% in the beginning of 2014, but this has happened mainly as a result of the 2G and 3G networks (Figure 2). Market penetration in 4G is still below 10%, which is partly because there is not enough good coverage and partly perhaps because not enough attractive offers are available to persuade consumers to switch to the new technology. Also, in several EU countries the government has not allocated the necessary spectrum for 4G network development (i.e. Bulgaria, Cyprus and Malta).

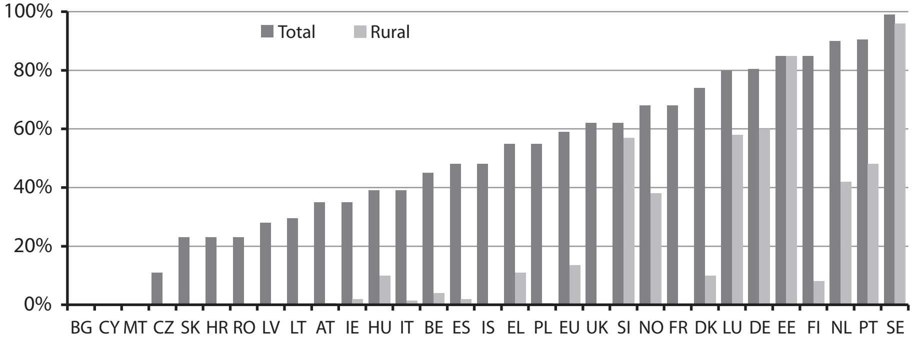
Figure 2: Mobile broadband penetration at the EU level (Jan 2009 – Jan 2014)



Source: European Commission (2014), Digital Agenda Scoreboard

Sweden and Estonia – our markets of focus - are EU leaders in terms of both total 4G network availability and availability in rural areas. Overall, total 4G coverage by area is currently 95% in Estonia and expected to be 90% in Sweden in 2015. Figure 3 shows availability by population in 2013 across the EU. Total 4G availability by population in Sweden was 99% and 96% in rural areas and in Estonia rural area coverage was 85%. The Netherlands and Portugal have higher total network availability than Estonia, but availability is below 50% in rural areas. This can be interpreted as an indicator of poorer overall quality of the 4G network in these countries. In most EU countries 4G availability is below 60% and is significantly lower than this for rural areas. Thus it appears that mobile broadband has emerged as a competitor for fixed broadband in areas where both are available, but in rural areas, where fixed broadband is not available and 4G could provide a viable alternative, 4G development lags.

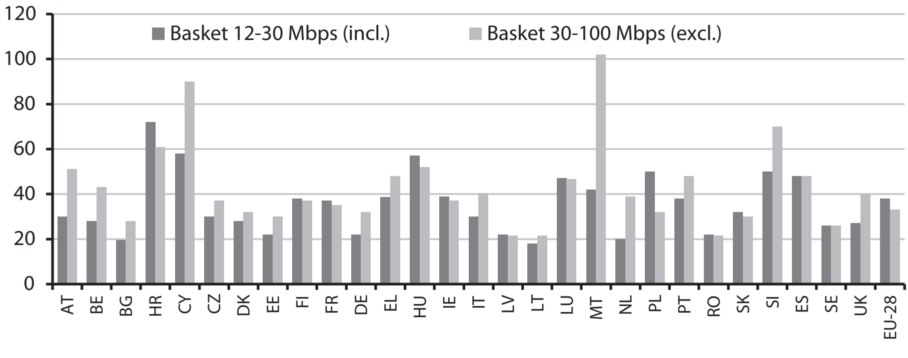
Figure 3: 4G network availability by population in EU countries (2013)



Source: European Commission (2014), Digital Agenda Scoreboard

Retail prices (PPP) for broadband stand alone offers are mainly in a range of 20 to 40 EUR per subscription (Figure 4). The cheapest offers are in Romania, Lithuania and Latvia. Prices in Sweden are below the EU-28 average, which means that prices for newest technology are not necessarily higher than for older technologies. For example, retail prices in Malta and Cyprus are significantly higher despite the fact they have no 4G services.

Figure 4: Broadband retail prices (EUR PPP) – stand alone offers, 2014



Source: European Commission (2014), Digital Agenda Scoreboard

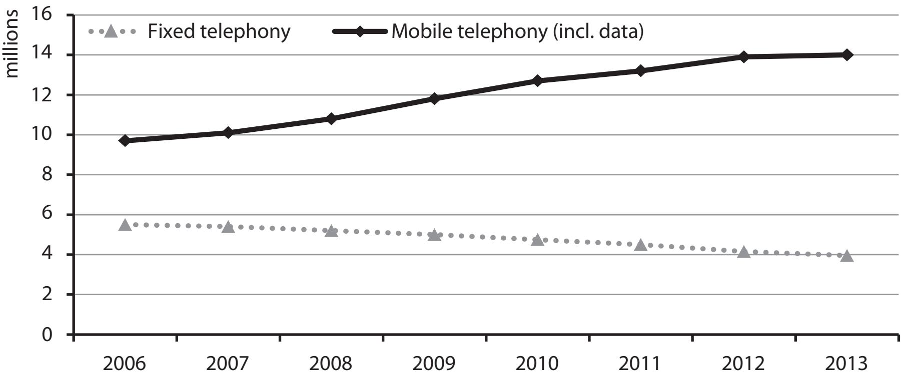
Sweden

Sweden, similarly to many other European countries, is in the process of a general transition from fixed to mobile network services. Fixed call services are declining, whereas mobile call and data services are growing, although at a slower pace than at the beginning of 2000s (Figure 5). As of the end of 2013, there were a total of 14.2 million mobile subscriptions in Sweden, which is 252,000 more than on the same date the previous year.

Mobile broadband as an add-on[3] service continued to account for the greatest increase in mobile subscriptions, although the rate of increase has slowed as compared with the year before (Figure 6). On 31 December 2013 there were 5.6 million such subscriptions, as compared with 4.9 million on the same date in 2012. This corresponds to an increase of 683,000 subscriptions, or 14 per cent.

The number of subscriptions for mobile broadband was almost 7.8 million at the end of 2013, which is an increase of 770,000 subscriptions, or 11 per cent, since 2012. Of these subscriptions, 28 per cent were for mobile broadband as a stand-alone service and 72 per cent were for mobile broadband as an add-on service, which is the fastest growing segment in the last years.

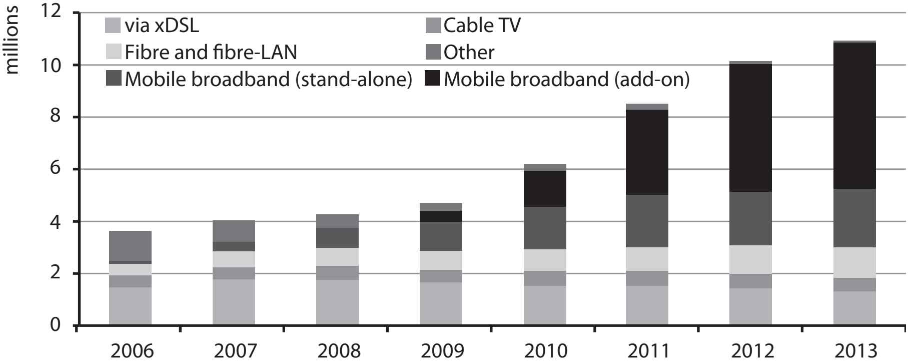
Figure 5: Number of fixed and mobile telephony subscriptions



Source: Swedish Post and Telecom Authority (2014a), The Swedish Telecommunications Market 2013

3 An ***add-on mobile broadband*** subscription is defined as one in which the mobile data service is a part of a bundle that includes calls, messaging and data, whereas with a ***standalone mobile broadband subscription*** the mobile data service is separate and not bundled with other services.

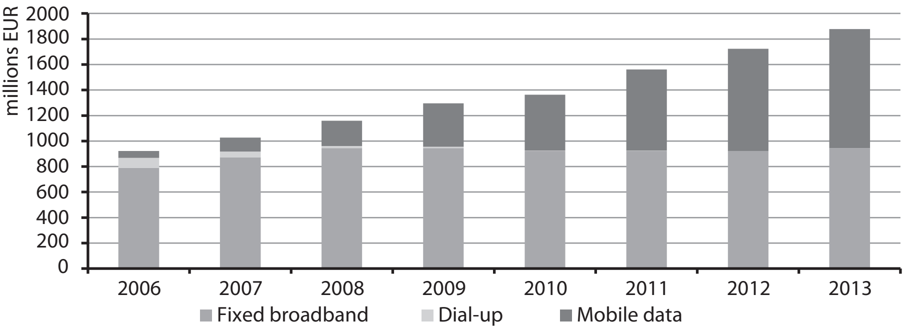
Figure 6: Number of broadband and internet services subscriptions



Source: Swedish Post and Telecom Authority (2014a), The Swedish Telecommunications Market 2013

In Sweden, revenue from mobile data traffic increased by 17 per cent in 2013, from SEK 7.0 to just under SEK 8.6 billion, and revenue from mobile data made up 29 per cent of total revenue from mobile call and data services (Figure 7). Clearly, mobile broadband meets a market demand and in the process has squeezed out some demand for fixed broadband because of the advantages of mobility and economies of scale (similarly to trends in mobile voice telephony against fixed voice).

Figure 7: Revenue from the end-user market for fixed internet services and mobile data



Source: Swedish Post and Telecom Authority (2014a), The Swedish Telecommunications Market 2013

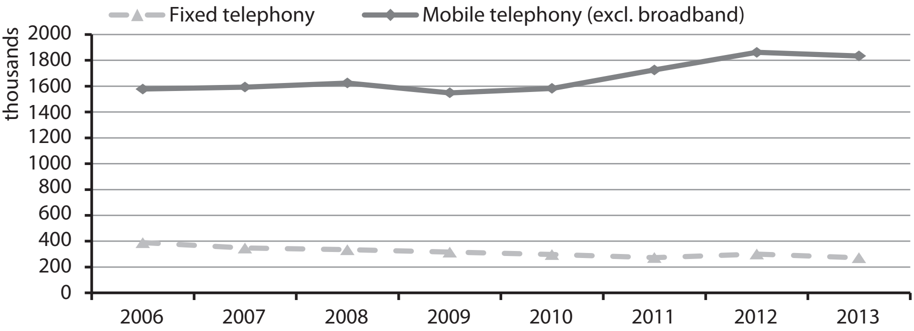
An important factor affecting market dynamics is the substantial increase in transmission speed over the last 5 years. 70% of broadband users now have at least 10 Mbps download speed and 30% of fixed broadband users have optical fibre, which offers at least 100 Mbps downstream – this degree of penetration has been achieved over 2009-2013 (Swedish Post and Telecom Authority (2014)). People are increasingly getting used to high-speed internet on mobile devices just as they have on their devices in the office or at home and this is a reason for the significant growth of mobile broadband subscriptions between 2011 and 2013.

In 2013, data traffic on mobile networks continued to increase at a high rate, although the percentage increase was not as large as that of the previous year. 270,300 TByte were sent and received on mobile networks in 2013, as compared with 176,000 TByte in 2012 (Swedish Post and Telecom Authority (2014)). This corresponds to an increase of 54 per cent. This compares with an increase of 75 per cent between 2011 and 2012. On average, a user used 7 GByte of data for a stand-alone service, 1.3 GByte for add-one service and 0.2 GByte for both call and data, but without add-on service for broadband.

Estonia

Estonia is a country with high mobile penetration and internet usage. 80% of Estonian households have Internet access and there are 1.6 mobile subscriptions (incl. prepaid cards) per person. Estonia is implementing the "EstWin" project that will provide countrywide broadband connection with at least 100 Mbps by 2018, including rural and other sparsely populated areas. Bundled offer penetration was 22% in July 2012: 85% of all broadband services, 96% of all telephone services and 78 % of all cable TV services are purchased in bundles. Historical trends indicate a decrease in fixed voice telephony services and satiation of mobile voice telephony (see Figure 8). The decrease in mobile telephony subscriptions observed in 2013 was the result of a fall in prepaid mobile services.

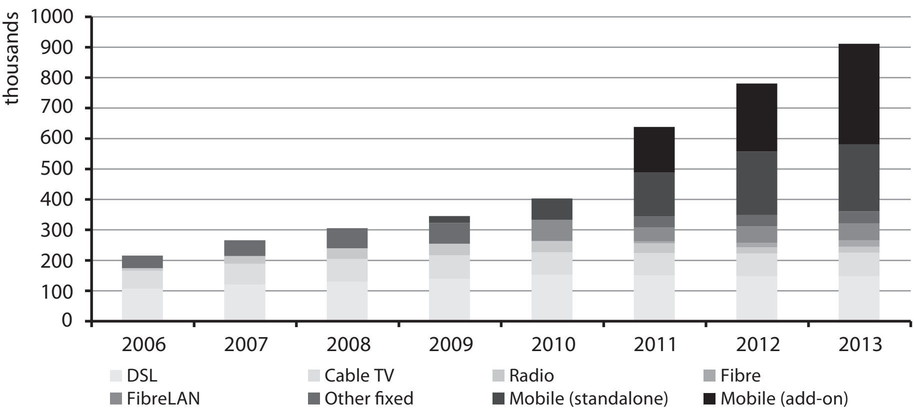
Figure 8: Number of fixed and mobile telephony subscriptions



Source: Swedish Post and Telecom Authority (2014b), Telecommunication Markets in the Nordic and Baltic countries

Estonia is one of four countries in the world with a nationwide 4G network. In 2009, the layout of broadband was designed to reach 98% coverage by 2020, so that no inhabitant is further than 1.5 km from the closest network access point. Internet subscriptions in 2013 reached 907 thousands, of which 61% is already for mobile data (Figure 9). Most of the expansion in this segment has taken place over 2011-2013.

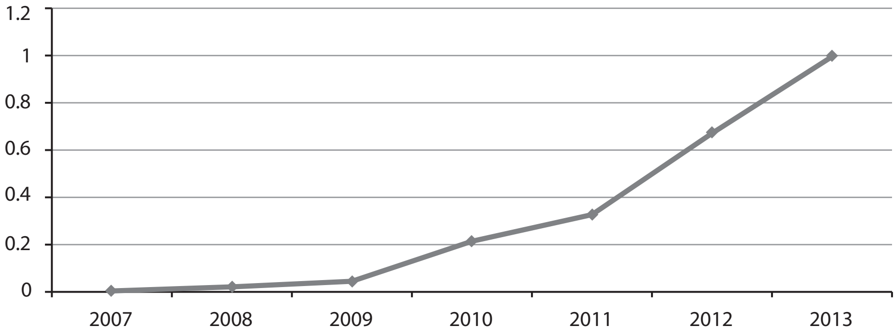
Figure 9: Number of broadband and internet services subscriptions



Source: Swedish Post and Telecom Authority (2014b), Telecommunication Markets in the Nordic and Baltic countries

With the expansion of the mobile data segment, there has also been a significant increase in the traffic of data. An end-user consumed on average 1GByte of data per mobile subscription in 2013, which was 43% more than a year before (Figure 10). Overall Estonia appears to follow Sweden in terms of market dynamics and development.

Figure 10: Traffic for mobile data services (GByte/month)

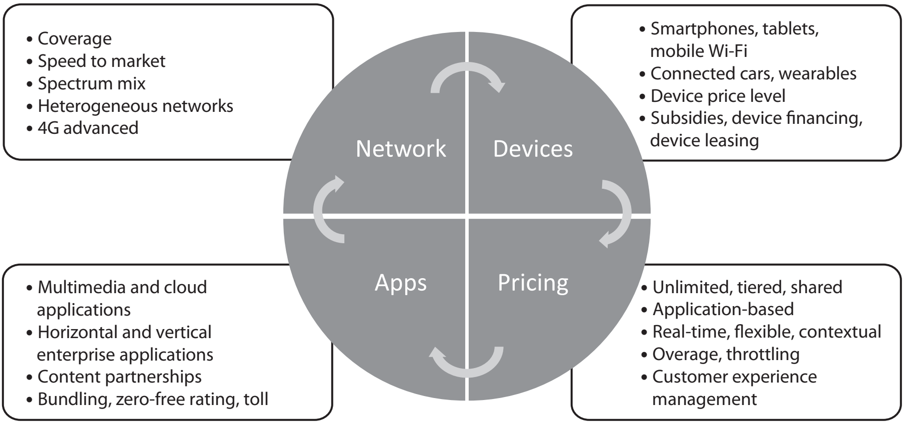


Source: Own calculation on data from Swedish Post and Telecom Authority (2014b), Telecommunication Markets in the Nordic and Baltic countries

4. Expected developments

According to (Ekholm 2014), four main factors determine the degree of 4G network penetration: network availability, availability of devices, pricing and apps (Figure 11). Network development depends on government decisions on spectrum availability for communications service providers (CSPs) and competition among CSPs in particular to realise first mover advantages. From the demand side it is important that personal electronic devices are available, popular and used among consumers. Pricing is important and pricing models are important for how quickly users upgrade technologies. Also, the development and spread of applications determine the pace of developments after the initial upgrading of technology. An abundance of these positive factors can be expected to result in a very rapid growth of penetration for 4G, while poor conditions with respect to one or more factors may result in sluggish growth.

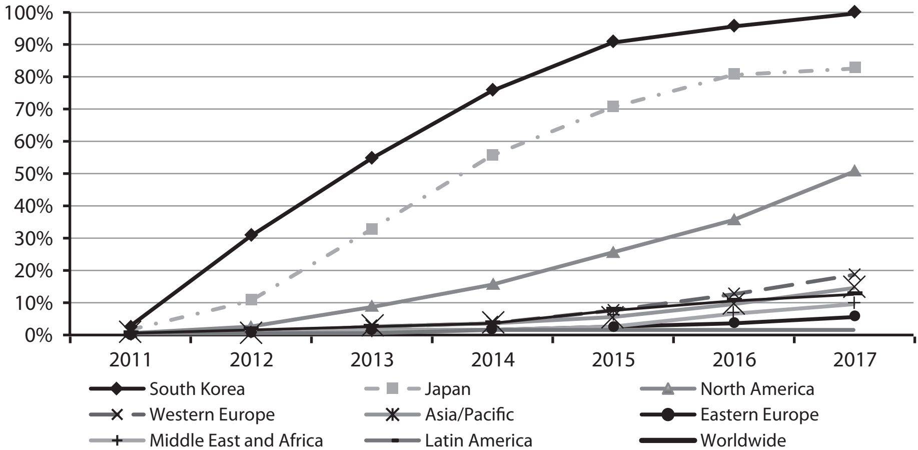
Figure 11: 4G network adoption circle



Source: Ekholm (2014)

Ekholm (2014) predicts that global 4G network coverage will increase from 10% in 2012 to 45% by the end of 2014. However, penetration is expected to lag coverage (Figure 12).

Figure 12: Projections of 4G network penetration globally



Source: Ekholm (2014)

As a result of competition and higher demand for 4G supported devices the price of devices is expected to fall below EUR 120 which is low enough for mass-market uptake of 4G services. From 2015 onwards, the price difference between 3G and 4G services is expected to shrink to less than 5%.

There are 3 plausible scenarios for the medium term development of 4G markets:

1. Very rapid and high penetration like in South Korea and Japan (high population density, cheap devices and active government).
2. Moderate growth and penetration like in the US (stiff competition, but high diversity of population density).
3. Slow growth and penetration as currently experienced in many European countries ("slow" governments and oligopolistic competition).

It is most likely that further growth in Sweden and Estonia, which are among the clear leaders in 4G development in Europe, will be more modest than hitherto since population density is unevenly spread in these countries, and the first movers (CSP) have already set barriers for new entrants. Therefore, CSPs will be less eager to provide such beneficial deals for end-users as hitherto, especially since already the price levels for mobile broadband are among the most competitive in the EU.

5. Estimated impacts

This section attempts to quantify some of the impact of 4G deployment with Sweden and Estonia as case studies. We start by applying the dynamic approach which is in some ways the most interesting i.e. how big is the incremental impact of 4G on the economy? Complementary, with this is the change in benefits not directly captured by changes in GDP. Finally we briefly address the question of the 'scale' of 4G in the Swedish and Estonian economies.

5.1 The dynamic effects: how big is the incremental effect of 4G on GDP?

The dynamic effects of 4G can be split in to two kinds of effect:

- the macro economic impact of the investments needed to roll-out 4G;
- the longer run productivity and growth impacts.

5.1.1 The macroeconomic impact of roll-out capital investments

There are no available official figures in the size of investments undertaken to roll-out 4G in Sweden and Estonia so we have used estimates provided by one of the main players in the two countries namely TeliaSonera. Based on this information the estimated 4G infrastructure investment in Sweden and Estonia is for all operators as follows:

> **Sweden:** SEK 5billion (or EUR 551m) over 2009-2014 plus SEK 1.4billion (EUR 154m) over the next 7 years making a total investment of SEK 6.4billion or about EUR 705m.
> **Estonia:** EUR 38.7m over 2010-2014 and EUR 19.3 over the next 7 years making a total investment of EUR 58m.

These are significant but not huge investments with the scale of annual investments representing about 0.14% of gross fixed capital formation in Sweden and about 0.2% of gross fixed capital formation in Estonia. Alternatively, as a concrete comparison, the annual investments in Estonia represent the equivalent of investing in a quay each year (EUR 7m) at the Port of Tallinn (see Port of Tallinn 2013).

Another method of assessing the scale of Swedish and Estonian investments in 4G roll-out is to compare with the GBP 5.5 billion estimate for the UK by Capital Economics (2012). In order adjust for the different population size we have calculated the per capita investment which in the UK is estimated at GBP 86 and for Sweden GBP 57. The difference can largely be accounted for by the fact that nearly 40% of the estimated UK investment (GBP 2.3b) is accounted for by investment in base station equipment[4] whereas for Sweden and Estonia this is largely excluded because the majority of base stations used for 4G re-use the existing 2G/3G masts and infrastructure.

In addition to the direct investment effects as estimated above, there are potential multiplier or spill-over effects to be considered. Two kinds of multiplier effects can be identified:

- the so-called 'supply chain' effects which are captured by the impact of infrastructure expenditures on upstream local or national suppliers and typically can be estimated using an input-output approach;
- the standard macroeconomic multiplier effects that are the result of additional expenditures made by households out of incomes generated by project expenditures.

4 The other expenditures are those on installation and software and network upgrades.

How big are the multiplier effects? For Sweden some evidence is provided by the Boston Consulting Group (2014) study on the impact of Facebook investments in digital data centres in Northern Sweden: they estimate the supply chain multiplier as 1.7 so an investment of EUR 1 billion could be expected to create an extra EUR 0.7 billion of output through effects in the supply chain; the more standard expenditure multiplier effect they estimate at an additional 0.6 so that the combined multiplier is 2.3. In other words the overall effect of a EUR1 billion investment would be an output increase of EUR 2.3 billion. Similar calculations have been made by Deloitte (2011) for the US where, applying what they call 'industry specific multipliers'[5], they estimate an overall multiplier for 4G investments of 2.873.

In general the size of these multipliers also depends on the 'leakages' from the domestic economy, so that the more open an economy the higher the leakages and the lower the multiplier. This could in part account for the lower estimated multiplier for Sweden as compared with the US. Thus according to the World Bank Development Indicators, the share of imports in in GDP is 17% for the US and 40% for Sweden and if these averages also correspond to the marginal propensity to import, then for a marginal propensity to save of say 0.2 the expenditure multipliers would be:

$$\text{US} = 1/(0.2 + 0.17) = 2.7$$
$$\text{Sweden} = 1/(0.2+0.4) = 1.67$$

Of course the overall multiplier effects also depend on the industry specific effects and the marginal propensity to save may be different in Sweden as compared with the US. However, Estonia has an import level that corresponds to 87% of GDP so if the marginal propensity to import is anything like the average propensity the Estonian expenditure multiplier is likely to be close to 1 (i.e. a zero spill-over effect).

Table 1 shows the GDP impact of Sweden's 4G investments when alternative multipliers have been applied and Figure 13 illustrates diagrammatically.

Table 1: Cumulative GDP effects of Swedish 4G investments

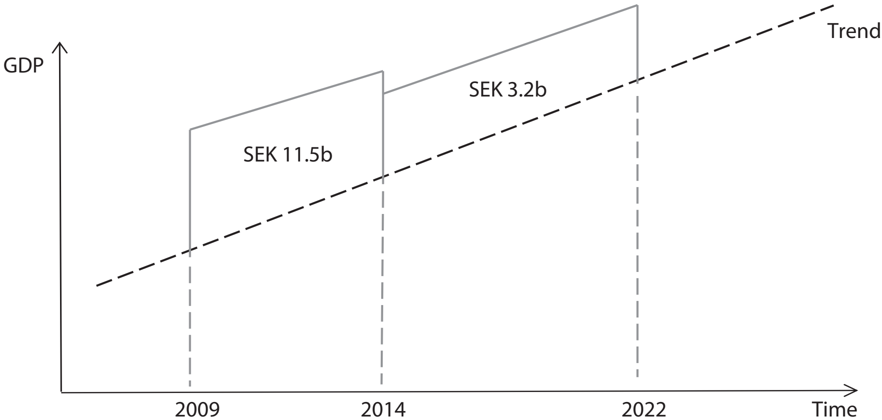
	2009-2014	2015-2022
Boston Consulting Group (Swedish data)	SEK 11.5b (EUR1.3b)	SEK 3.2b (EUR 0.35b)
Deloitte (US data)	SEK 14.4b(EUR 4.0b)	SEK 4.0b (EUR 0.44b)

Source: Own calculations

5 For wireless broadband the weights are 0.93 for wireless communications equipment and 0.07 for construction.

For Estonia the macro-economic impact of roll-out investments is smaller, partly of course because the investments are smaller and partly because the expenditure multipliers are likely to be smaller because of a higher propensity import. Also the timing of impacts is expected to be different from Sweden because roll-out started a year later in 2010.

Figure 13: Cumulative GDP impact of Swedish 4G investments



Unlike Sweden no direct multiplier estimates at all are available for Estonia. For Ireland, which is a small open economy like Estonia, O'Farrell (2012) suggests an impact multiplier of 1.6. This might not be unreasonable for Estonia and using this multiplier the GDP impact of 4G roll-out for Estonia would be:

- 2010-14: EUR 62m
- 2015-22: EUR 31m

Employment effects

Although several studies (Deloitte (2011) or Capital Economics (2012)) provide at least indirect information on the potential employment effects of 4G infrastructure investment the results are subject to considerable interpretation and are likely to be sensitive to where in the business cycle the economy is. Thus in a boom the net employment effect is likely to be considerably less than the first round impact effect. Moreover, just as with the GDP effect the employment impact of infrastructure investment is likely to be transitory – when the investment ceases the employment effect vanishes.

Just as with the GDP effects, the Boston Consulting Group (2014) study probably offers the most reliable estimates of employment effects in a Swedish context. They argue that an investment of SEK 1 million will have different effects depending on whether the investment is in construction or in computer equipment: for constriction SEK 1m is estimated to generate 1.28 fulltime equivalent jobs and a similar investment in computer equipment is estimated to create 0.64 full time equivalent jobs. The employment effect of investment in computer equipment is lower because of a bigger estimated leakage into imports. Accordingly an annual investment of SEK 1 billion would have an employment effect of

- 1280 jobs if all the investment is in construction.
- 640 jobs if all the investment is in computer equipment.

As a check one can note that the Capital Economics (2012) report suggests that the equivalent of a SEK 1 billion investment in the UK would have created just over 1300 jobs. This at the upper end of the range estimated for Sweden because of the dominance of base station construction in the UK estimates.

As with the GDP effects, for Estonia, the employment effects are likely to be considerably smaller because of higher leakages into imports.

5.1.2 Productivity and growth

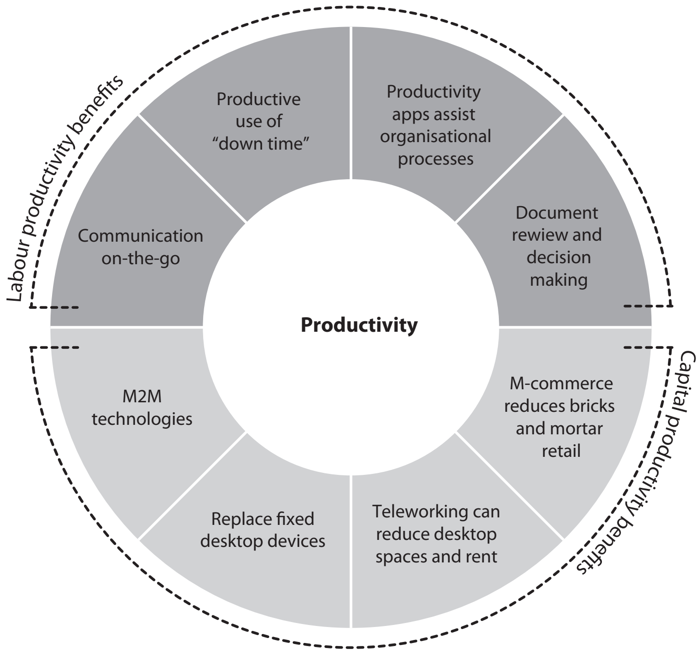
It is in its impact on productivity and growth that 4G will (and already has) contribute sustainable economic benefits rather than in the macro-economic effects of roll-out which although valuable (especially at a time of low economic activity as was the case in the Swedish and Estonian roll-out phases) are transitory. Here the impacts are easier to describe than to measure.

There are considerable reasons to suppose that mobile technology and networks have a significant impact on business productivity (especially in the service sector). Mobile technology can affect labour productivity by saving time of employees to do a particular task or capital productivity by reducing the need for specific devices, vehicles, office space and other capital resources.

An important productivity gain comes from communication “on the go” – sending and receiving emails, video calls, sharing and editing documents on a cloud without being physically in the office. Another aspect is productivity growth on “down time”. 4G can offer at least one fifth of the download times as compared with 3G (depending on country and provider) which means users do not spend time watching a file or email being loaded. Productivity and organizational apps can significantly reduce administrative resources and time needed to perform simple tasks (e.g. calendars, customer relation management, voting). These tools are nowadays available on mobile devices all the time.

According to the McKinsey Global Institute (2012), there is considerable unrealised productivity potential in mobile technologies. It is estimated that the productivity of interaction workers could increase by 20-25% with the implementation of social technologies: email communication can be moved to a social collaboration platform, searching and gathering information can be faster and immediate, supervision and decision making can be done without physical presence.

Figure 14: Productivity gains from mobile devices



Source: Deloitte Access Economics (2013)

In terms of capital productivity, businesses can save with teleworking (office rent, ICT and electricity), logistic apps (for more efficient exchange of information with distributors and suppliers), and m-commerce (on physical store space, warehouse occupancy and efficient inventory management).

These are powerful and plausible arguments but to date few empirical studies directly measure these impacts and translate them into productivity or growth numbers. The Capital Economics (2012) and Deloitte (2011) reports use studies of broadband impact and studies of mobile telephony impact to make inferences and draw conclusions. This is also the approach adopted here.

Measuring the impact of mobile technology on output and growth

The literature contains two kinds of approaches to measuring the impact of developments in mobile technology on growth and productivity:

- One approach is what might be called a 'case study' approach where researchers have attempted to calculate the difference the new technology can make to work practices.
- The other approach is econometric i.e. researchers have attempted to estimate what kind of difference various developments have made to GDP growth rates or total factor productivity.

Case study approaches

Case study approaches are focussed on measuring specific aspects of gains generated by 4G – most particularly the gains from time saved doing existing activities as a result of the faster speeds with 4G as compared with 3G. The study by Firth and Lazanski (2011) uses Ofcom data to estimate that for the UK a 4G system delivering an average speed of 6.6 Mbps would generate annual time savings of 37 million hours – time that would otherwise be spent watching devices download data. The value of this depends on the value attached to time saved. A conservative approach is to use the cost of time to employers[6] which yields an estimate of the annual efficiency gain of £730 million or 0.048% of GDP.

The Capital Economics (2012) study suggests that a better indicator of the value of gained time is value added per hour i.e. it should reflect lost output. On that basis the value of time saved would be £1.1billion or about 0.73% of GDP in 2011. The study by Entner (2008) for the US estimates that mobile wireless applications save 30 minutes per day and that this would apply to about 25% of the workforce. This translates into a 4G time saving gain of

6 This is assumed to be £19.60 per hour.

0.4% of GDP. Table 2 shows this range of possible benefits translated into SEK and EUR and applied to Swedish and Estonian 2013 GDP.

Table 2: Value of efficiency gain (time saved) under different scenarios

	Per cent of GDP	Sweden	Estonia
Saved wage cost	0.048	SEK 1.8 billion	EUR 9 million
Saved value added per hour	0.073	SEK 2.75 billion	EUR 13.67 million
Entner (2008) using US data	0.4	SEK 15.1billion	EUR 75 million

Source: Own calculations based on various researches

The Capital Economics (2012) study also suggests that with full-rollout (3-4 years) and realisation of potential together with growth of data a 'cautious estimate' of the efficiency gain might be 0.5% of GDP. This translates into SEK 18.9 billion for Sweden and EUR 93.7 million for Estonia.

Econometric approaches

The literature contains three kind of econometric studies on the relationship between mobile telephony and GDP growth:

1. What is the quantitative link between mobile penetration in general and economic growth?
2. How does a switch from 2G to 3G affect economic growth?
3. How does an increase in the use of mobile data affect economic growth?

1. *General impact:* A large number of studies have found a positive relationship between mobile penetration and growth of GDP and productivity. A good example is the paper by Gruber and Koutroumpis (2011) who use data from 192 countries over the period 1990–2007 to assess the impact of mobile telecommunications on economic growth. They find that the effect on high-income countries was almost double that of the effect in low-income countries – 0.20% as against 0.11%. For Sweden the GDP growth impact was estimated at 0.209% and for Estonia it was 0.196%. For some countries Gruber and Koutroumpis were able to estimate the impact on productivity growth, which generally was higher than the GDP impact. Thus for Sweden the contribution to productivity growth was 0.36%.

There are two problems with this approach: one is the so-called 'reverse causality' problem i.e. did mobile penetration 'cause' GDP growth or was it the other way round. Gruber and Koutroumpis (and other authors using this kind of approach) argue they have addressed this issue, but not everyone is convinced. The other problem is that in countries such as Sweden or Estonia mobile penetration as such is saturated and 4G is about the 'kind of mobile' rather than the quantum.

2. *The effects of an upgrade:* while substitution of 3G for 2G does not increase mobile penetration as such it may nevertheless generate measurable benefits on GDP growth. Econometric estimates in Deloitte (2012) based on a panel of 96 countries over 2008-2011 suggest that for a given level of mobile penetration a 10% increase in 3G penetration would increase GDP growth by 0.15 percentage points.

As before there is a reverse causality issue but additionally can we reliably apply figures based on a transition from 2G to 3G to the further transition to 4G? Will the effect be smaller? Or will it be larger? Arguably it could be larger because relatively speaking the transition to 4G may prove to be more 'revolutionary'.

3. *The mobile data effect:* an alternative metric to penetration rates by which to measure the impact of the higher capabilities of 4G is in its ability to handle a much greater quantum of data. Again Deloite (2012) offer an estimate of this effect based on a sample of 14 countries over 2005-2010 and report the result that for a given level of 3G penetration a doubling of data usage is associated with an increase of 0.5 percentage points of GDP growth. Again there are reverse causality/endogeneity issues.

5.2 Consumer benefits, consumer surplus and social effects

Consumers benefits

4G technology as compared with its predecessors has changed consumer behaviour completely – the mobile has become a universal device that serves almost all possible ways of communication, engagement and entertainment. First, consumers use around three times more data on 4G networks than they do on 3G networks. The observed increase in data usage has been mainly due to social media, video and video services that account for 57% of total data usage (Table 3). 4G networks enable high speed and high quality video streaming that has hitherto been confined to television. Most advanced users do not subscribe to TV services – they rather use local media streaming devices like Chromecast to transmit videos from their mobile devices to a TV screen.

Consumers are also using more shopping and banking apps due to increased reliability and speed. Every modern bank has its own mobile app that is secure and provides an almost full package of banking services. It gives flexibility and speed with which business and services can be done faster. The remote card reader is also an innovation that will spread more globally in near future. For example, with Square small and medium business sales personnel can accept banking cards wherever mobile connection is available. It extremely eases the life of consumers and business owners.

Table 3: Usage of the 4G network by Everything Everywhere (EE) consumers in the UK

Content	
Web browsing and email	35%
Social media	21%
Video uploading, downloading and streaming	20%
Video calling and other	16%
Music and apps	6%
File sharing	2%

Source: Informa Telecoms & Media (2014)

Evidently, there should be higher growth coming from 'music and apps' and 'file sharing' in the near future. Traditional music devices are losing popularity, but consumers have one or several of them that can still be used. Due to limited hard drive space on most mobile devices and rocketing need for data storage, data storage on a cloud is growing very fast. According to IT Business Edge, already in 2013 60% of businesses had chosen to store their data in the cloud due to lower storage and maintenance costs. Since private users have smaller need for data storage, the transition to the cloud technology will be slower, but still inevitable. Thus, we might expect that users will store most of their media files and documents in the cloud in the near future, as media files become larger and with higher quality.

Higher consumer benefit explains user willingness to pay more for their mobile data services, which results in a 2.5 times higher ARPU for data services of 4G as compared with 3G. Despite the fact that price per data minute is decreasing, consumers on average are spending more money on monthly mobile subscriptions due significantly growing data usage. Some of the monetary savings because of 4G technology thus accrue to 4G CSPs – as people spend less on some services (e.g. banking, post) they have to return some of these savings to pay for a more efficient technology

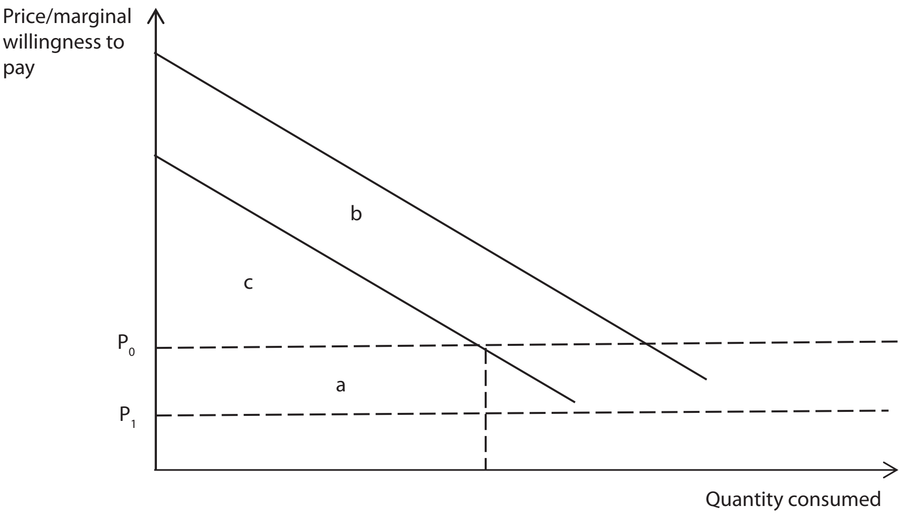
Consumers surplus

Consumers surplus represents the benefit consumers enjoy from consuming a product over and above what they pay for it or what is captured by revenues accruing to suppliers. Thus it represents a form of benefit not captured by GDP. The deployment of 4G can be expected to increase consumers surplus in the following ways:

- A lower price for existing services consumed;
- Better quality of existing services consumed;
- The benefit to consumers over and above their willingness to pay a new product or services.

These effects are illustrated in Figure 15.

Figure 15: Consumers surplus gains illustrated



The area *a* in Figure 15 illustrates the gain from being able to consume existing services for a lower price i.e. from a fall in price from P_0 to P_1; the area *b* illustrates the increase in willingness to pay for a quality improvement and the area *c* can be interpreted as the gain from the introduction of a new service or product at the price P_0. In principle these consumers surpluses can be estimated if we know the demand curves (willingness to pay) illustrated in Figure 15. However, such information is typically not available in a direct form and especially not for products or services not yet available but which could be once 4G is more widely adopted. In the absence of such data researchers have used a variety of indirect techniques to elicit willingness to pay, e.g. survey methods or time spent on the internet. However, to quote Capital Economics (2012): "overall the evidence is patchy and at times implausible" (p25). Nevertheless, the Capital Economics study concludes that the annual consumer surplus in the UK for existing users of mobile data services represents between 0.06% and 0.09% of GDP. This translates into between SEK 2.24 billion and SEK 3.5 billion in terms of 2013 GDP for Sweden and for Estonia into between EUR 11.1 million and EUR 17.3 million. These estimated gains correspond to the areas *a* and *b* in Figure 15, but do not include potential consumers surplus on new services and products (area *c*) which is likely to be quite significant in the medium to long run.

Long run employment effects

It is not at all obvious what the medium to long run employment impact of 4G is likely to be. Unlike the impact of the construction phase of 4G development even the short run employment impact of the changes induced by 4G is uncertain. Are the changes likely to be labour-using or are they labour-saving? Probably both kinds of change are likely to be observed and 'lost' jobs in one area are likely to be replaced by created ones in another. In the long run the evidence is that productivity growth and employment are complementary. For example McKinsey Global Institute (2011b) report that in the United States, over an 80 year period (1929-2009), there has been only one ten-year period where employment declined while productivity increased, whereas there were 7 ten-year periods when both productivity and employment increased.

Social Impact

Mobile broadband technologies have emerged and transform almost all aspects of consumer social life: relationships, community, work, individual and national governance.
Thus we observe that:

- consumers are increasingly connected;
- immense data are stored and secured on cloud;
- there is expansion of content and video in mobile devices;
- new business models.

During the last years, mobile devices have significantly enriched digital experience: in addition to calls and messaging mobile devices offer photo, video, maps, location-based services, internet, social networks, gaming and millions of services that have become daily necessity.

The convenience and efficiency of additional functionality makes consumer lives easier but also dependent on technology.

Mobile technologies significantly increase interpersonal communication that allows contacting anyone from anywhere at low or no costs. For a fixed subscription fee consumers can receive unlimited voice, video and messaging services via different applications. Also, consumers can record a message and send it to the recipient via storage in the cloud. In general, consumers can keep in touch with more people on a smart phone than on a simple phone or a computer. Verbal and non-verbal communication becomes real-time and effective.

Mobiles and 4G networks have an impact on re-shaping work the environment – people can work not only from home or a public space, but also while being in transit. There is flexibility in combining personal life with work, not sacrificing one or other. People can work from a distance and save on commuting or long-distance drives. Increased mobility and flexibility transforms offices. There is more and more short-term co-working office space available for people in need of occasional physical office space, meeting rooms or reception services. It is crucial for start-ups or small businesses that are sensitive to office rent costs.

Development of social media is responsible for the emergence of virtual communities that can exist with a small number of members and low income. At the same time these communities can provide active involvement due to virtual connectivity. Some virtual communities are disrupting traditional businesses by offering a cheaper and socially more engaging environment. Examples of such businesses include: Airbnb, a peer-to-peer accommodation service, which represents competition for hotels by offering cheaper and more home like accommodation while travelling. Uber and Lyft compete with taxi companies by creating an informal transportation market. Amazon competes with book and general stores, offering a full range of books, digital content, electronics and home goods. Coursera deformalizes education with the creation of a cheap and high-quality lifelong learning platform. Square, WiseTransfer and PayPal compete for the money transfer market with banks. The business models of most of these apps could not exist without mobiles and the 4G network.

Interconnectedness and speed in social networks provide instant news or can mobilize large masses of people with the same problem. Revolutions in the Middle East have taken place due to mobile networks and social media. The very fragmented market for mobile apps is hard to control or censor by governments. If government can control media and its content in technologically undeveloped countries, it is much harder in a country where technologies are available and evenly spread out. Mobile network and content diversifies traditional media and works as a catalyst for truthful information.

Technologies also transform some daily actions providing wireless signals to vehicles or home devices. It is possible to manage energy consumption in the house remotely from your mobile phone. There are apps that can unlock cars doors, bike locks, home doors with a smart phone. You can avoid traffic jams by checking real time maps for traffic speed. There are apps where you can check availability of parking space in a particular area. Especially, cities become "smarter", because city councils and citizens get used to big data services that provide real time information for many services; thus, increasing convenience and efficiency in cities.

Benefits from mobile technologies are already significant, but continue to have high upside potential, because there are many opportunities for productivity and effectiveness gains in areas such as: energy, healthcare, education and other primary sectors that are highly regulated.

An important potential social effect is on rural and other sparsely populated communities where fast fixed broadband is not available and may never be available. Here 4G can effectively bring equivalent benefits to such communities.

5.3 The scale effect – how big is 4G?

According to the Swedish Post and Telecom Authority (2014) the size of the end-user market for electronic communications in 2013 was just over SEK 52.3 billion which represented 1.39% of Swedish GDP in 2013 of which nearly 55% was generated in mobile call and data services[7]. This makes the scale of the Swedish electronic communications sector rather similar to that of say the manufacture of paper and paper products or about one fifth of the size of the retail sector. Mobile data in turn generated SEK 8.6 billion representing more than 16% of total electronic communications revenues.

According to the Estonian Competition Authority (2014) the estimated turnover of communication services provided by market operators in 2013 was EUR 675 million. This represents about 3.6% of GDP and is therefore a relatively bigger sector than in Sweden. Of this mobile telephony generated just over 37% of total revenues.

In summary the 'mobile' sector in both countries represents a significant part of the electronic communications sector (more than 50% in Sweden) and the importance of mobile broadband has been growing strongly in both countries.

7 Revenue is in general larger than value added which is the most useful indicator of the size of a sector. Thus for 2011 value added in telecommunications in Sweden was just over 1% of GDP.

However, it needs to be recognised that because 4G is a general purpose technology such 'share of mobile' statistics significantly understate the overall impact of the new technology.

6. Concluding remarks

4G is the next phase of the mobile revolution. Development is well advanced in Asia and the United States but lags in Europe. However, in Europe, Sweden and Estonia are in the vanguard of 4G development. How big will the impact of 4G be? It is tempting to see it as a marginal change relative to 3G and that diminishing returns are likely to set in. While it is too early to be sure, the whole history of the digital revolution warns against this. What was once regarded as science fiction a generation ago is now commonplace in the digital arena. Thus, rather than diminishing returns there are reasons to suppose that the network and social externalities of 4G will generate increasing returns and as yet unimagined impacts and benefits.

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