Chapter 2.

Infrastructure for Sweden's digital economy

This chapter examines trends and structural features of the telecommunication market as well as broadband infrastructure and services. It concludes with recommendations to continue to spur broadband deployment and use in Sweden.

Connectivity provides access to information and communication technologies (ICTs) – the backbone of today's digital economies and societies. The Swedish government has set an ambitious broadband targets to achieve ubiquitous "ultra-fast" broadband connectivity by 2025 and progress is reviewed in this chapter.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

This chapter examines trends and structural features of the telecommunication market in Sweden. It provides an overview of investment and revenue in the communication sector, including the fixed and mobile broadband markets, and developments in machine-to-machine (M2M) subscriptions, as well as in the deployment of key enablers such as IPv6. Furthermore, it examines developments in Sweden related to access and connectivity, such as infrastructure sharing, next-generation networks, and the regulatory treatment of communication bundles.

Communication networks are critical for the development of the digital economy. Mindful of their importance, the Swedish government has set forward successive broadband strategies to achieve connectivity goals. The most recent Broadband Strategy of 2016 has set an ambitious agenda for 2025. This chapter examines progress to date and concludes with a consideration of further measures to spur broadband deployment and use in Sweden.

Objectives and challenges for Swedish digital infrastructure

By most measures of telecommunication infrastructure and service development Sweden has always been among the leading OECD countries. Keenly aware of the importance of the sector for economic and social development, successive governments have set out plans and goals to meet their objectives. As early as March 2000, for example, Sweden proposed goals to make information and communication technologies (ICTs) available to all people. This included making funding of USD 0.9 billion available for broadband infrastructure deployment in regional areas, which can in some ways be considered as the policy that kick-started broadband developments in Sweden (Mölleryd, 2015).

In 2009, Sweden set out a strategy for where it would like to be, in terms of broadband infrastructure, by 2020. The ambitious goals surpassed those set by most peers and those found in the Digital Agenda for Europe. The main target was to achieve 90% coverage of households and business with 100 megabits per second (Mbps) by 2020. In 2017, the Ministry of Enterprise and Innovation expected this goal to be fulfilled as planned. While most of the investment has come from market participants, including private as well as publicly owned network operators, investment in the sector was complimented by public funding in the order of USD 0.19 billion for the 2007-13 period, and USD 0.57 billion for the period 2014-20.[1] In addition, property owners contribute to financing the roll-out of next-generation networks by making an upfront payment for the instalment of fibre infrastructure leading to their properties.

Sweden completely connected by 2025: The 2016 Broadband Strategy

Given that the targets established in the 2009 plan are expected to be achieved,[2] the government published a new Broadband Strategy in December 2016 with the aim of achieving "access to high-speed broadband in all of Sweden" by 2025 (Government Offices of Sweden, 2016). This goal has three milestones: achieve 95% of connected households and businesses by 2020 with broadband of at least 100 Mbps; by 2023, all of Sweden should have access to reliable high-quality mobile services; and by 2025, 98% of the population should have access to 1 gigabit per second (Gbps) broadband in their residences and workplaces, the remaining 1.9% with 100 Mbps, and 0.1% with 30 Mbps (Government Offices of Sweden, 2016).

To fulfil the goals set out in the 2016 Broadband Strategy, the Swedish government has focused on, among other things, three strategic areas of work: i) roles and rules; ii) cost-efficient network deployment; and iii) enabling infrastructure and services for everyone (Government Offices of Sweden, 2016). In other words, the different roles and

rules for operators in the broadband market still need to be clarified, incentives have to be clear for cost-efficient network deployment, and obstacles for co-operation between players and technologies mitigated or eliminated. Thus, the main emphasis of the Broadband Strategy is to foster the market-driven deployment of broadband networks, supplemented with public support.

The authorities responsible for the Broadband Strategy in Sweden are the Ministry of Enterprise and Innovation, the Swedish Post and Telecom Authority (PTS), and the Broadband Forum, which has its administrative offices within the PTS.[3] The Ministry of Enterprise and Innovation is responsible for topics related to, among other things, regional development, transport and ICTs. The PTS monitors and regulates the communications market to ensure that every citizen has access to affordable and efficient communication services, and the Broadband Forum, established in 2010, is tasked with providing an arena for dialogue among different stakeholders (i.e. government, public authorities and firms) of the Swedish broadband market (European Commission, 2017b).

The Broadband Forum, which has a steering committee headed by the Ministry of Enterprise and Innovation, has served as an important form of co-operation contributing positively to fibre expansion in Sweden. Among other things, namely it has: i) contributed to increasing the collaboration between public and private players in mobile and fixed broadband expansion; ii) provided guidance to municipalities regarding robust fibre networks; iii) identified relevant barriers for infrastructure deployment; iv) provided solutions for establishing "fibre villages"; v) established measures to support for broadband deployment in rural areas; and vi) acted as a Secretariat for regional broadband co-ordinators.

Since 2011, Sweden's functional access to broadband has been defined at a minimum speed of 1 Mbps. In February 2017, however, the Swedish government instructed the PTS to evaluate the minimum connection quality for Internet access for all users in the country. The government decided in January 2018 to raise the level of functional access to broadband from 1 Mbps to 10 Mbps. The government also allocated funding for procurement of solutions to the small amount of households and businesses located where there are no offers on the market to access 10 Mbps.

Challenges to meet the objectives

Notwithstanding Sweden's strong performance in terms of broadband connectivity, when compared to other OECD countries, some challenges persist in meeting objectives for the current and future Digital Agenda. Certain areas for improvement in terms of connectivity include:

- enhancing co-ordination among national, regional, and local strategies and plans for broadband (fibre) deployment, and fostering robust fibre networks
- promoting the deployment of high-speed broadband networks in sparsely populated areas, including the use of European Agricultural Funds for Rural Development and the European Regional Development Fund
- spurring the uptake of IPv6.

In addition, in terms of measurement of the digital economy, where Sweden is a leader, one recommendation is:

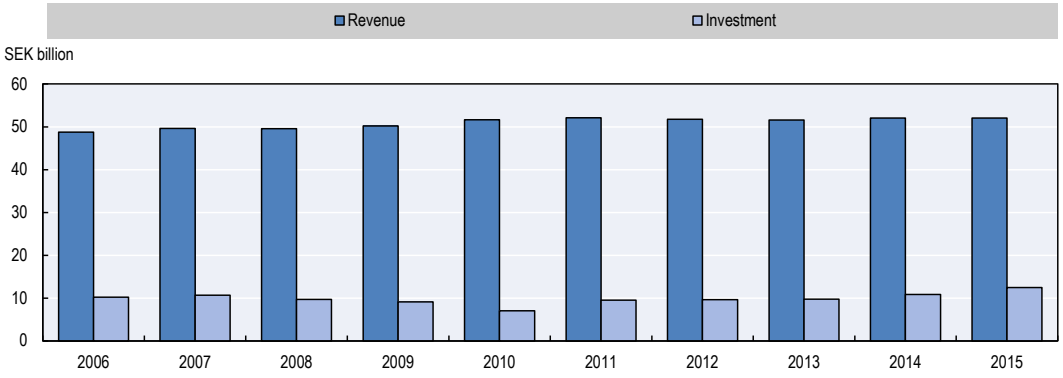
- to further develop M2M data collection by introducing a category for subscriptions and data generated by autonomous vehicles.

The remainder of the chapter will provide an overview of communication developments and market structures in order to support these recommendations.

Developments in Swedish communication markets

In Sweden, as in a number of OECD countries, there has been an historically strong relationship between an increase in communication subscriptions and a growth in the size of the sector's revenues. In recent years, also mirroring other countries, this relationship has somewhat decoupled. Overall, revenues and investment in the Swedish telecommunication sector have remained relatively stable since 2006, with the exception of the 2009 crisis (Figure 2.1). By 2015, total revenue and investment in the telecommunication sector in Sweden amounted to SEK 52 billion (USD 6.2 billion) and SEK 12.5 billion (USD 1.5 billion), respectively.

Figure 2.1. **Trends in telecommunication revenues and investment in Sweden**



Source: OECD (2018b), "Telecommunications database", http://dx.doi.org/10.1787/tel_int-data-en.

At the same time, the number of telecommunication subscriptions (measured in terms of "access paths"), continues to grow in Sweden, from 21.3 million access paths in 2006 to 36.8 million in 2015 (OECD, 2018a). The growth in communication access paths in Sweden is due to an increase in mobile and fixed broadband subscriptions, as well as the growth of M2M subscriptions in recent years (OECD, 2018a). In contrast, similar to the trend in most OECD countries, the number of fixed telephony lines in Sweden continues to decrease, passing from 5.07 million in 2006 to 1.7 million in 2015 (OECD, 2018a).

Broadband networks

Communication services can be assessed using a number of key measures. These include the availability of services, the quality of those services, and the level of prices faced by business and consumers. Regarding broadband availability, digital agendas aiming to ensure access to broadband can formulate such an objective using a number of metrics. These include indicators such as the number of broadband subscriptions per 100 inhabitants (i.e. broadband penetration rates), the number of households or businesses with access to broadband, or by geographical coverage (e.g. urban, rural and remote areas).

A further indicator for broadband assessment is the quality of communication services. One element of the quality of a broadband service is the download speed of a connection. Some broadband plans or digital agendas, in addition to penetration goals, have the

speeds they are expected to enable. For example, the Digital Agenda for Europe has a target of 100% of households having access to broadband at speeds of 30 Mbps by 2020, with a further aim of 50% of households having speeds above 100 Mbps (European Commission, 2010). Sweden, in contrast, went beyond this target, aiming for 90% of households to have 100 Mbps by that date and subsequently raising that to 1 Gbps for 98% of households by 2025.

Finally, the availability of prices at competitive rates is a key indicator for benefiting from the opportunities created by digital economies. The OECD uses a pricing methodology that incorporates usage baskets (e.g. for fixed and mobile broadband) in order to compare prices of communication services. This provides information on how Sweden's prices for fixed and mobile communication services compare to the OECD average for each basket as well to other countries.

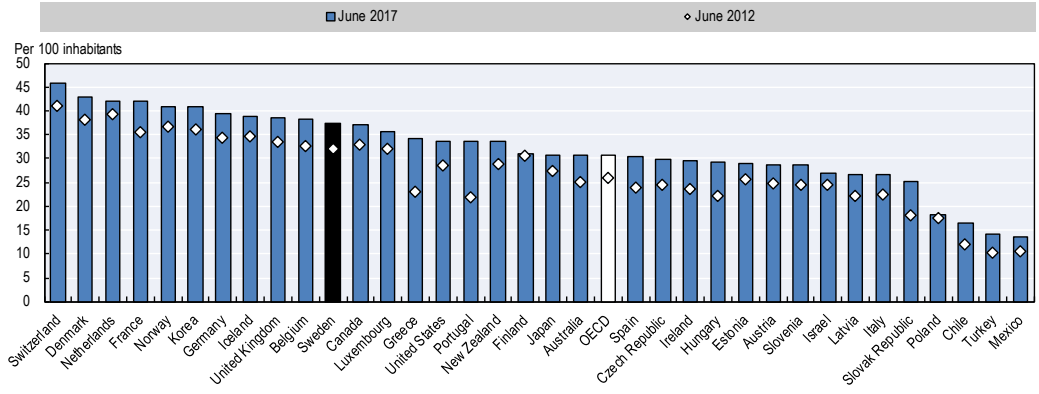
The following subsections present indicators of Swedish communication markets over these three aspects (i.e. availability, quality and prices).

Access to broadband

In Sweden, as in most OECD countries, fixed and mobile broadband subscriptions have continued to grow, reflecting the ongoing complementarity of both networks (OECD, 2017b). Fixed broadband subscriptions per 100 inhabitants in Sweden increased from 32% in June 2012 to 37.5% in June 2017 (Figure 2.2).

On the other hand, while Sweden is still among the leaders in broadband penetration, other countries have had higher growth rates in recent years (OECD, 2018a). Over the past five years (i.e. between Q2 2012 and Q2 2017) Sweden had a similar growth of fixed broadband subscriptions per 100 inhabitants (16.7%) as the OECD (16.8%). In terms of fibre subscriptions growth, in 2017 Sweden reported a higher annual growth (i.e. 17.9%) than the OECD average (i.e. 15.3%).

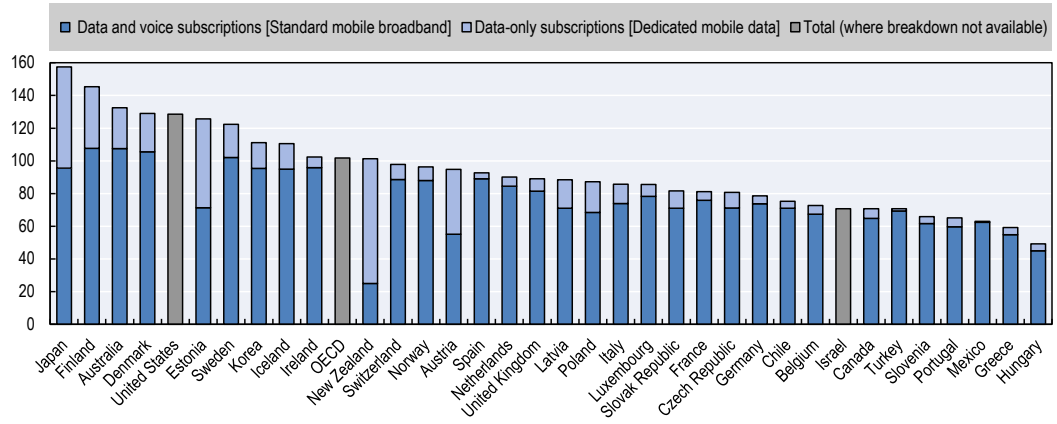
Figure 2.2. **OECD fixed broadband subscriptions per 100 inhabitants**



Source: OECD (2018a), Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

In June 2017, in terms of mobile broadband subscriptions per 100 inhabitants, Sweden was ranked 7th in the OECD with 122.4% (Figure 2.3). This was up from 105% in 2012. In June 2017, most of these subscriptions (i.e. 102%) were "data and voice subscriptions", whereas 20.4% were "data only" subscriptions (OECD, 2018a).

Figure 2.3. **OECD mobile broadband subscriptions per 100 inhabitants, by technology, June 2017**



Note: Data for Israel is from GSMA Intelligence; data for Luxembourg, Mexico, Switzerland and the United States are estimates.

Source: OECD (2018a), Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

Quality of broadband

A key indicator associated with assessing the quality of fixed and mobile broadband services are the speeds experienced by users. Fixed broadband download speeds in Sweden are high compared to the OECD. Internet speeds are always from the perspective of the networks involved, and as a content distribution network, Akamai provides one of the largest such views (Akamai, 2017). According to Akamai data on fixed network connectivity, Sweden ranks among the leading three countries in the OECD, with an average actual download speed of 22.5 Mbps, compared to an OECD average of 15.3 Mbps in Q1 2017 (Akamai, 2017).

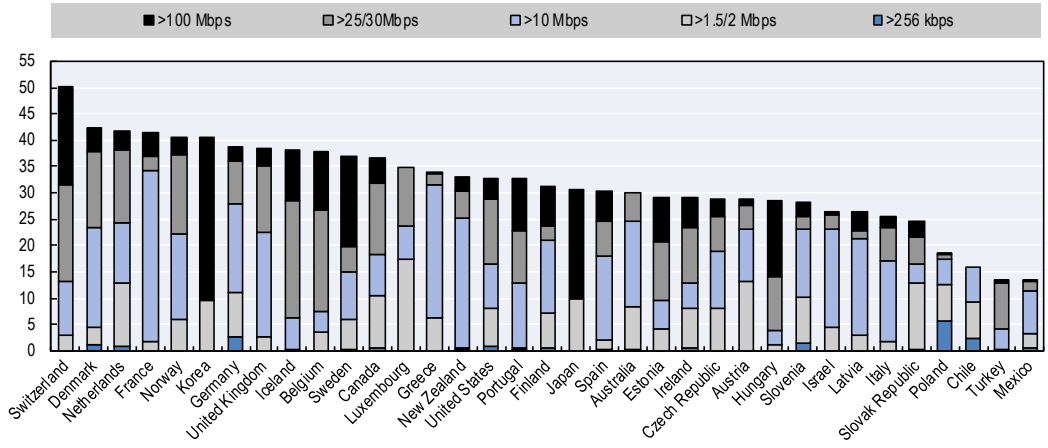
A useful measure to complement any assessment of broadband services is to combine penetration rates with the actual speeds experience by users. Not only does Sweden have a relatively high broadband penetration, it also has among the largest proportion of uses at the highest tier measured by the OECD. In 2016, 16.7% were greater than 100 Mbps, second only to Korea (Figure 2.4).

A further way to consider average download speeds across countries is to look at one of the most Internet Protocol (IP) traffic intensive applications: online games. One source of such data is the platform Steam (Figure 2.5), with the statistics reflecting network performance for one of the most demanding groups of Internet users. Download speed data for the Steam application was retrieved for the week of 10 November 2017 (Steam, 2017). The leading country for average download speed for games played when the sample was taken was Korea with 99 Mbps, followed by Sweden (50.8 Mbps). OECD countries represented 54% of total Steam traffic in terms of total petabytes (PB). The United States alone constituted 16% of worldwide Steam traffic in the week of measurement (with 32.5 PB), whereas Sweden represented 1.3% of total traffic for this gaming application measured in petabytes (with 2.5 PB).

At the time the sample was taken (November 2017), there were 3.15 million active Steam users in Sweden (SteamSpy, 2017). With a population of roughly 9.9 million (2016), a sample of 3.15 million Swedish users comprises almost one-third of the country's population, which is an outstanding sample to measure broadband speeds. The

average playtime of Swedish Steam users was 2 hours per day and these players own around 37 Steam games on average (SteamSpy, 2017). This makes Sweden the fifth OECD country, after Luxembourg, Iceland, Japan and Latvia, in terms of average playtime per user for Steam games.

Figure 2.4. **Fixed broadband subscriptions per 100 inhabitants, by speed tiers, December 2016**

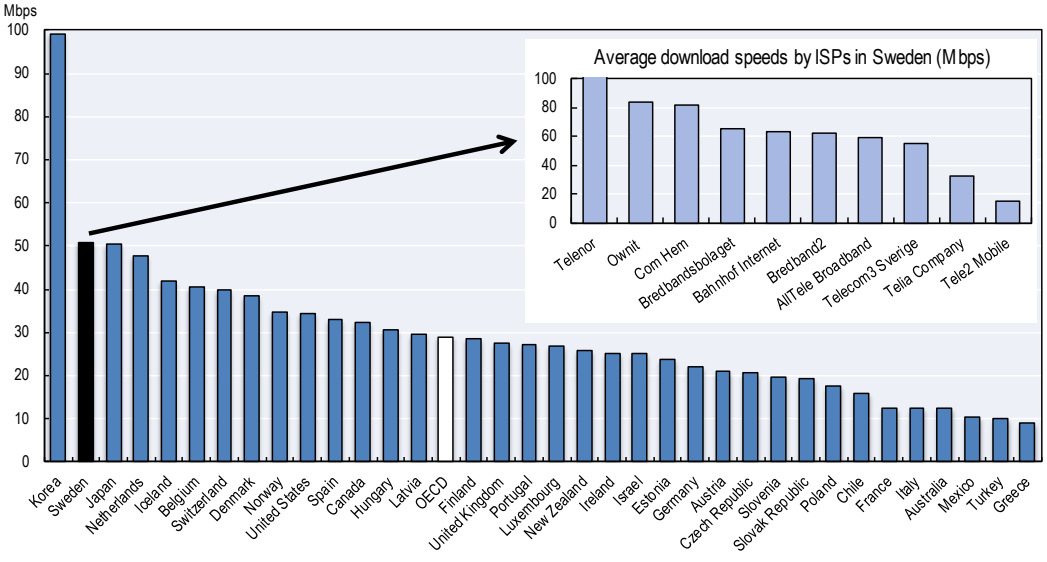


Notes: Mbps = megabits per second; kbps = kilobits per second. In Korea, 96.2% of subscriptions have a speed above 50 Mbps.

Source: OECD (2017a), "Broadband database", www.oecd.org/sti/broadband/oecdbroadband portal.htm.

Figure 2.5. **Average download speed of Steam games, OECD countries, November 2017**

Right hand side of figure shows the average download speed for Sweden disaggregated by Internet service provider



Notes: ISP = Internet service provider; Mbps = megabits per second. Data retrieved 10 November 2017, displaying the average download speed of the past seven days.

Source: Steam (2017), "Steam global traffic map (most recent 7 days)", http://store.steampowered.com/stats/content.

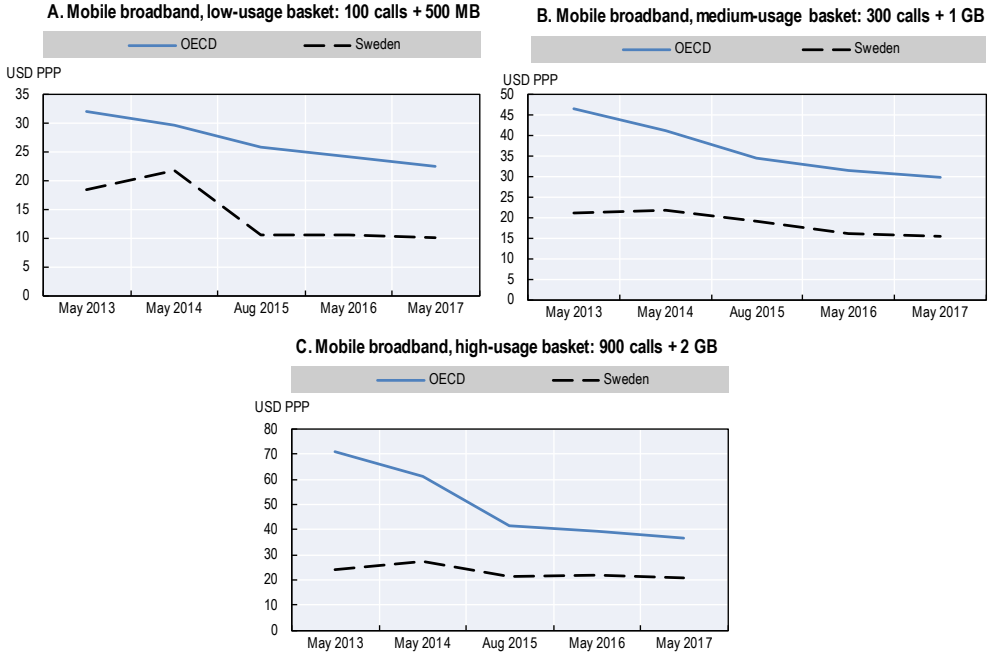
Prices of fixed and mobile broadband services

Prices of communication services depend greatly on the competitive conditions of the market in each country and in some instances regulation for specific services. In a sector with high fixed costs and barriers to entry, as is often the case for some telecommunication segments, the institutional and regulatory framework bears weight on the resulting market structure, and hence, has a direct influence on the affordability of communication services and the disciplines applied to prices by competition.

In this sense, the prices of communication services and levels of investment provide useful indicators of competition and framework conditions of the Swedish market. In the next section, market share indicators of communication markets will also be provided as an overview of the latest regulatory developments in Sweden which complement pricing data.

The OECD telecommunication baskets provide information on how Sweden's prices have evolved for fixed and mobile broadband. Sweden's prices for all three mobile broadband baskets (i.e. low, medium and high usage) are significantly below the OECD average, and prices within Sweden decreased between 2013 and 2017 (Figure 2.6).

Figure 2.6. **Trends in mobile broadband prices in Sweden compared to the OECD average**



Notes: PPP = purchasing power parity; MB = megabyte; GB = gigabyte. Data for 900 calls + 2 GB are for November 2014 instead of May 2014.

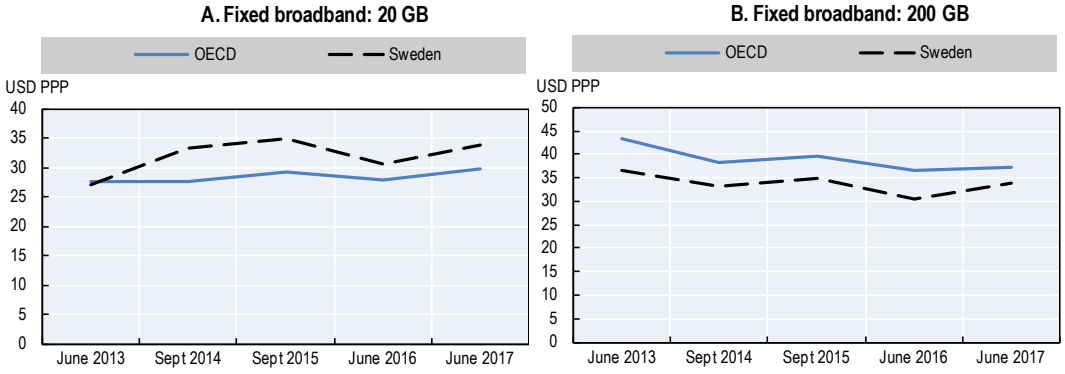
Source: Author's calculations based on Strategy Analytics (2017), "Broadband", https://www.strategyanalytics.com/access-services/service-providers/tariffs---mobile-and-fixed/broadband.

In particular, the price of the low-usage mobile broadband basket (i.e. 100 calls + 500 megabytes [MB]) has experienced a sharp decrease in the last four years, decreasing from 18.48 USD PPP in May 2013 to 9.73 USD PPP in November 2017 (Figure 2.6A). Between 2013 and 2017, the price of the medium-usage basket (i.e. 300 calls + 1 gigabyte [GB]) also decreased, going from 21.09 USD PPP to 14.85 USD PPP, while the price of the high-usage basket (i.e. 900 calls + 2 GB), exhibited a similar drop, with a price of 23.94 USD PPP in 2013 to 14.85 USD PPP in November 2017 (Figures 2.6B and 2.6C).

The difference in prices in Sweden with respect to the OECD average is less striking for the fixed broadband baskets. In fact, during the period of 2013-17, the price of the "low-usage" fixed broadband basket (i.e. 20 GB) in Sweden increased from 26.96 USD PPP in June 2013 to 33.36 USD PPP in December 2017, and this basket exceeds the OECD average over the whole period. For instance, in December 2017, the price for the 20 GB fixed broadband basket in Sweden was 33.36 USD PPP, and compares to the OECD average price of 29.74 USD PPP. That being said, it is likely that there are few offers in the Swedish market that fit this profile. Indeed, in their absence, a tariff with more data included will be used, hence the price being the same for baskets with higher usage levels.

The "high-usage" fixed broadband basket (i.e. 200 GB) prices in Sweden were slightly lower than the OECD average price for such a basket for the period 2013-17 (Figure 2.7). The price of this higher usage basket in Sweden was 33.36 USD PPP in December 2017, slightly lower than the OECD average price for December 2017 of 36.33 USD PPP.

Figure 2.7. **Trends in fixed broadband prices in Sweden compared to the OECD average**



Note: PPP = purchasing power parity; GB = gigabyte.

Source: Author's calculations based on Strategy Analytics (2017), "Broadband", https://www.strategyanalytics.com/access-services/service-providers/tariffs---mobile-and-fixed/broadband.

Data (IP) traffic over broadband networks

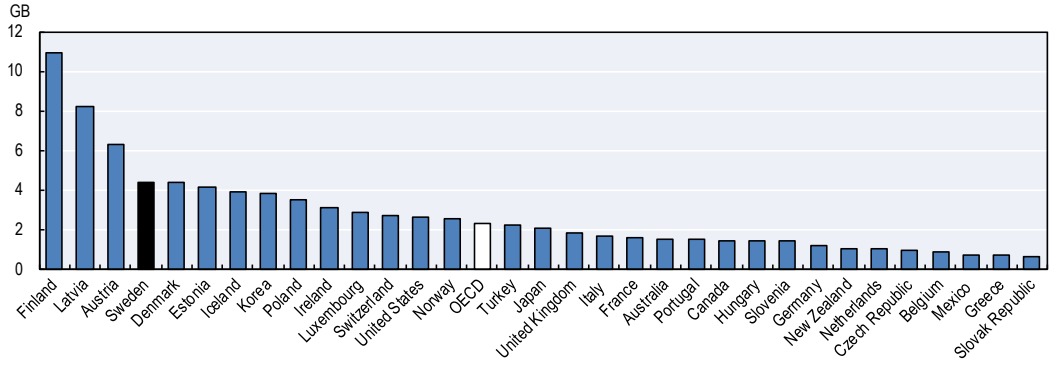
Mobile traffic: Complementarities between fixed and mobile networks

One indicator that is closely linked to affordability of broadband packages is the amount of data used by subscribers. Sweden is among the top five OECD countries in mobile data usage per mobile broadband subscription, behind Finland, Latvia and Austria in the past six years (OECD, 2018a). The average mobile broadband subscription in Sweden was 4.38 GB per month, whereas the OECD average was 2.3 GB per month in 2016. Compared to Nordic countries, Sweden comes second after Finland (10.95 GB per month) and has almost the same usage as Denmark of 4.37 GB per month per subscription (Figure 2.8).

The Cisco VNI provides information for 13 OECD countries[4] on the percentage of smartphone data traffic offloaded through fixed networks using Wi-Fi. In 2016 this was 61% of mobile traffic for Sweden. In addition, the *OECD Digital Economy Outlook 2017* surveyed all OECD countries on the amount of mobile traffic generated per mobile broadband subscription through cellular networks. It recorded that the amount of data usage per mobile broadband (cellular) subscription in Sweden was 4.38 GB per month (OECD, 2017b). One way to see the total amount of IP traffic used by smartphones is to

combine both sets of data. By doing so, one can estimate the total amount of traffic in terms of gigabytes generated by mobile devices, that is, the sum of the traffic that is offloaded through Wi-Fi, plus the traffic that is transmitted through cellular networks (Figure 2.9). Using this approach, Sweden had the largest amount of total data usage per smartphone device, behind only Korea (Figure 2.9).

Figure 2.8. **Mobile data usage per mobile broadband subscription, 2016**

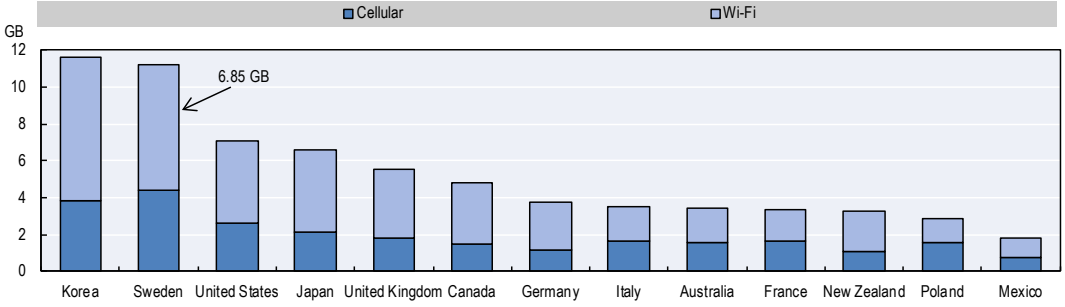


Note: GB = gigabyte.

Source: OECD (2017a), "Broadband database", www.oecd.org/sti/broadband/broadband-statistics.

Figure 2.9. **Total data per mobile broadband user (smartphone) per month, 2016**

Mobile traffic disaggregated by the Wi-Fi offloaded traffic and cellular network traffic



Notes: GB = gigabyte. Offloaded Wi-Fi traffic calculated using Cisco VNI data of percentage of smartphone offloaded traffic (e.g. for Sweden it was 61%).

Source: Author's calculations using data from Cisco VNI (2017), "VNI mobile forecast highlights for Sweden", https://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/#~Country and from OECD (2017b), *OECD Digital Economy Outlook 2017*, http://dx.doi.org/10.1787/9789264276284-en.

Sweden's increasing use of mobile data is expected to continue its upward path in the coming years. According to Cisco VNI, in Sweden, mobile data traffic will double from 2016 to 2021, a compound annual growth rate of 20%. Mobile data are expected to reach 132.8 PB per month by 2021 (i.e. the equivalent data for 33 million DVDs each month), up from 53.2 PB per month in 2016 (Cisco VNI, 2017). In addition, Cisco forecasts that mobile traffic per mobile-connected end user in Sweden will reach 7.6 GB per month by 2021, up from its earlier estimate of 3.59 GB per month for 2016, a compound annual growth rate of 16% (Cisco VNI, 2017). The latter figure by Cisco (i.e. 3.59 GB) turned out to be similar to the actual result reported by the regulatory authority, the PTS (i.e. 4.38 GB).

Internet exchange points and data centres in Sweden

Two elements of Internet infrastructure enabling efficient management of IP traffic are Internet exchange points (IXPs) and data centres. There are 14 IXPs in Sweden (PCH, 2017). Furthermore, Sweden's unique geographical position, extensive connectivity, as well as thriving digital environment makes it very appealing for Internet companies to establish data centres in Sweden (Business Sweden, 2017b). In 2017, for example, Amazon Web Services announced a new data centre region in the Stockholm area, to become operational in 2018 (Business Sweden, 2017a).

Structure of communication markets in Sweden

One characteristic of the Swedish market is that there is coverage in areas with lower population density by multiple providers. A major factor in this outcome has been the lower cost to deploy this infrastructure by the prevalence of infrastructure-sharing agreements. In addition, the use of municipal fibre networks has played an important role in making essential infrastructure available (OECD, 2014c).

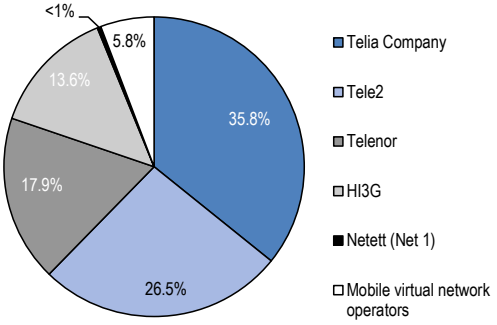
Mobile market developments

Competition

Sweden's mobile telecommunication market has exhibited robust levels of competition since the turn of the century, when the first spectrum was awarded for 3G services. Apart from the management of spectrum, the primary regulatory intervention is on mobile termination rates, where by its very nature each operator has a termination monopoly for its own customers. Operators are free to make commercial agreements with mobile virtual network operators and provide wholesale access, but there are no obligations to do so in either respect.

There are five mobile network operators (MNOs) in Sweden. These are Telia, Tele2, Telenor, Hi3G (or 3) and Net 1 (an operator in the 450 megahertz [MHz] band). The 4 mobile operators held 94% of the market in 2016, while 21 mobile virtual network operators held around a 6% share. In December 2016, the market shares of the two largest MNOs (i.e. Telia and Tele2) were 35.8% and 26.5% of the market (Figure 2.10).

Figure 2.10. **Market shares of mobile operators in Sweden, December 2016**



Note: There are 41 mobile virtual network operators and 5 MNOs in Sweden.

Source: PTS (2017i), "Table 1 Key data: The market for electronic communications", http://statistik.pts.se/en/the-swedish-telecommunications-market/tables/electronic-communications/table-1-key-data.

At present, there is nearly 100% 4G and 3G network coverage in Sweden (European Commission, 2017c). Authorities believe a number of factors have contributed to this coverage, including lower costs as a result of allowing infrastructure sharing, sound spectrum management and the extensive geographical availability of fibre networks to provide backhaul.

Infrastructure sharing

Passive and active infrastructure sharing can be viewed as a means to reduce costs, particularly those associated with expanding coverage, while ensuring robust competition under appropriate safeguards. Fixed infrastructure sharing includes all passive equipment such as towers, masts and ducts, as well as wholesale arrangements of dark fibre. Whereas mobile infrastructure sharing includes active parts of the network, such as radio access network (RAN) sharing agreements. A key aspect of successful infrastructure sharing is the agreements put in place between network operators. In Sweden, such agreements, for both mobile and fixed networks, were made before the building of much of today's shared facilities and were subject to careful examination by the Competition Authority and the regulator (OECD, 2014c).

All four MNOs in Sweden have had long-standing arrangements for network sharing. In particular, they all have RAN-sharing agreements, where a site and all equipment are shared.[5] This has contributed to the high network coverage in Sweden.

Fixed and mobile networks continue to be complimentary in many respects, especially given that mobile networks rely on fixed networks for backhaul. Stockholm's Stokab municipal fibre network provides one example of backhaul over shared infrastructure. Net4Mobility, a joint-venture infrastructure company providing backhaul for the long-term evolution (LTE) network of two mobile operators (i.e. Tele2 and Telenor), is one of Stokab's clients. The long-term commitment by Net4Mobility has allowed Stokab to extend its network into new areas of the city. At the same time, Net4Mobility stated that fibre network sharing has allowed the company to deploy its mobile network at a faster pace compared to regions where such shared infrastructure did not exist (OECD, 2014c).

Spectrum management

While a comparative selection process was used for the turn of the century 3G allocations, since that time the PTS has used auctions for all spectrum allocations. In addition, PTS' strategy has been to use spectrum sharing where possible.

According to PTS's "Spectrum Policy", spectrum should be managed as to maximise its social benefit and promote innovation. To achieve this, the PTS highlights three important points: i) licenses should be technologically neutral; ii) auctions should be preferably applied when selection procedures are warranted; and iii) license exemption should be introduced when there is little risk of harmful interference (PTS, 2006).

In February 2017 the PTS published an "Orientation plan for spectrum management" with the aim of presenting updates of spectrum assignment and use in the upcoming years. Several frequency bands are currently being studied, while some are expected to be licensed in the future. For instance, the PTS plans to award the license for the 450 MHz band in the first half of 2018, whereas the 1.5 gigahertz (GHz) and 2.3 GHz band are planned for 2018 or later (PTS, 2017e).

The 700 MHz band auction in Sweden was due to start in December 2016, but the PTS cancelled the planned auction on 31 October 2016 given a decision that the frequencies of this band were still to be used for broadcasting until May 2018. Furthermore, due to an

evolving policy situation, there is also a consideration of whether this band should be used to ensure communications of the defence and the emergency services authorities. This overturned a previous decision by the authority in 2014 (PTS, 2017a). In June 2017, the PTS resumed the work for the 700 MHz band by opening a public consultation (PTS, 2017a).

The PTS is at present participating in the preparatory work for the ITU World Radio Conference that will take place in November 2019, where there will be discussion of possible allocation of bands for the new generation of wireless services or "5G" (PTS, 2017e). At the same time, the European Commission, which also decides on harmonisation of frequencies among member countries, has already identified the 700 MHz band, the 3.6 GHz band and the 26 GHz band as pioneer bands for 5G deployment in Europe.

In addition, given many industry developments in 5G in Sweden, the PTS planned to allocate test licences for 5G trials through administrative procedures in the first half of 2017 (PTS, 2017d). During the public consultation that took place in February 2017, market players expressed support of PTS' proposal on the Spectrum Plan for 5G tests, which includes trial licenses in the 3.4-3.6 GHz and 26 GHz bands (PTS, 2017d).

5G developments in Sweden

Industry players in Sweden are undertaking 5G trials in the millimetre wave bands, and collaborations and joint partnerships between different stakeholders are occurring in others to test 5G technology and other related applications. For example, Ericsson, in collaboration with Telia, has performed outdoor testing in Kista, Stockholm (Ericsson, 2016). Also, in August 2017 Telia, Boliden, Ericsson, Volvo, ABB, RISE SICS and LTU Technologies joined forces to test 5G technology for safety communications in the Kankberg underground mine in Boliden, Sweden (RR Media Group, 2017). In January 2016, Telia and Ericsson announced that by 2018 they would launch a 5G network in Stockholm and Tallinn. In November 2016, Telia announced a similar joint venture with Nokia to launch a 5G network in Helsinki (Telia, 2017a).

An application that is closely related to 5G and the Internet of Things (IoT) is autonomous driving. Volvo is planning to offer customers fully autonomous vehicles by 2021, and initiated in January 2017 a massive trial of 100 self-driving vehicles tested by ordinary people in the city of Gothenburg (Carlström, 2017).

Internet of Things: Sweden a leader in machine-to-machine connections

As highlighted at the OECD Cancun Ministerial, following the convergence between fixed and mobile networks and between telecommunication and broadcasting, the IoT represents the next step in convergence between ICTs and economies and societies on an unprecedented scale. It holds the promise of substantially contributing to further innovation, growth and social prosperity, and as with any such development, policy makers and other stakeholders need evidence to inform the decisions they will take in the coming years. The Cancun Ministerial Mandate identified a set of areas for stakeholder engagement to promote IoT deployment. In particular, it highlighted the importance of developing metrics to measure the effects of adoption of the IoT in different policy areas (OECD, 2016).

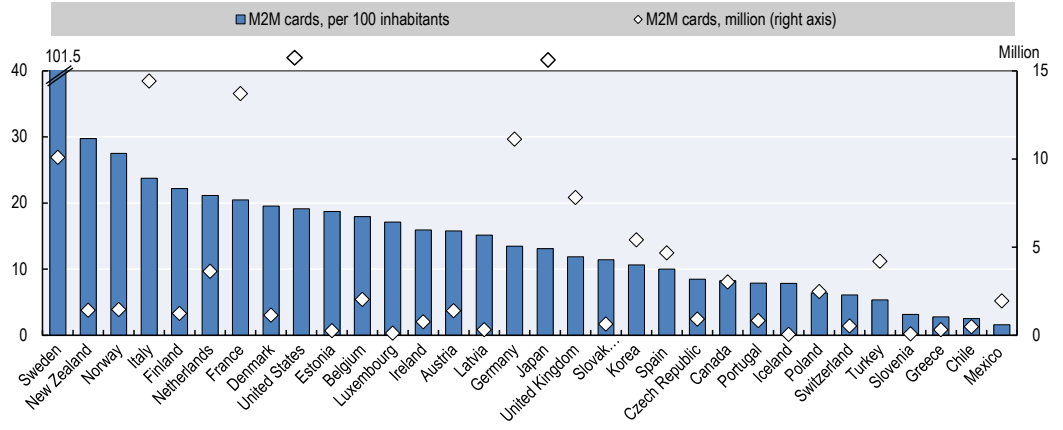
The IoT is expected to grow exponentially, connecting many billions of devices in a relatively short period of time (OECD, 2015). Sweden has been at the forefront of this market development, especially in terms of M2M communications. M2M connected devices are a small subset of the IoT as, increasingly, IoT connected devices are becoming IP-based and platform-agnostic (i.e. operating on mobile, fixed and other networks).

M2M devices are characterised by autonomous data communication with little or no human interaction (OECD, 2015).

Since 2012, OECD countries have been collecting data on M2M embedded mobile cellular subscriptions.[6] By June 2017 there were 174.5 million M2M communication subscriptions in the OECD, up from 108 million at the end of 2014 (OECD, 2017b). In terms of M2M penetration, Sweden has 101.5 M2M SIM cards per 100 inhabitants – a much higher level than for most other OECD countries, and well above the OECD average of around 16% (Figure 2.11). It is important to note one caveat for M2M data and that is that not all of these devices are located in Sweden.

In regards to enabling robust development of the IoT, the PTS has allocated spectrum that is used by various applications for the IoT and M2M. In addition, as early as 2005, the PTS had identified numbering as one of the regulatory issues surrounding the IoT, and since then has dedicated number series for both fixed and mobile networks allocated exclusively for M2M (i.e. a total of 10 billion numbers).

Figure 2.11. **M2M/embedded mobile cellular subscriptions, June 2017**



Notes: The OECD defines machine-to-machine (M2M) on mobile networks as "the number of SIM-cards that are assigned for use in machines and devices (cars, smart meters, and consumer electronics) and are not part of a consumer subscription". This means that dongles for mobile data and tablet subscriptions should be counted by countries under the mobile broadband definition; whereas SIM cards in personal navigation devices, smart meters, trains, automobiles, etc., should be counted under the M2M category.

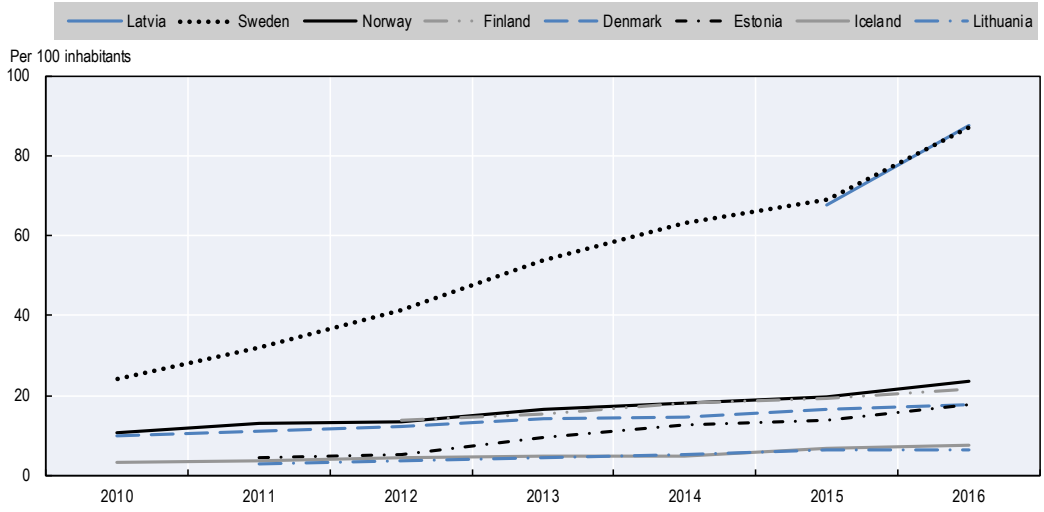
Source: OECD (2018a), Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

In June 2017, there were approximately 10.1 million M2M-embedded SIM cards in Sweden (Figure 2.11). Meanwhile, using a different definition of M2M, the number of mobile-connected M2M "modules" or devices in Sweden reached 4 million in 2016, and is expected under this measure to reach 13 million in 2021 (Cisco VNI, 2017).

The policies that the PTS has followed in terms of numbering have undoubtedly contributed to Sweden's leading position in IoT development. Some of this has occurred domestically, but it has also opened opportunities for Swedish firms in foreign markets. This is why Sweden's M2M penetration is recorded as being much higher than that of other OECD countries (Figure 2.11), including in the Nordic and Baltic regions (Figure 2.12). At the forefront Telenor Connexion, which held 81% of the M2M market share in Sweden in 2016 according to PTS figures, uses its numbering (IMSI numbers) not only for Sweden, but also for its clients around the world. For example, if Volvo, a

client of Telenor Connexion, sells an automobile with a SIM card and this vehicle is sold outside Sweden anywhere around the world, it shows up in the M2M figures of Sweden provided by the PTS. In this case, the Volvo vehicle shows up in the local network outside Sweden as a foreign roamer. The most recent data for 2016 indicate one or more connectivity providers in Latvia are also likely benefiting from the use of M2M numbering for foreign services.

Figure 2.12. **M2M subscriptions per 100 inhabitants in Nordic and Baltic countries**



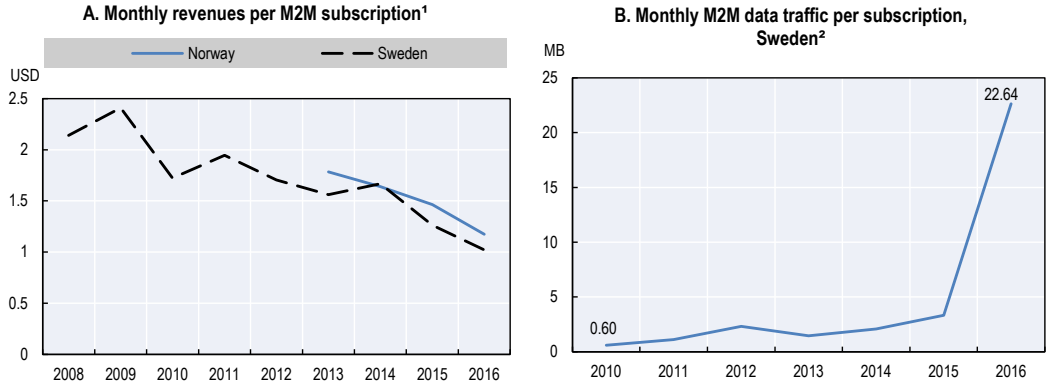
Sources: PTS (2017g), "Telecommunication markets in the Nordic and Baltic countries", http://statistik.pts.se/en/nordic-baltic-telecom-market/tables/mobile-call-and-data-services/table-1-subscriptions; OECD (2018c), Population (indicator), http://dx.doi.org/10.1787/d434f82b-en.

As mentioned previously, since 2012 most OECD countries have been collecting data on M2M subscriptions, and Sweden has gone a step further by complementing these data by gathering information on how much revenue is generated per year by M2M subscriptions. Furthermore, since 2010, the PTS has collected data on the amount of M2M traffic. The collection of data for all these indicators is commendable, as they provide relevant information for all stakeholders, and such information is likely to be increasingly pivotal for informing future developments across the digital economy.

While still relatively small when measured per M2M subscription compared to smartphones, such traffic grew from less than 1 MB per M2M subscription in 2010 to almost 23 MB in 2016 (Figure 2.13B). Notable, however, was the sharp increase in 2016. This is likely due to an evolution in the M2M market, with some application of the technology being used in areas that generate higher amounts of traffic, such as connected automobiles. According to Cisco VNI data, M2M traffic in Sweden will grow tenfold from 2016-21 (compound annual growth rate of 59%), and will account for 9% of total mobile data traffic, compared to 2% at the end of 2016 (Cisco VNI, 2017).

The PTS also collects data on the amount of revenue generated by M2M subscriptions. On a per subscription basis these have declined since 2008, decreasing from a little more than USD 2 per month in 2008-09 to roughly USD 1 in 2016 (Figure 2.13A). Another Nordic communications authority collecting data on M2M revenues is in Norway, where the experience has been similar to that of Sweden, as monthly revenues per M2M subscriptions have declined over the past three years. This may be because of the large increase in M2M devices and new tariff plans.

Figure 2.13. **Monthly M2M revenues and traffic per subscription in Sweden**



1. Revenues of M2M are compared between Sweden and Norway. The number of M2M subscriptions of both countries was taken from PTS (2017g).

2. The PTS defines M2M as communication between machines used for telematics and telemetry.

Notes: MB = megabyte. The PTS defines subscriptions as contract subscriptions plus pre-paid cards. Pre-paid cards are reported according to the three-month rule. The increase in traffic for data services between 2015 and 2016 depends on Telia's reporting. Telia reported for 2016 around 2 000 Tbytes and for 2015 76 Tbytes. Telia says that the 2015 data are too low, but an actual value is not available.

Source: Author's calculations using data from the PTS and the Norway National Communications Authority (2018), "M2M sales" (in Norwegian), https://ekomstatistikken.nkom.no/#/statistics/details?servicearea=Mobiltjenester&label=Maskin-til-maskin%20-%20omsetning.

In the future, different M2M applications are likely to generate very different usage patterns. Environmental sensors, for example, may only generate very small amounts of data relative to connected bicycles and robots, right up to perhaps the largest amounts in the case of autonomous vehicles. This is why, for the future, the PTS should consider breaking out M2M traffic for categories of devices that may make tremendous demands on networks. As an M2M leader and likely to be one of the first countries to deploy 5G, as well as having leading automobile and telecommunication equipment manufacturers, Sweden is in an ideal position to assess the implications of autonomous transport for the digital economy.

Although OECD countries have witnessed high growth of M2M connected devices, in terms of revenues, M2M is still a nascent market. For instance, according to the PTS, M2M only generated SEK 908 million (USD 106.05 million) in revenues 2016, making up 1.7% of the total Swedish telecommunication market.[7] Nevertheless, M2M as subset of the IoT has the potential to grow in the near future with new business cases emerging. That is, although at present M2M is not large in terms of revenues, with the growth of the IoT and evolving business models, it is expected to become the majority of connections, with implications for infrastructure with the advent of 5G and autonomous vehicles.

Fixed market developments

Competition

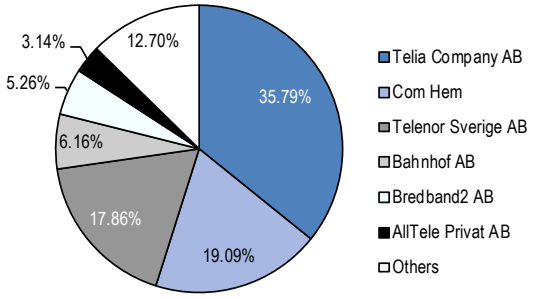
In Sweden, 111 fixed network operators owned and controlled their own infrastructure in 2016. Telia is the historical incumbent and owns the only network with public switched telephone network (PSTN)/xDSL technology, with plans to gradually transition its legacy copper network. The total number of subscriptions for the two largest fixed operators (measured in terms of PSTN and broadband) are 3 316 400 and 903 600 for Telia and Com Hem, respectively.

The Swedish government has a 37.3% share in the ownership of Telia. Many networks are fully owned by municipal governments. At the end of 2016, there were 156 providers of fibre subscriptions to end users in Sweden (PTS, 2017h). Out of these fibre providers, 43 were municipality networks (municipalities or municipality-owned enterprises).

In 2017, there were 156 municipal fibre networks in Sweden. However, most of them provided wholesale products such as "dark fibre" and Ethernet capacity. According to the PTS, the municipal networks that do provide broadband subscriptions are typically, though not always, smaller municipalities. In terms of fixed broadband subscriptions to end users, municipal networks accounted for approximately for 4% of the market share, where the largest municipal network registered 9 064 fibre subscriptions at the end of 2016.

The three largest fixed broadband operators, Telia, Telenor and Com Hem, accounted for almost 73% of fixed broadband subscriptions in December 2016 (PTS, 2017h). The fixed broadband market in Sweden is comprised of 3.7 million subscriptions, of which 54% were on either Telia's or Telenor's network in 2016 (Figure 2.14).

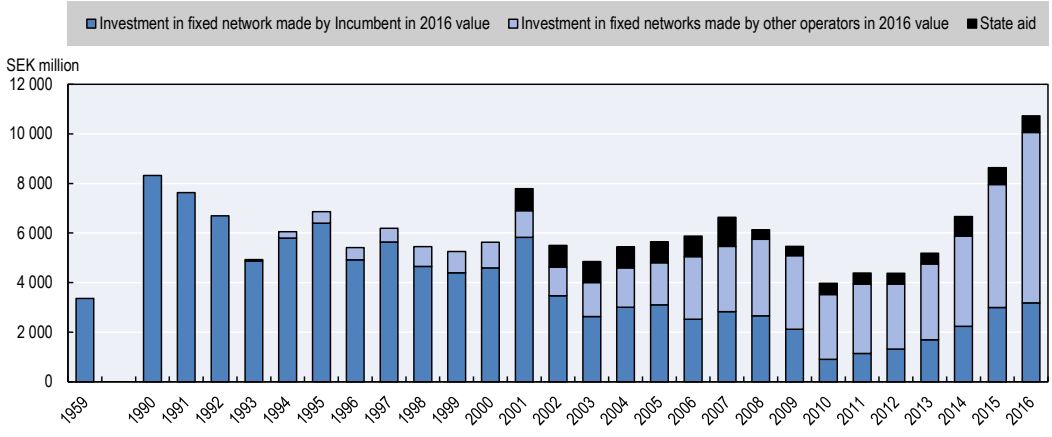
Figure 2.14. **Fixed broadband market shares in Sweden, December 2016**



Note: "Others" includes 169 active and smaller ISPs in Sweden.

Source: PTS (2017i), "Table 1 Key data: The market for electronic communications", http://statistik.pts.se/en/the-swedish-telecommunications-market/tables/electronic-communications/table-1-key-data.

Figure 2.15. **Historical investment in fixed networks in Sweden, 2016 prices**



Source: Data provided by the PTS.

Historically, the incumbent, Telia, invested the most in fixed network infrastructure, and a peak can be observed in the mid-1990s, which represented investments in PSTN technology. A decrease in investment levels from the incumbent operator can be observed since 1990. Although Telia still accounted for 50% of investment in fixed infrastructure over the last decade, since 2006, investment by other players (e.g. IP Only and municipal fibre networks), together with state aid, have taken a more prominent role. This has coincided with the PTS reportings that IP Only, an entrant in the fibre infrastructure market, invested SEK 3.3 billion (USD 0.39 billion) during the period 2013-16.[8] Investment in fixed network infrastructure reached a record high in 2016 (Figure 2.15).

Next generation access in Sweden

The OECD has used the term "next-generation" access (NGA) networks to describe the requirement of fibre coming closer to the end user, or providing the direct connection (OECD, 2011). Aside from fibre to the home (FTTH), NGA access can also include wireless technologies, and other access networks with different technologies (e.g. VDSL, fibre to the premises [FTTP] and DOCSIS 3.0). This section considers mostly networks that deliver "ultra-fast broadband" (or speeds higher than 100 Mbps), in line with the connectivity targets that Sweden aims to achieve.

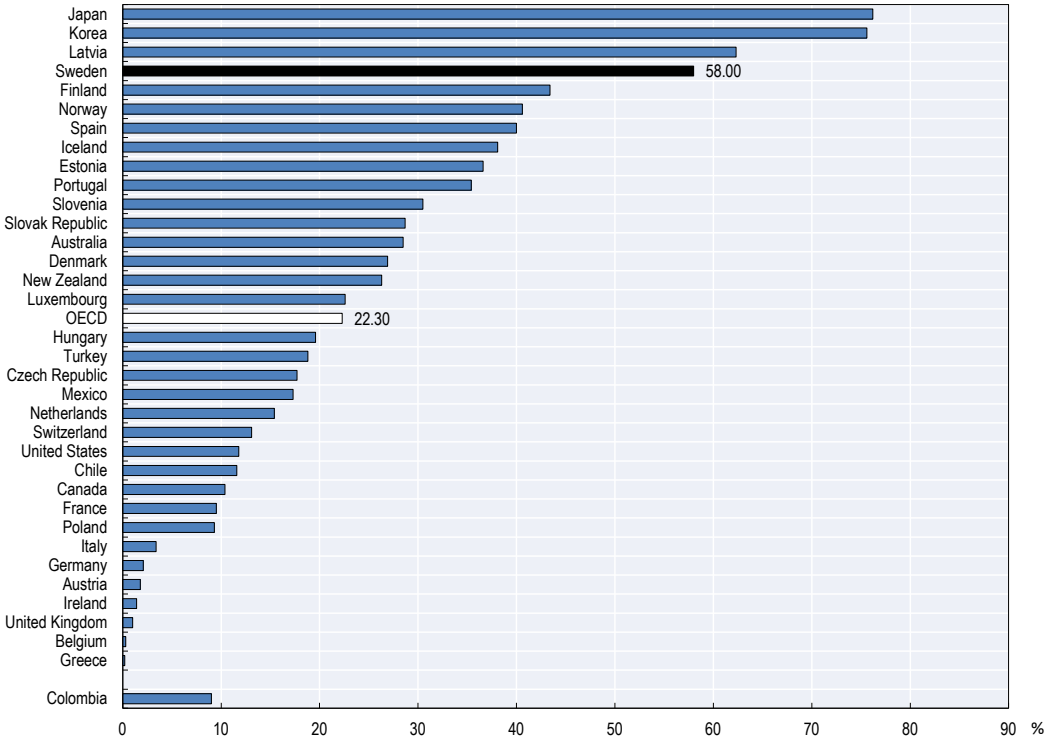
According to the European Commission's definition, the overall NGA coverage in Sweden, measured by the percentage of households with access to broadband via VDSL, FTTP or DOCSIS 3.0 technologies, was 77.7% in 2017, up from 56.6% in 2012 (European Commission, 2018). However, the PTS has mentioned a caveat regarding European comparison of coverage statistics, as it would seem the definition for NGA coverage according to the European Union is FTTP, whereas Sweden reports FTTH figures. In addition, the PTS has pointed out that Sweden's target of remote areas may be more ambitious than that of other EU countries.[9] With this caveat in mind, national coverage of NGA in 2017 in Sweden was similar to the EU28 average of 80.1%; however, there is a sharp difference when compared to the rest of Europe in terms of NGA coverage in rural areas. In Sweden, only 22.7% of rural households had access to NGA networks, whereas the average for the EU28 was 46.9% in 2017 (European Commission, 2018).

In June 2017, the share of fibre in broadband connections in Sweden was one of the highest in the OECD, just behind Japan, Korea and Latvia (Figure 2.16).[10] From December 2012 to December 2016, the share of fibre subscriptions in Sweden increased from 33.7% to 55%, whereas this same share as a percentage of total broadband subscriptions in the OECD went from 14% to 21.2% (OECD, 2018a).

The decreasing share of DSL connections in Sweden in overall broadband subscriptions, from almost 47% in 2012 to 23.4% in June 2017, is an indication of the ongoing reduction in the use of the legacy network of Telia (Figure 2.17). Telia is planning to gradually transition its copper network. These copper lines are planned to be replaced by fibre, fixed wireless services or wireless connectivity. The point of comparison can be Japan, another country with a high fibre penetration rate. In Japan, NTT East and NTT West have both said they will cease to offer asymmetric digital subscriber line (ADSL) services from 2023, citing the declining number of subscriptions and difficulty to get maintenance parts (NTT East, 2017).

Although Telia does not have any universal service obligation, during this ongoing transition from the existing PSTN based on copper to an all IP network, Telia has made a commitment to safeguard communication to all concerned households currently connected to the part of the copper network that will soon be transitioned (PTS, 2015).

Figure 2.16. **Percentage of fibre connections in total broadband among countries reporting fibre subscribers, June 2017**



Notes: Fibre subscription data include FTTH, FTTP and fibre to the building (FTTB) and excludes fibre to the cabinet (FTTC). Some countries may have fibre but did not report figures, so they are not included in the graph. Israel, Switzerland and the United States: data for December 2016 are estimates; Germany: fibre includes fibre lines provided by cable operators; United Kingdom: no fibre data are available as digital subscriber line (DSL) includes all fibre technologies (FTTH, FTTP, FTTB and FTTC) because the breakdown between these technologies is not available yet.

Source: OECD (2018a), Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

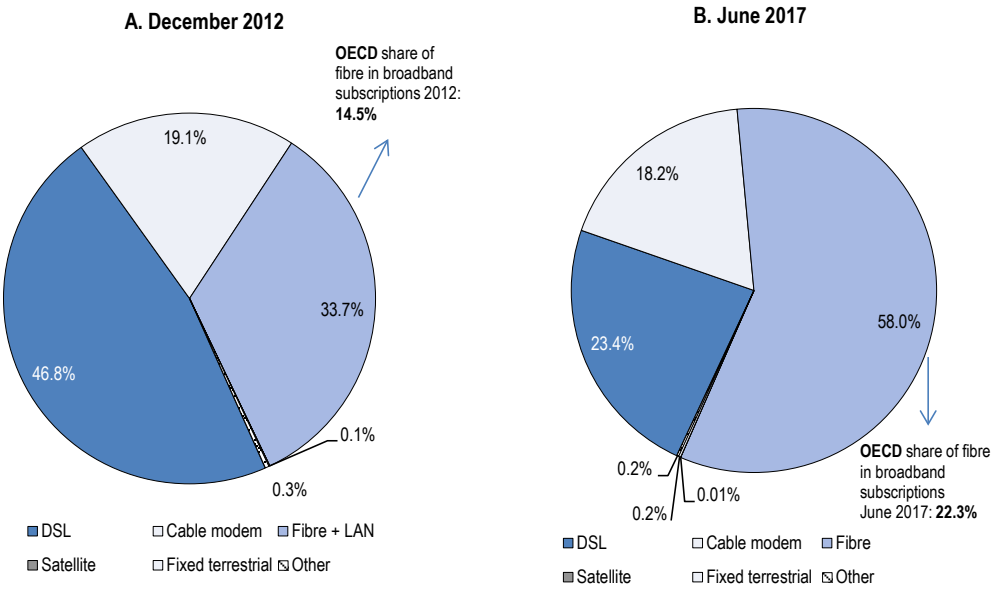
Telia aims to streamline its network and close down small and unprofitable exchanges from its copper legacy network. It is involved in an ongoing project for "the network of the future", which consists of dismantling small exchanges and instead providing consumers with mobile communications (PTS, 2015). This mobile connectivity may be done through 4G and 5G networks. In fact, Telia plans to deploy 5G networks by 2018 (Telia, 2017b). Furthermore, by 2025, the company aspires to build a single "seamless, borderless, roaming free network that delivers 1 Gbps across the entire Nordic and Baltic region" (Telia, 2017b).

The second relevant player in the deployment of NGA networks is a new entrant in the fibre market called IP Only. In 2016, this entrant had a 2.3% share of the fibre access market measured in terms of revenues, whereas Telia held 31% of the same market (PTS, 2017c). Given that IP Only deploys an open network where Internet service providers (ISPs) provide retail services, the subscriber numbers for IP Only do not reveal how large of a share the company has on the infrastructure market. This makes the revenue share more relevant. IP Only is in a race with Telia, the incumbent, as well as with municipal networks, to provide fibre, and the PTS reports that it invested SEK 3.3 billion (USD 0.39 billion) during the period 2013-16.[11] The company says it has invested EUR 1.5 billion since it entered the market, out of which half of its investment in infrastructure is dedicated to rural areas in the country. In fact, in 2017 the European Investment Bank

provided IP Only with EUR 125 million in debt financing to extend its fibre network in rural areas (European Commission, 2017a). IP Only is one of the main players selling network capacity or Ethernet to players that are not telecom operators (i.e. leased lines), holding a 17% market share in December 2016, whereas Telia held 30% of this market measured in terms of revenue (PTS, 2017c).

Figure 2.17. **Fixed broadband subscriptions by technology in Sweden, 2012 vs. 2017**

OECD share of fibre over total broadband subscriptions



Note: DSL = digital subscriber line; LAN = local area network.

Source: OECD (2017a), "Broadband database", www.oecd.org/sti/broadband/broadband-statistics.

The third group of fixed network players are the 156 municipal fibre networks present in 200 of the 290 municipalities of Sweden. Most of these networks only provide wholesale products such as dark fibre and Ethernet capacity (i.e. bitstream access). There are also 43 municipal networks that provide fibre subscriptions to end users, who hold approximately 4% of the retail fibre market share according to PTS data of December 2016. IP Only accounts for 0.4% of the market, whereas the vast majority of fibre connections to end users are provided by Telia (i.e. 30%) (PTS, 2017c).

The following section provides more details on this group of actors that have played a key role in the deployment of high-speed networks in Sweden since the 1990s.

Ex ante *asymmetric regulatory measures applied to dominant players*

Sweden, as many other European countries, has a set of NGA and local loop unbundling regulations for an operator with significant market power (SMP). These SMP measures are based on EU directives and recommendations. Accordingly, since 2010 Telia, given that it holds SMP status, has the obligation to provide access to the unbundled local loop on copper and wholesale access to fibre. However, the price of fibre access is not regulated by the PTS, whereas the price of local loop unbundling (i.e. copper) is set by the regulator.

Price regulation on wholesale access to fibre was relaxed for Telia in December 2016. Henceforth, with regards to fibre-based local access, Telia is obliged to provide wholesale

access on a non-discriminatory basis meeting the requirements of equivalence of inputs (i.e. the same price Telia would charge to its retail unit). That is, rivals should be able to economically replicate services in the retail market based on wholesale access to the fibre. The latter is examined through an economic replicability test, which is not a full-fledged margin squeeze test, but rather a safeguard that Telia is not abusing its dominant position.

Municipal networks in Sweden

A decisive factor in Sweden's high fibre take-up is that municipal networks have been widely deployed in the country since the liberalisation of the communication market (Mölleryd, 2015).

In Swedish municipalities, broadband is viewed as a utility, where local authorities are responsible of providing a significant proportion of public services and infrastructure. Local governments view municipal fibre networks as a basic infrastructure for their communities. Two notable examples of municipal networks are Stokab in Stockholm,[12] leasing dark fibre to ISPs, MNOs and other interested parties, and Fiberstaden in the Hudiksvall municipality.

Most Swedish municipal networks provide retail "operator"-neutral network infrastructure based on fibre to the building or FTTH. That is, their business model relies on open networks where they act as physical infrastructure providers offering wholesale access to retailers on a non-discriminatory basis. This has led to a notion of "open" municipal networks, which contrasts with other business models for backbone and backhaul provision of fibre that rely on completely vertically integrated telecommunication operators present both in wholesale and retail markets (Mölleryd, 2015).

It needs to be noted that the concept of "openness" when it comes to municipal networks depends on the definition of vertical integration. Vertical integration here is understood as a player present in two downstream markets, even if both are on a wholesale level (e.g. infrastructure provider and network operator of active equipment). Some municipal networks act only as dark fibre providers, and are truly "operator neutral" at the active equipment layer (network providers), as well as the service provision level (ISPs), whereas many municipal networks are vertically integrated in both wholesale markets which may limit the players in the bitstream access market. Few municipal networks are present in all three layers (both wholesale markets as well as retail markets).

Municipal networks in Sweden vary in terms of cost structures and commercial strategies, therefore wholesale prices will also exhibit differences. Wholesale prices influence the number of ISPs that will be present in the local broadband market. The competition between ISPs strongly influences retail prices. In 2014, an OECD report found that retail prices of broadband subscriptions in municipal networks in Sweden with several ISPs were 23-38% lower than the prices of Swedish ISPs with national coverage. In addition, broadband prices with several ISPs present in a municipal network were on average 25% lower compared to municipal networks with only one ISP present (Mölleryd, 2015).[13]

For the most part, there are three roles different stakeholders take in fibre networks in Sweden depending on the layer of broadband infrastructure and services:

- infrastructure provider (e.g. dark fibre)
- network operator (e.g. manage and own active network infrastructure, for example bitstream access)
- service provider (e.g. Internet or pay-TV service provider).

Some municipal networks act in one, two or all three of the roles outlined above if they are completely vertically integrated up to the retail level. In the latter case, they could have a dominant position if there were no other ISPs in that area. In Sweden, following the SMP regulatory framework, as a result of the product market definition, the market for "wholesale local access provided at a fixed location" (i.e. EU market "3a") is national in geographic scope. Hence, only one player in Sweden, Telia, has SMP status and is regulated *ex ante* through a decision based on the Electronic Communications Act.[14] This means that municipal networks acting in all three roles, at present, would not be susceptible to competition remedies or regulatory actions.[15] Municipal networks may be regulated if the PTS deems that they have SMP status in specific relevant markets and that these should be regulated.[16]

Depending on how fibre deployment costs in Sweden change when examined at a local level, the model used by municipal networks (i.e. what roles they adopt) will vary. Deployment costs, and hence the models adopted by municipal networks, are likely to depend on several factors, including demand, population density and geography (i.e. urban/rural). In addition, Swedish end users have a high willingness to pay the upfront fee for the roll-out of FTTH. For example, owners of single dwelling units in Sweden in 2014 paid an installation fee of around EUR 2 000 (USD 2 667) (BEREC, 2016).[17]

Some stakeholders have even attributed the lack of upgrading of Swedish networks to support IPv6 to the heterogeneous open access models that exist for fixed networks, suggesting that some models have worked better than others, in the sense of providing incentives to upgrade network equipment. For instance, in the case of municipal networks, different models exist regarding the level of presence of a given player in the passive and active wholesale level which determines the degree of open access of the network.

A common business model for municipal networks is one of open networks where municipal networks act as infrastructure providers, that is they own and maintain the passive infrastructure (e.g. "dark fibre") and offer wholesale access on a non-discriminatory basis to network providers (Mölleryd, 2015).

Municipal networks adopting open network architecture and acting only at the passive level of the infrastructure (i.e. playing only the role of infrastructure provider), may provide more incentives to network operators (and service providers) to upgrade active parts of the networks (or services). One example of a network that plays only the role of infrastructure provider (as it leases dark fibre) is Stokab.

The "Stokab municipal network model" is an open network providing access to dark fibre. Proponents say the key factor behind Stokab's success is that it only provides passive infrastructure (as opposed to bitstream access or active infrastructure), facilitating investment by ISPs and mobile operators as they maintain the incentives to improve services for their customers. One of the outcomes of this "open access" model has been extensive availability of high-speed broadband networks with a dynamic ISP market in Stockholm. This partially reflects the fact that Stokab is present in a location with multiple dwelling units present, but also the success of the wholesale model it follows.

In the 1990s, the liberalisation of the telecommunication market in Sweden not only encouraged alternative operators to expand and the creation of municipal networks, but also local communities to form co-operatives for the roll-out of fibre networks, commonly referred to as village networks. The Broadband Forum estimates that there are around 1 000 village fibre networks, and each of these networks connects on average 150-200 households (Box 2.1).

Box 2.1. The village fibre approach in Sweden

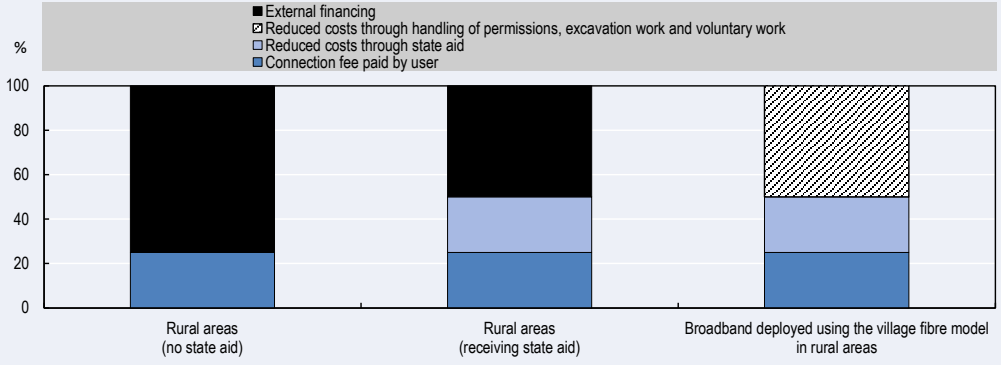
Deployment cost savings of village fibre

The "village fibre" approach is based on the premise of community involvement to plan, build and operate local fibre networks in co-operation with municipalities and commercial operators.

Proponents say the village fibre approach facilitates fibre deployment at a considerably lower cost compared to commercial operators through a combination of three factors: i) handling of permissions; ii) excavation work and trenching; and iii) voluntary work in respect to aggregation of demand. Moreover, the deployment of fibre networks through village fibre as well as all other operators is facilitated by consumers' willingness to pay upfront fees of around USD 2 300 to connect single dwelling units, and the possibility to apply for a subsidy from public funds.

Deployment costs of fibre are much higher in sparsely populated areas than in urban ones, and thus, state aid is primarily intended to offset these differences. Given that village networks are deployed in areas where no commercial operators are deploying fibre networks, they meet the key criteria for state aid. Compared to commercial broadband projects, village fibre projects can achieve cost savings of some 50% using an innovative handling of permissions as well as excavation and voluntary work. A further reduction of some 25% is achieved through state aid, making the connection fee equivalent to that of urban areas (Figure 2.18).

Figure 2.18. **Estimated cost savings by village fibre compared to operators**



Note: Index based on the commercial cost in rural areas.

Source: PTS.

Coverage objectives: Regional deployment and access

Setting broadband availability targets in terms of speed will have an influence on the network costs that are required to meet the goals within a digital agenda. For instance, broadband speeds above 100 Mbps or, as the case of Sweden at 1 Gbps, may require upgrades of existing infrastructure to NGA networks, which consequently impacts deployment costs depending on the country (given its geography and existent legacy network).

Given the evolution of fibre networks through the municipal open network infrastructure, as well as the deployment in rural areas by IP Only and Telia, Sweden is well ahead of the curve in terms of NGA deployment, and will most likely meet the objectives with a speed of 100 Mbps. This being said, to meet the "last-mile" of the Digital Agenda's objective (i.e. to connect all households, even those in very remote or

rural areas), Sweden may face challenges. In addition, the advantages of the municipal network approach that until now have enabled extensive fibre deployments, could represent a challenge going forward when considering a ubiquitous coverage goal at such high speeds with a multiplicity of stakeholders and municipal network models, which may face interoperability issues at a larger scale.

According to the PTS, in 2017, 78.5% of Sweden's households had access to broadband at speeds higher than 100 Mbps, up from 68.7% in 2015. Therefore, it seems likely that Sweden may be able to comply with the broadband target established in 2009, i.e. 90% of households and businesses with broadband access of 100 Mbps by 2020.

For Sweden's new broadband strategy, which aims to provide 98% of households with 1 Gbps broadband by 2025, a wider deployment of NGA networks will perhaps be necessary. In terms of NGA coverage, defined by the European Commission as including VDSL, FTTP and DOCSIS 3.0, 77.7% of households had coverage in 2017, compared to 56.6% in 2012 (European Commission, 2018). There is a difference with household uptake of NGA broadband in rural communities, as this amounted to only 22.7% of rural households in Sweden by 2017, albeit up from 6.3% in 2012 (European Commission, 2018). Thus, there is regional heterogeneity in the access to high-speed broadband in Sweden, as can be seen in the broadband speed maps. For instance, in Stockholm municipality 97% of households have access to 100 Mbps broadband, whereas in the Stromsund municipality only 31% of households and businesses have access to connections at these speeds (PTS, 2018).[18]

The broadband market in Sweden is highly disaggregated, comprised of at least 500 stakeholders and hundreds of fibre associations (Swedish National Audit Office, 2017). As a result, there may be a role for current fibre infrastructure of the central government to be used more effectively, as has been outlined in the recent document "State broadband infrastructure as a resource" (Ministry of Industry, 2016). The report contains several suggestions on how to improve the use of the over-capacity of the government's broadband infrastructure. For instance, how publicly owned dark fibre and ducts, as well as other forms of passive infrastructure, should be made available to private actors to reduce deployment costs by market players. It also highlights the role that regional broadband co-ordinators should have to facilitate "co-deployment" of broadband infrastructure with other network deployment initiatives (e.g. roads, electricity).

With the aim of improving co-ordination among the plethora of actors in the broadband market, in 2017 the Swedish government appointed funds for regional broadband co-ordinators, organised under the Broadband Forum. Albeit the regional broadband co-ordinators cannot fully address the issue, they are specifically tasked with the responsibility to promote and streamline the expansion of both fixed and wireless broadband deployment.

While municipal networks and the village fibre approach can assist in addressing broadband deployment costs, and contribute to achieving Sweden's broadband targets for 2020, it is important to highlight the potential risks of the uneven deployment of "ultra-fast" robust broadband networks. For example, in 2017 the Swedish National Audit Office report highlighted that there is a risk of uneven distribution of "robust" fibre networks in Sweden. Particularly, the report found a lack of robustness in access networks owned by non-profit associations that build broadband infrastructure in rural areas (known as fibre associations or the village fibre approach) as well as some municipal networks that lease active infrastructure, such as bitstream access (Swedish National Audit Office, 2017).

Other than providing state aid through European Union funds (i.e. the Rural Development Programme and the European Regional Development Fund), there are other ways the European Commission is supporting Sweden to extend fibre deployment in rural communities. For example, the European Investment Bank has provided IP Only, the entrant in fibre deployment at the national level in Sweden, with EUR 125 million in debt financing over the next four years to deploy fibre networks in rural areas, covering almost 400 000 households and firms (European Commission, 2017d).

Although initiatives to help fund rural broadband deployment, in addition to the village and municipal network approaches, could help mitigate the current issues of uneven broadband deployment in Sweden between rural and urban households, other potential issues remain to be addressed. Such issues include the incentives to upgrade networks given the degree of vertical integration of municipal networks at a wholesale level (i.e. the presence of one player in both the passive and active infrastructure layers).

Furthermore, given inherent difficulties in terms of business cases for market actors to provide broadband in some rural areas of Sweden, the policy co-ordination among broadband initiatives at the national, regional and municipal level becomes even more critical. Continued broadband support in sparsely populated areas is a key factor for Sweden to meet its ambitious broadband targets. At the same time, Swedish authorities also need to be cautious of the possibility of state aid interfering with deployment incentives by the private sector (Swedish National Audit Office, 2017). For the Swedish government, it is very important for state aid to be targeted to areas where commercial deployment is not available or planned. In its response to the Audit Report, it has outlined the tools in place to ensure this goal. Some of these tools include prior market analysis to identify the areas that are not commercially attractive, and once the areas are detected, public consultations of the planned financed expansions so that private operators can identify if these plans clash with a planned commercial development (Government Offices of Sweden, 2017).

There are many actors involved in the co-ordination and allocation of subsidies for rural deployment of broadband. Such subsidies include the European Agricultural Funds for Rural Development and the European Regional Development Fund. The two funds have different orientations for broadband deployment and are managed by two separate authorities, but the broadband measure in each fund is created to complement each other. The government has instructed the managing authorities to co-operate regarding their respective broadband measure in order to create an efficient deployment.

IPv6 in Sweden

One potential challenge for the future of the Internet is its ability to scale to connect tens of billions of devices and machines, and a key aspect of that scalability is the use of the IP. The IP specifies how communications take place between one device and another through an addressing system (Perset, 2010). There are two versions of the IP in use, one which is largely exhausted in terms of the distribution of unassigned addresses (Internet Protocol version 4 [IPv4]) and another that is plentiful but has had a slower than desirable adoption (Internet Protocol version 6 [IPv6]).

Encouraging the deployment of IPv6 has been a long-standing goal for OECD countries. In the 2008 Seoul Declaration, for example, ministers highlighted the importance of fostering IPv6 adoption, in particular through its deployment by the private sector and by governments through tools such as public purchasing (OECD, 2008).[19] At present, the exhaustion of IPv4 is one reason new entrants with large numbers of users, such as

Reliance Jio in India, have emphasised the use of IPv6 in establishing their network (Ghosh, 2017), and why traditional players such as Verizon have ceased assigning fixed IPv4 addresses to business customers (Sharwood, 2017).[20]

In order to transition to IPv6, previous OECD reports have recognised how multiple players (i.e. ISPs, backbone providers, device manufacturers, content providers and so forth) have to co-ordinate (OECD, 2014a). The IPv6 transition can be thought of as a "technology adoption model" characterised by the presence of direct and indirect network effects that can make it harder for a new platform standard to achieve critical mass because different stakeholders may find it difficult to co-ordinate (OECD, 2014a). This raises the question of whether some of the market structures used in Sweden are ensuring the necessary co-ordination between wholesale and retail providers of infrastructure and services.

There has been a relatively slow take-up in the use of IPv6 in Sweden compared to other OECD countries and this may have a range of potential economic implications. For instance, existing technologies that enable the sharing of limited IP addresses (i.e. Carrier Grade network address translations) may break some applications and disrupt the modularity of the Internet, which in turn may degrade the quality of Internet service for some users. In addition, when resources become scarce, such as IPv4 addresses, innovation may be hampered due to a rise in transaction costs. In this sense, the rise of secondary markets for IPv4 addresses may increase the costs of developing new applications and services (OECD, 2014b).

In respect to the IoT, IPv6 is important not only because of scalability, but also potentially from a security perspective. This is because IPv6 may be more conducive to end-to-end encryption, which may be favourable for the security of industrial IoT applications. In addition, the increase in transaction costs linked to current IP address exhaustion may affect the IoT by making it more difficult and costly to roll out these devices (OECD, 2014b). Hence, promoting the adoption of IPv6 is an effective way to support the development of the IoT (OECD, 2016), and ensure markets are open for new entrants.

Sweden exhibits a strong performance for most communication indicators. It is therefore, somewhat surprising to observe that Sweden fares relatively worse than the OECD average in terms of IPv6 adoption (Figure 2.19).

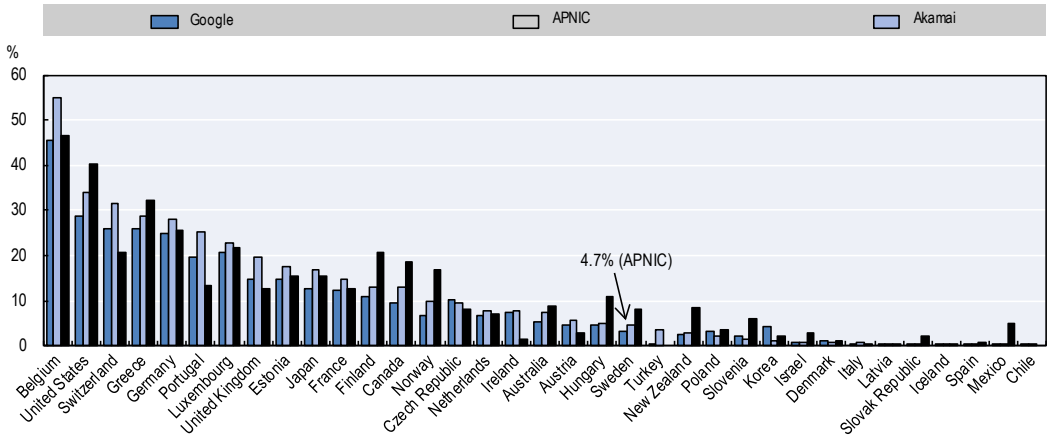
Measuring an evolving process such as the adoption of IPv6 requires the use of different methodologies to assess different layers of the Internet infrastructure (OECD, 2014b), and thus Figure 2.19 displays three different sources measuring IPv6 adoption (Akamai, Google and APNIC). Using the Asia Pacific Network Information Centre (APNIC), IPv6 adoption in Sweden was 4.7% in 2016 (ranked 21st among OECD countries), compared to a 10% OECD average (Figure 2.19). Sweden is significantly behind OECD leading countries, such as Belgium which had a 55% IPv6 adoption rate as of September 2017 according to APNIC data.

Cisco 6lab using data from Google and APNIC has found that IPv6 adoption in Sweden grew from about 1% at the end of 2014 to a little more than 4% in 2017 (Cisco 6lab, 2017). The bottleneck does not appear to be from terminal devices. Indeed, according to Cisco VNI, in Sweden, 93% of smartphones and tablets were IPv6-capable in 2016 (equivalent to 10.6 million devices) (Cisco VNI, 2017). This points to a potential lack of upgrading in the core network.

The reasons behind the lack of incentives to upgrade network equipment in order to foster IPv6 adoption may be several. That being said, some stakeholders in the Swedish

Internet technical community have pointed to the possibility that the low rate of adoption of IPv6 may be a symptom of a larger issue related to the interoperability of fixed networks stemming from the municipal network model used for fibre deployment.

Figure 2.19. **Country adoption of IPv6**



Note: APNIC = Asia Pacific Network Information Centre.

Sources: Google (2016), "Per-country IPv6 adoption", https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption&tab=per-country-ipv6-adoption; APNIC (2017), "IPv6 measurement maps", http://stats.labs.apnic.net/ipv6; Akamai (2016), "State of the Internet IPv6 adoption: Q1 2016 report", https://www.akamai.com/uk/en/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp.

The specific model used for municipal networks will create different incentives among the three types of players in the broadband market to upgrade network equipment. An approach like the one taken by Stokab, leasing only "dark fibre" (i.e. passive infrastructure), versus the model where municipal networks offer bitstream access (i.e. active infrastructure), may well work better in terms of the incentives of network operators to upgrade equipment to IPv6.

With regards to IPv6 adoption within the country, the PTS has statistics for the deployment of IPv6 in the central government administration, and in local municipalities, as the government's previous Digital Agenda had stated that all central government authorities should have introduced IPv6 by 2013.[21]

Although the Swedish government has not tasked the municipalities with implementing IPv6, there are also statistics of IPv6 adoption by municipalities. These statistics reveal that of the 290 municipalities in Sweden, only 40 have authorities using IPv6 via email, webpages and Domain Name Systems (PTS, 2017b).

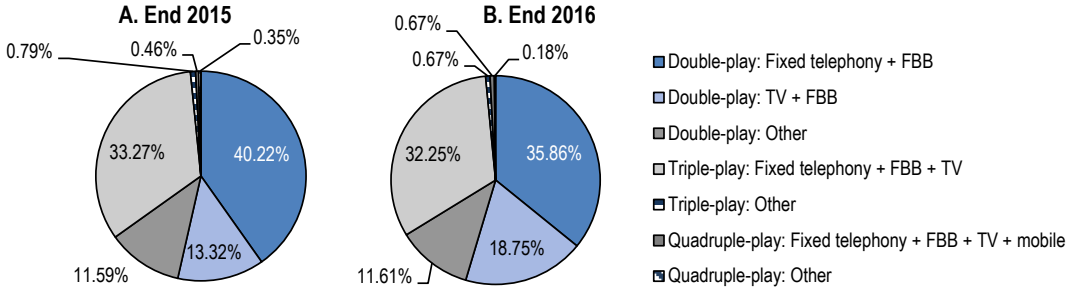
Convergence

Fixed broadband services are typically bundled with television services in Sweden. Between 2015 and 2016, television subscriptions via a fibre connection increased by 23%, becoming the main form TV subscription for Swedish people. This contrasts to previous years, where cable was the main technology used to access TV services up until 2015 (PTS, 2017f). Both Telia and Telenor have pay-TV offerings, and although they offer mobile services on a stand-alone basis, they don't usually offer quadruple-play bundles.

By the end of 2016, there were 1 637 000 end user bundled subscriptions in Sweden, out of which most were double play offers (66.2%) or triple-play bundles (33%). The most popular bundle composition was fixed telephony and fixed broadband (almost 36%), and the fixed telephony bundled with fixed broadband and television (32%). The quadruple-play bundle of fixed telephony, broadband, television and mobile telephony remains less than 1% of total bundled offers (Figure 2.20).

The composition of bundles has evolved greatly in Sweden since 2012, when most bundled offers were fixed telephony and broadband (71%); in 2016 this bundle only represented about 36% of bundled subscriptions. Furthermore, in just one year, the double-play bundle of pay-TV and fixed broadband is gaining popularity compared to the fixed telephony and fixed broadband double-play bundle, as the former represented around 13% of bundled subscriptions in 2015, gaining momentum in 2016 with 18.75% of total bundled subscriptions (Figure 2.20).

Figure 2.20. **Composition of bundled services[1] in Sweden**



1. Bundled services covers combination offers, which contains two or more services such as fixed and mobile telephony, television or broadband and are offered and marketed as an offer or with a price list for the bundled services.

Note: FBB = fixed broadband.

Source: PTS (2017a), "Assignment in the 700 MHz band", https://www.pts.se/en/english-b/radio/auctions/700.

There are no bundling restrictions on communication services in Sweden, with the caveat that only consumer rules should apply. That is, bundled offers should be transparent and consumers should be treated fairly. In addition, there is no special regulatory treatment or status of video-on-demand services (i.e. streaming) if they are distributed over broadband networks. Some commercial broadcasters even offer services to watch broadcasted content live via the Internet (e.g. SVT play and TV4 provide content over the Internet).[22]

Policy recommendations

As the relationship between citizens and the government, and in general all of the economic activities of society, become increasingly digital, access to fast and reliable broadband connections becomes a necessary condition for Sweden's digital economy.

Connectivity is a building block of the digital transformation, and in this regard in many ways Sweden exhibits a stellar performance in terms of broadband availability, quality and affordability among OECD countries. Sweden is an historical leader in the OECD in mobile broadband penetration, a leader in terms of mobile data usage, and also one of the most developed countries in terms of NGA. For instance, it is the fourth OECD country in terms of fibre as a share of broadband connections. It is also a leader in M2M subscriptions

(with the noted caveat that Telenor's foreign M2M SIMs are reported within Sweden though nonetheless highlighting the benefits for serving other markets and supporting exports).

Overall, Sweden is on a solid path to achieve its broadband connectivity targets for 2020. However, some issues still remain, which, if addressed, will further foster the robust deployment of ultra-fast networks in both rural and urban areas, so that by 2025 Sweden can reach its ambitious target of 98% of households and firms with access to 1 Gbps broadband connections.

Although Sweden is on a very positive path to achieve its broadband access goals, areas to continue building upon in terms of connectivity include:

- enhancing co-ordination among national, regional, and local strategies and plans for broadband (fibre) deployment, and increasing the "robustness" of fibre networks
- promoting the deployment of high-speed broadband networks in sparsely populated areas
- spurring the uptake of IPv6.

An additional recommendation to continue enhancing Sweden's current innovative approach in terms of measurement of the digital economy is:

- further develop M2M measurement by introducing a category for subscriptions and data generated by autonomous vehicles.

The specific recommendations regarding each of these opportunity areas are detailed below.

Enhancing policy co-ordination to promote broadband deployment and robustness of fibre networks

The broadband market in Sweden is characterised by more than 500 stakeholders and hundreds of fibre associations (also called "village fibre" networks). There exists a plethora of municipal networks adopting different models in terms of the roles played by infrastructure providers, network operations and service providers. The multiplicity of players in the fibre market is said to have been among the main reasons why Sweden has reached the levels of fibre deployment it has today. Going forward, and with ambitious broadband targets including 1 Gbps connections for all Swedish citizens in mind, potential policy co-ordination issues among different stakeholders at a national, regional and municipal level may become a challenge. This could be the case for digitalisation programmes that require co-ordination among all relevant actors of the different initiatives.

Regarding the robustness of fixed broadband networks, the Swedish National Audit Office published a report on the state of broadband deployment in Sweden pointing out that the risk Sweden faces today is an uneven distribution of "robust" fibre networks (Swedish National Audit Office, 2017). The lack of "robustness" stems from the diversity of players involved in the access network, such as not-profit associations like the village fibre projects, and municipal networks that also engage in operating active parts of the network (i.e. bitstream access).

The Broadband Forum, which has a steering committee headed by the Ministry of Enterprise and Innovation, has served as an important form of co-operation contributing positively to fibre expansion in Sweden. Given the importance of a co-ordinated approach (among several levels of government and among the multiplicity of players in the broadband market), when striving for more ambitious connectivity targets, it is therefore recommended to enhance the role of this forum to promote co-ordination and address issues which arise.

In particular, although there is still no harmonised definition or indicators on what "robust fibre networks" imply, the government should enhance co-ordination among players to improve Swedish fibre networks. The PTS has already taken a number of initiatives in this regard, such as "robust fibre instructions" and the "PTS Operational Safety Regulations", which are steps in the right direction. An additional measure to assist in this respect is to enhance the role of the Broadband Forum in the promotion of robust fibre networks.

Promoting the deployment of high-speed broadband networks in sparsely populated areas

The Broadband Strategy in Sweden is striving for ubiquitous ultra-fast connectivity. At the current state of communication infrastructure in Sweden, there is uneven access to broadband of at least 100 Mbps. For example, at a national level, 68.7% of households have access to this type of broadband connection, whereas only 21.5% of rural households had access to broadband at these speeds in 2016 (European Commission, 2017a).

In addition, Sweden is facing a technology shift, where the incumbent is transitioning parts of the copper network. At present, many households still use copper connections to access fixed broadband (e.g. 869 000 users were connected to fixed broadband through an xDSL by mid-2017). In terms of mobile broadband options, in most cases households have access to 4G (LTE) or other wireless solutions, as Sweden has achieved almost 100% coverage of LTE networks (i.e. meaning that these households have access to 10 Mbps connections). Therefore, in rural areas, Telia has announced that copper technologies will be replaced by mobile technologies. However, the question still remains whether the speeds offered by LTE will be sufficient to compensate households that lose their DSL connections.

The PTS should remain vigilant on how Telia conducts the retirement of its copper network, and ensure that all households that will no longer have DSL connections receive a similar or better technological alternative. This is especially important given the current connectivity targets for 2025 in Sweden.

The government should continue its effort to enhance co-ordination among stakeholders in the administration of the regional funds for rural deployment of broadband (i.e. the European Agricultural Funds for Rural Development and the European Regional Development Fund). In this sense, the establishment of the Broadband Forum was a move in the right direction. The newly created Digitalisation Council could also assist in enhancing co-ordination.

Spurring the uptake of IPv6

The only indicator where Sweden fares extremely poorly, and much worse than the OECD average, is on IPv6 adoption (i.e. around 4% in Sweden compared to 10% for the OECD average). Some stakeholders have pointed out the possibility that the low rate of adoption of IPv6 may be a symptom of larger issues related to the interoperability of fixed networks stemming from the degree of "open access" of these networks. This consideration depends on the different levels of presence in passive and active wholesale participation of infrastructure providers, such as for municipal networks, and the incentives for co-ordination of networks and services. There is a lot of diversity in the municipal network models in Sweden.

The specific model used for municipal networks (i.e. passive infrastructure open access policies compared to bitstream or active infrastructure "open access" policies), may

create different incentives to upgrade network equipment among the three types of players in the Swedish broadband market. That is, incentives may depend on the terms of which the network owner grants access on various wholesale levels. For IPv6 adoption to succeed under the current Swedish market conditions, both the ISP and the communication provider of the bitstream access would have to offer the same technical solution. In the cases when an ISP has to use active equipment of a sole provider, the ISP may lack incentives to upgrade equipment. In this sense, fostering competition in the access to infrastructure (with the absence of fibre unbundling) may improve incentives to upgrade and deploy IPv6 equipment.

An approach such as the one taken by Stokab, leasing only "dark fibre" (i.e. passive infrastructure), versus the model where municipal networks offer bitstream access (i.e. active infrastructure), may provide more incentives for network operators to upgrade equipment to IPv6 due to more competition present in the different layers of the network, regardless of ownership. In this sense, the Swedish government should evaluate the incentives that result from municipal networks (or private operators) vertically integrated in two wholesale levels (i.e. passive and active infrastructure layers), and the degree of "open access" of all three layers (i.e. the infrastructure provision, bitstream access and the ISP layer). Incentives to upgrade equipment may vary among networks where the owner of the infrastructure is present only in the passive layer, from those vertically integrated (i.e. present in two downstream markets.

Furthermore, although in 2015 the PTS assessed the geographical definition of broadband markets, the regulator should remain vigilant as to whether there is a concern of lack of competition at the local level in some localities. That is, the PTS should continue ensuring that there is sufficient competition in infrastructure provision within the possibilities of the current SMP framework. Promotion of competition may enhance incentives to upgrade equipment.

Finally, a "focal user" or application can play an important role in facilitating the transition to IPv6, and governments and large companies can sometimes play this role (OECD, 2014b). In this sense, the Swedish government should work as an enabler of the IPv6 transition by establishing government promotion programmes to adjust Internet services for which it has responsibility, by adapting government purchasing and ensuring multi-stakeholder task forces to foster IPv6 deployment.

Further develop M2M measurement

Sweden is a leader in M2M penetration, and is one of the few OECD countries that captures more detailed statistics on M2M, such as revenue and traffic generated by M2M. Ericsson, Volvo and many Swedish companies are engaging in the future of the IoT and 5G and leading the way forward for the rest of the world. The IoT application that is expected to have the most implications in terms of data traffic, and hence, infrastructure requirements, are autonomous vehicles. Sweden, with Volvo, is already leading the way with a massive experiment of 100 autonomous vehicles in Gothenburg.

Given its position of leadership in the IoT and M2M, and taking advantage of the fact that Sweden is already a leader in developing IoT indicators, it is well placed to break out statistics for M2M. More specifically, it could report SIM cards related to connected and automated vehicles as opposed to other M2M applications. This will help policy makers to start measuring an application that may have important implications for communications infrastructure in the near future.

Notes

1. In the *Digital Economy Outlook* questionnaire sent in 2016 (for the 2017 publication), Sweden answered that it had set aside SEK 1.63 billion for 2007-13 and SEK 4.85 billion for 2014-20 to achieve the goals of the Broadband Strategy of 2009 (i.e. 100 Mbps service to 90% of all households and businesses in Sweden by 2020). Using the annual exchange rate of 8.561992 SEK/USD for 2016, these figures are equal to USD 0.19 billion and USD 0.57 billion.

2. Europe's Digital Progress Report-2017 (telecoms chapter) for Sweden mentioned the following: "The Ministry of Enterprise and Innovation notably expects that the 90% coverage target described above will be fulfilled before the initial target date of 2020" (European Commission, 2017d).

3. The Broadband Forum has a steering board headed by the Ministry of Enterprise and Innovation, and all members of this board are appointed by the government. The administrative offices of the forum are within the PTS, as the PTS supports the work of the Broadband Council. The Broadband Council Administrative Office is an autonomous unit placed structurally under the Director General of the PTS, though it reports to the Government Offices of Sweden (www.bredbandivarldsklass.se/Om-Bredbandsforum/Styrgrupp).

4. The countries for which Cisco VNI Mobile Highlights 2016-2017 (Cisco VNI, 2017), includes information for are: Australia, Canada, Chile, France, Germany, Italy, Japan, Korea, Mexico, New Zealand Poland, Spain, Sweden, the United Kingdom and the United States (Cisco VNI, 2017).

5. The RAN consists of the site, mast, antenna, BTS and backhaul. The company managing the site will lease the whole package to an MNO and carry the data to the core network of the MNO. It can use the same radio equipment to broadcast and receive traffic of multiple spectrum license holders.

6. To calculate the number of M2M/embedded mobile cellular subscriptions, the OECD defines M2M on mobile networks as "the number of SIM-cards that are assigned for use in machines and devices (cars, smart meters, and consumer electronics) and are not part of a consumer subscription".

7. This price in USD takes into account the annual exchange rate of 8.56 SEK/USD for the year 2016.

8. See endnote 7.

9. The PTS has pointed out that there are difficulties in comparing numbers between European countries based on the statistics reported to the European Commission since all countries measure coverage in their own way. It states the following: "In general the PTS statistics provide more detailed numbers than average. For example – in Sweden the PTS reports numbers for FTTH (not FTTP) for NGA coverage. The PTS

does not have coverage for FTTP, since that measure is not used in Sweden. In many countries FTTP is measured as having NGA-coverage within 500 metres from the house. The definition of rural areas is not the same in all EU-countries and PTS target quite remote areas in comparison."

10. Sweden holds a similar ranking taking into account that Latvia was not an OECD country in 2012. However, in 2012, Latvia had 45.77% of fibre connections as a percentage of total broadband, thus if it had been an OECD country then, Sweden would have held the exact same ranking (i.e. 4th) after Korea, Japan and Latvia.

11. This price in USD takes into account the annual exchange rate of 8.56 SEK/USD for the year 2016.

12. Stokab, a municipal fibre network owned by the Stockholm City Council, is an "operator-neutral" provider, offers wholesale access to passive fibre infrastructure (i.e. it offers dark fibre on a wholesale only basis). Stokab leases its dark fibre to multiple network providers, who attach their own active equipment on Stokab's passive infrastructure and provide transmission capacity either to end users or to service providers (i.e. ISPs). Stokab's network has 1.25 million kilometres of fibre (a length equivalent to 30 times around the earth). Since the company was established in 1994, its stated goal has been to "build a competition-neutral infrastructure capable of meeting future communication needs, spur economic activity, diversity and freedom of choice, as well as minimizing disruption to the city's streets" (Stokab, 2017). A "competition neutral" network, as the company describes itself, should be understood as pertaining only the retail level (and not the competition in the horizontal level).

13. Although it is difficult to tease out the driver of lower retail prices (i.e. whether it was due to lower costs through the wholesale price effect, or the competition effect of more ISPs being present), both factors are very much linked and create a virtuous circle.

14. The statement refers to the moment of writing of the report. However, the PTS is currently considering other market definitions for future regulation. Please refer to: https://www.pts.se/sv/nyheter/internet/2017/preliminara-forslag-till-marknadsavgransning-pa-bredbandsmarknaderna/.

15. Although the Swedish Competition Act as well as the Treaty on the Functioning of the European Union Articles 101 and 102 are still applicable. In addition, municipalities subject to other laws.

16. See: www.pts.se/sv/Bransch/Telefoni/Konkurrensreglering-SMP.

17. This price takes into account an exchange rate of 0.75 EUR/USD for the year 2014.

18. The PTS provides broadband coverage maps according to speed. See: http://bredbandskartan.pts.se/#.

19. OECD countries agreed to: "Encourage the adoption of the new version of the Internet protocol (IPv6), in particular through its timely adoption by governments as well as large private sector users of IPv4 addresses, in view of the ongoing IPv4 depletion."

20. "Having only commercially launched in September 2016 as the first LTE, all-IP mobile network in India, Reliance Jio Infocomm Limited boosts India past 20% IPv6 capability". See: https://blog.apnic.net/2017/02/07/reliance-jio-boosts-india-past-20-ipv6-capability.

21. See list of authorities using IPv6 at: http://e-tjanster.pts.se/internet/ipv6/Listning.aspx.

22. There are several video-on-demand services available in Sweden (e.g. according to Mediavision, Netflix reported 685 000 subscriptions in 2015 and HBO Nordic 100 000 subscriptions in 2014). In general, over-the-top services in Sweden are not specifically regulated apart from the rules of net neutrality that apply to network operators.

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