

U.S. vs. European Broadband Deployment: What Do the Data Say?

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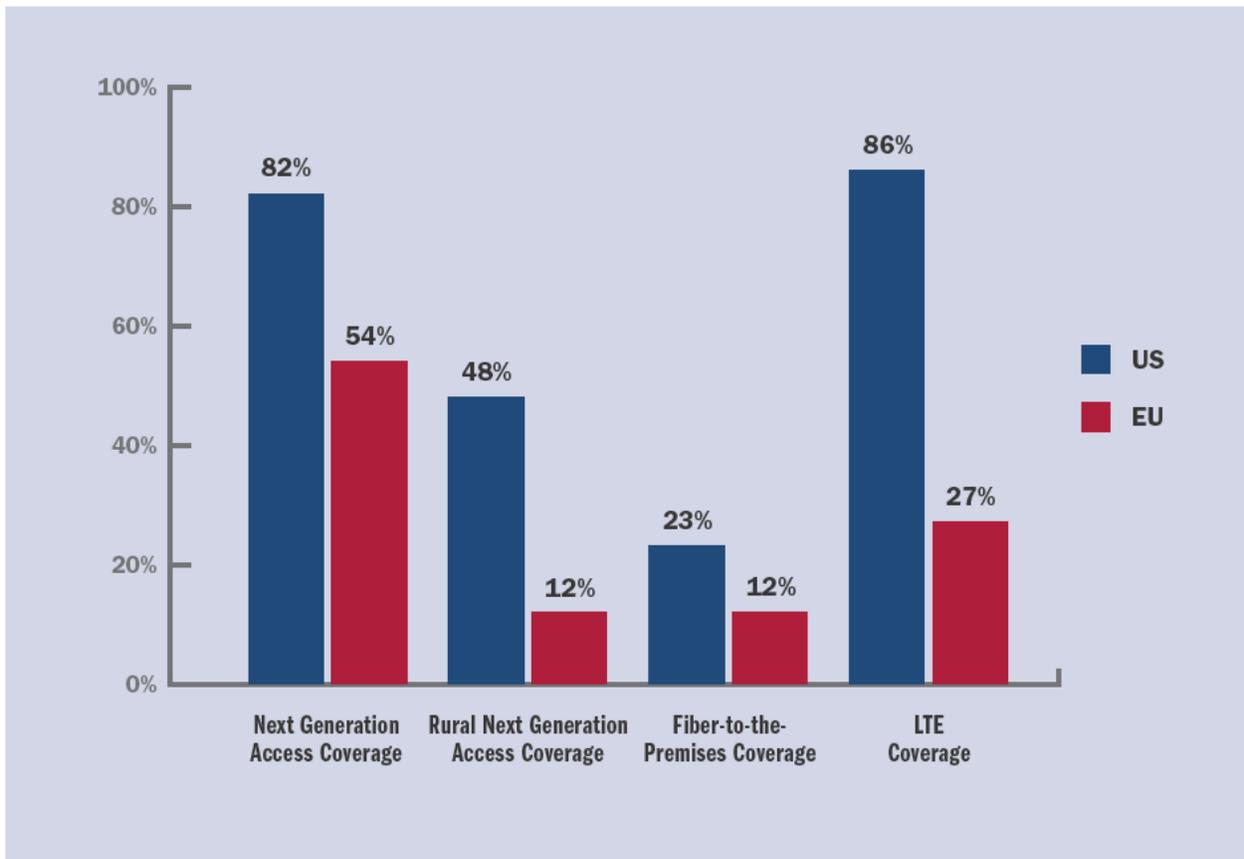
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EXECUTIVE SUMMARY

As the Internet becomes more important to our everyday lives, commentators debate over the best policies and models to drive even more widespread adoption and deployment of broadband technologies. Some claim the European model of service-based competition, induced by stiff telephone-style regulation, outperforms the facilities-based competition practiced in the U.S. in promoting broadband. Data analyzed for this report reveals, however, that the U.S. led in many broadband metrics in 2011 and 2012.

- **High-Speed Access:** A far greater percentage of U.S. households had access to Next Generation Networks (NGA) (25 Mbps) than in Europe. This was true whether one considered coverage for the entire nation (82% vs. 54%) or restricted the analysis to rural areas (48% vs. 12%), suggesting that the U.S. approach proved more effective than the European approach at narrowing the digital divide.
- **Fiber and LTE Deployment:** Turning to specific technologies, the data indicate that the U.S. had better coverage for fiber-to-the-premises (FTTP) (23% vs. 12%) and for the fourth-generation wireless technology known as Long-Term Evolution (4G LTE) (86% vs. 27%). Furthermore, empirical analysis undercuts claims that the provision of high-speed Internet depended exclusively on fiber. In short, FTTP remained a minor contributor to NGA coverage, and those countries that emphasized fiber were the bottom broadband performers among the eight European countries studied.
- **Regulatory Policies and Competition Models:** Disparities between European and U.S. broadband networks stemmed from differing regulatory approaches. Europe has relied on regulations that treat broadband as a public utility and focus on promoting service-based competition, in which new entrants lease incumbents' facilities at wholesale cost (also known as unbundling). The U.S. has generally left buildout, maintenance, and modernization of Internet infrastructure to private companies and focused on promoting facilities-based competition, in which new entrants are expected to construct their own networks. Regression analysis indicates that the U.S. approach has proven more effective in promoting NGA coverage than the European approach.
- **Investment:** The difference in regulation and competition models influenced the amount of broadband investment in the U.S. and Europe. In Europe, where it was cheaper to buy wholesale services from an incumbent provider, there was little incentive to invest in new technology or networks. In the U.S., however, providers had to build their own networks in order to bring broadband services to customers. Data analysis indicates that as of the end of 2012, the U.S. approach promoted broadband investment, while the European approach had the opposite effect (\$562 of broadband investment per household in the U.S. vs. \$244 per household in Europe).
- **Download Speeds:** U.S. download speeds during peak times (weekday evenings) averaged 15 Mbps, which was below the European average of 19 Mbps. There was also a disparity between the speeds advertised and delivered by broadband providers in the U.S. and Europe. During peak hours, U.S. actual download speeds were 96% of what was advertised, compared to Europe where consumers received only 74% of advertised download speeds. The U.S. also fared better in terms of latency and packet loss.

Coverage in the U.S. and Europe, 2012



- Price:** The European pricing study reveals that U.S. broadband was cheaper than European broadband for all speed tiers below 12 Mbps. U.S. broadband was more expensive for higher speed tiers, although the higher cost was justified in no small part by the fact that U.S. Internet users on average consumed 50% more bandwidth than their European counterparts.

Data analyzed for the study resolves the question whether the U.S. is running behind Europe in the broadband race or vice versa. The answer is clear and definitive: As of 2012, the U.S. was far ahead of

Europe in terms of the availability of NGA. The U.S. advantage was even starker in terms of rural NGA coverage and with respect to key technologies such as FTTP and LTE. The empirical evidence thus confirms that the United States is faring better than Europe in the broadband race and provides a strong endorsement of the regulatory approach taken so far by the U.S. It also suggests that broadband coverage is best promoted by a balanced approach that does not focus exclusively on any one technology.

Case studies of eight European countries (Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, and the United Kingdom) confirm that facilities-based competition has served as the primary driver of investments in upgrading broadband networks. Moreover, the countries that emphasized FTTP had the lowest NGA coverage rates in this study and ranked among the lowest NGA coverage rates in the European Union. In fact, two countries often mentioned as leaders in broadband deployment (Sweden and France) end up being rather disappointing both in terms of national NGA coverage and rural NGA coverage.

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Data analysis indicates that the U.S. approach promoted broadband investment, while the European approach had the opposite effect.

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Comparison between U.S., EU and Case Study Countries, 2012

	Total NGA	Rural NGA	Investment per HH	Bandwidth per User	Percentage Rural HHs
U.S.	82%	48%	\$562	27	19%
Europe	54%	12%	\$244	18	15%
Sweden	57%	6%	\$280	n/a	17%
France	24%	1%	\$326	12	18%
Italy	14%	0%	\$291	12	13%
Denmark	73%	3%	\$457	n/a	17%
Spain	64%	13%	\$255	13	18%
Netherlands	98%	85%	\$450	n/a	8%
UK	70%	18%	\$215	31	9%
Germany	66%	26%	\$197	14	11%

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“ Survey after survey shows U.S. broadband quality, speed and adoption rates falling dangerously behind that of countries in Asia and Europe.

– Free Press

“ [W]hile digital technology and content has improved, and countries around the world, from the US to Asia, are starting to reap the benefits out of it, Europe is falling behind.

– Neelie Kroes (2013b)

1. INTRODUCTION

Articles periodically appear in the U.S. media raising the concern that the U.S. is falling behind Europe in the broadband race. These stories typically characterize U.S. high-speed broadband as widely unavailable, expensive, and slow. The proposed solution is to reform U.S. broadband policy so that it is more like Europe's (see, e.g., *New York Times* 2013, 2014b; *NPR* 2014; *USA Today* 2014).

Media reports and speeches by policymakers on the other side of the Atlantic tell a very different story. The concern there is that Europe is falling behind the United States and that the low levels of investment in broadband infrastructure indicate that Europe should consider adopting a more U.S.-style regulatory approach (see, e.g., Kroes 2012a, 2012b, 2013a, 2013b, 2013c; *Süddeutsche Zeitung* 2013 (quoting Angela Merkel)).

The contradictory nature of these statements invites a closer examination of the true state of affairs with respect to broadband in different parts of the world (although this study focuses on Europe and defers consideration of Asian broadband until another study planned for later this year). The most frequently cited basis for comparison is the data about broadband subscriptions collected by the Organisation for Economic Co-operation and Development (2013). However, these data are problematic for several well-recognized reasons. First, the OECD defines broadband as any service capable of delivering 256 kbps. As a result, the data provide information about a service tier that is generally regarded as obsolete. Second, broadband subscribership represents a rather murky indicator of broadband availability and investment. Studies have consistently shown that the primary reasons that people do not subscribe to broadband are a lack of interest, lack of a computer, difficulties in using the Internet, lack of computer skills, and age rather than nonavailability or high prices (EC 2013b, 13; Ofcom 2013a, 368; Pew Research Center Internet Project 2013).

Broadband penetration levels thus reflect a broad range of considerations unrelated to coverage and infrastructure investment. What is needed is a direct measure of broadband availability. Although the OECD tracks this information, the data currently available are rather old, having not been updated since 2009, and again track the obsolete 256 kbps standard.

Fortunately, both the European Commission (EC) and the U.S. government have recently commissioned studies providing detailed information about the extent of broadband coverage as of the end of 2011 and 2012 (NTIA and FCC 2012a, 2013a; EC 2012a, 2013a). These studies report coverage levels for a wide range of speed tiers and technologies in both urban and rural areas. The European mapping study focuses on Next Generation Access (NGA), which it defines to be service providing download speeds of at least 30 Mbps, a close analysis reveals that the study actually reports data for 25 Mbps service (EC 2013a, 6).

These data reveal that concerns that the U.S. is losing the broadband race are misplaced. As an initial matter, a far greater percentage of U.S. households have access to NGA than in Europe. Interestingly, this is true whether one considers coverage for the entire nation or one restricts the analysis only to rural areas, suggesting that the U.S. approach is more effective than the European approach at narrowing the digital divide. Turning to specific technologies, the data also indicate that the U.S. also has better coverage for cutting-edge technologies, including fiber-to-the-premises (FTTP) and for the fourth-generation wireless technology known as Long-Term Evolution (4G LTE).

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The mapping data also provide insight into the long-standing debate between the regulatory philosophies underlying U.S. and European broadband policy. European broadband policy has focused on promoting service-based competition, in which new entrants lease the incumbents' facilities at wholesale cost, while U.S. broadband policy has focused on promoting facilities-based competition, in which new entrants are expected to construct their own networks. The mapping data are sufficiently detailed to permit regression analysis to determine which approach is better at promoting high-speed broadband coverage. The regressions indicate that the U.S. approach is promoting broadband investment, while the European approach is having the opposite effect. More specifically, service-based com-

petition has a statistically significant negative impact on NGA coverage, while facilities-based competition has a statistically significant positive effect on NGA coverage. The fact that these regressions yield such strong results despite being based on a relatively small number of observations attests to the strength of these conclusions.

These results have clear implications for public policy. For example, they shed light in to how Europe can meet its Digital Agenda goal of 100% NGA coverage by 2020. In addition, as noted above, European policymakers have begun an active debate over whether they should shift their emphasis away from their traditional focus on promoting service-based competition in favor of an approach focused on increasing incentives to invest in infrastructure. In the U.S., comparisons with the European experience are sometimes invoked as support for proposals to reclassify the Internet to bring it within the regime of common carriage or public utility regulation that has governed traditional telephone service (FCC 2014). The experience under the different approaches to regulation will also provide insights into how to manage the IP transition as well as how best to update the U.S. communications statutes.

These mapping studies have been supplemented by other studies conducted or commissioned by the EC or the FCC that examine other key information, such as broadband investment, pricing, and download speeds (EC 2012b, 2013d, 2014c, FCC 2012b). The European pricing study reveals that U.S. broadband is cheaper in the U.S. than European broadband for all speed tiers up to 12 Mbps. U.S. broadband is more expensive for higher speed tiers, although the higher cost is justified in no small part by the fact that the average U.S. household consumes 57% more bandwidth than its European counterpart.

The study supplements the European-level analysis with case studies of eight leading European countries. These studies reveal that three countries that did not face vigorous competition from cable and emphasized FTTP over DSL (Sweden, France, and Italy) achieved the lowest NGA coverage rates in this study, ranking near the very bottom of the EU, and were particularly weak in rural NGA coverage. The only country of these countries to achieve significant fiber penetration (Sweden) did so through government subsidies that led to public ownership of 40% to 50% of the fiber. Sweden still ranked only 20th of 28 EU states. The five countries with effective competition from cable all exceeded EU NGA coverage levels. Among the two countries that

The European pricing study reveals that U.S. broadband is cheaper in the U.S. than European broadband for all speed tiers up to 12 Mbps.

emphasized FTTP over DSL, Denmark's FTTP initiative (driven largely by energy companies) has stalled, while Spain's is increasing its deployments. Among countries emphasizing VDSL, FTTP coverage remains surprisingly modest in the Netherlands, notwithstanding the well-publicized fiber initiatives associated with Reggefiber and CIF. Germany and the UK have achieved respectable NGA coverage despite focusing on VDSL almost to the total exclusion of FTTP. These outcomes suggest that policymakers should not focus too narrowly on any one technology. Instead, they should take a flexible approach that takes into account existing deployments and the different economics underlying each technology.

2. THE EUROPEAN AND U.S. MAPPING STUDIES

2.1 Next Generation Access (NGA) Coverage

As noted above, for purposes of measuring broadband investment, coverage is the better way to measure outcomes than subscriptions. Fortunately, both the EC and the U.S. government have recently commissioned mapping studies that have generated high-quality data regarding broadband availability as of the end of 2011 and 2012. The European study encompasses the member states of the EU as well as Iceland, Norway, and Switzerland, although it reports data for the EU as well as for all of the study countries. The U.S. study reports both nationwide and state-level measures. Both studies also report broadband coverage for rural areas and break out each of these measures by all of the leading broadband technologies.

A comparison of the top-line statistics reveals the U.S. is far ahead of Europe in terms of total NGA coverage.

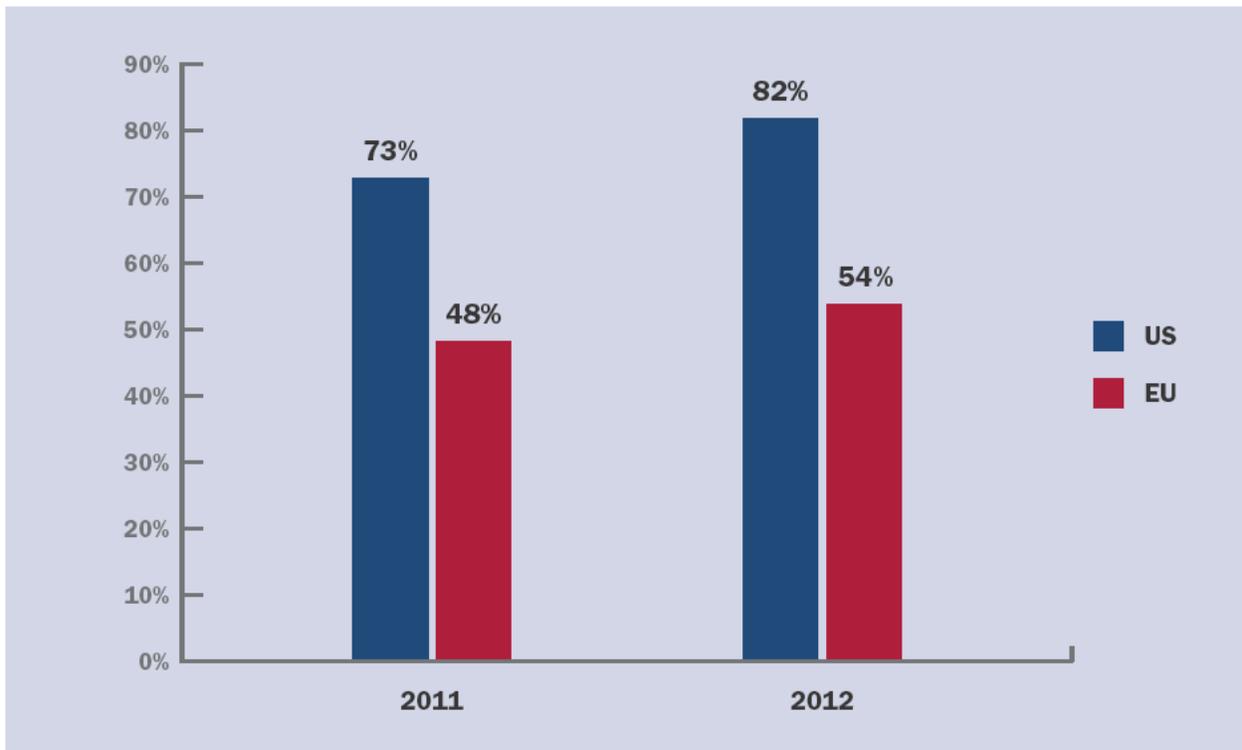
One major difference between the studies is the speed tiers analyzed. The U.S. study reports results for a wide variety of download speeds, including 768 kbps, 1.5 Mbps, 3 Mbps, 6 Mbps, 10 Mbps, 25 Mbps, 50 Mbps, and 100 Mbps. The European study reports results for only two speed tiers. The first is standard broadband, which the study defines as service providing download speeds of at least 144 kbps. The second is what the European Commission calls Next Generation Access (NGA). Although the EC's Digital Agenda defines NGA as 30 Mbps service, the mapping study defines NGA to include three technologies: VDSL, cable broadband provided through DOCSIS 3, and fiber-to-the-premises (FTTP), which includes both fiber-to-the-home (FTTH) and fiber-to-the-basement (FTTB). VDSL was in turn defined to include services capable of supporting download speeds of at least 25 Mbps (EC 2013a, 6). Although the European VDSL data is supposed to include only services capable of delivering download speeds of 25 Mbps, two countries (Belgium and the UK) included all VDSL services without limiting to those that met that threshold. Moreover, the European study

could also not confirm whether the data reported by six other countries (Austria, Poland, the Czech Republic, Greece, Italy, and Hungary) included only VDSL services that delivered 25 Mbps. As a result, the European data may overstate VDSL coverage slightly. The data for NGA coverage reported in the European mapping study is thus better regarded as representing coverage for 25 Mbps service, which matches up nicely with the data on 25 Mbps service provided in the U.S. study.

In addition, the U.S. mapping study was implemented by contracting separately with agencies in each state. Variations may thus exist in the way the U.S. data were collected. For example, the U.S. mapping data reports that VDSL provides 25 Mbps service to only 9.5% of U.S. households as of the end of 2012 even though AT&T reports providing its U-verse service to 24.5 million or 18% of U.S. households as of that date (AT&T 2012). Indeed, Ofcom places U.S. VDSL 30 Mbps coverage at 21% as of 2012 (Ofcom 2013b, 42). Despite such discrepancies, this study relies on the U.S. mapping data as reported to ensure consistency. Since that time, VDSL in the U.S. has continued to expand. In November 2012, AT&T announced its Project VIP which included \$6 billion to extend its VDSL coverage from 24.5 million to 33 million homes, while deploying a technology known as IP DSLAMs to improve DSL service to an additional 24 million homes by the end of 2015. Together these technologies will provide 45–75 Mbps to 57 million homes.

Any comparisons based on the mapping studies must thus be made in terms of the tiers included in the European mapping study: standard broadband and NGA/25 Mbps. As it turns out, U.S. and European coverage for standard broadband are almost identical. Standard coverage is available in 99.5% of U.S. households and 99.4% of European households. Standard fixed coverage is available in 95.8% of U.S. households and 95.5% of European households. The fact that the European data reflect lower download speeds (144 kbps) than the U.S. data (768 kbps) indicates that if anything, these data understate the slight advantage enjoyed by the U.S.

Rural standard broadband coverage (98.4% for the U.S. vs. 96.1% for Europe) and rural standard fixed broadband (82.1% for the U.S. vs. 86.3% for Europe) are also quite similar, although as noted earlier the U.S. data reflect higher download speeds than the European data. Mobile broadband coverage at 3G speeds also fall within quite similar ranges, covering 98.5% of U.S. households and 96.3% of European

FIGURE 1:**NGA Coverage (25 Mbps) in the U.S. and Europe, 2011 and 2012**

Sources: EC (2013a); NTIA and FCC (2012a, 2013a).

households. The U.S. does enjoy an advantage with respect to rural 3G mobile broadband (94.9% for the U.S. vs. 82.1% for Europe).

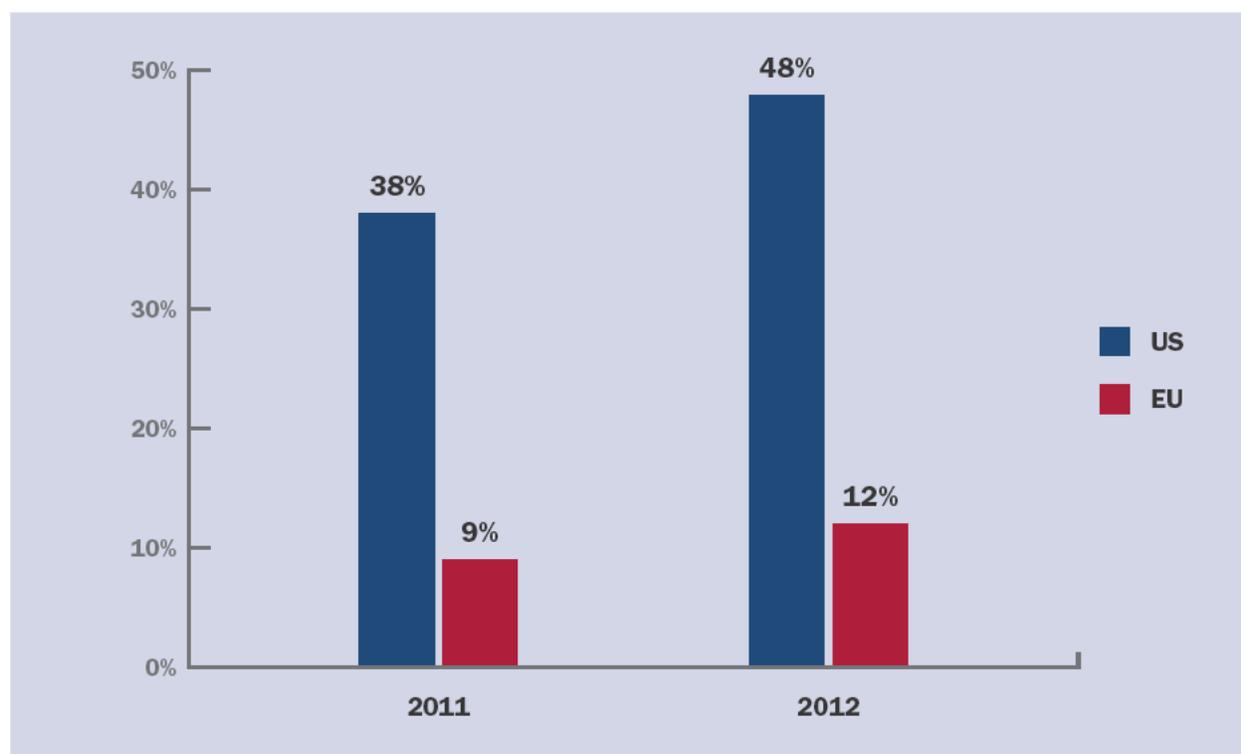
The data for 25 Mbps service reveal more significant differences. A comparison of the top-line statistics reveals the U.S. is far ahead of Europe in terms of total NGA coverage. Specifically, NGA service was available in 73% of U.S. households as of the end of 2011 and in 82% of U.S. households as of the end of 2012. By contrast, NGA service was available in only 48% of European households by the end of 2011 and in 54% of European households by the end of 2012.

A paired t-test indicates that the difference between U.S. and European NGA coverage is statistically significant at the 98% confidence level. Moreover, the U.S. advantage increased over time: In 2011, the difference between the U.S. and Europe NGA coverage was 25 percentage points, whereas by 2012 the difference had increased to 28 percentage points. Given the high levels of U.S. NGA penetration, it is unlikely that the U.S.

will be able to maintain this lead with respect to 25 Mbps service in the future, although the gap may persist at higher speed tiers. That said, it is clear that the U.S. enjoyed substantially greater national coverage of 25 Mbps service in 2011 and 2012.

2.2 Rural NGA Coverage

In addition to national data, both the U.S. and European studies include data for NGA coverage in rural areas. The U.S. and the European study applied slightly different definitions of rural areas. The European study viewed an area as rural if the population density was less than 100 people per square kilometer. The U.S. study viewed an area as rural if the population density was less than 500 people per square mile, which is the equivalent of 193 people per square kilometer. The U.S. definition includes areas that have slightly higher population density and thus is more forgiving.

FIGURE 2:**Rural NGA Coverage (25 Mbps) in the U.S. and Europe, 2011 and 2012**

Sources: EC (2013a); NTIA and FCC (2012b, 2013b).

In addition, the European mapping study identifies rural areas based on the European Kilometre Grid (EKG), which divides countries into squares one kilometer across and provides population density and basic land-use data for each square. The U.S. mapping study identifies rural areas in terms of census blocks (U.S. Census Bureau 1994).

With respect to rural NGA coverage, the gap between the U.S. and Europe was even wider than for total NGA coverage. As of the end of 2011, NGA service was available in 38% of U.S. rural households and 9% of European rural households. By the end of 2012, NGA service increased to 48% of U.S. rural households and 12% of European rural households. Given the wide disparity in these numbers, it is unlikely that it can be explained by the difference in definitions of what constitutes a rural area.

A paired t-test indicates that this difference is statistically significant at the 96% confidence level. Moreover, the U.S. advantage increased over time: In 2011, the

difference between the U.S. and Europe was 29 percentage points, whereas in 2012, the difference increased to 36 percentage points. As noted above, the fact that the U.S. study is based on a more generous definition of rural than the European study means that the actual difference is likely to be somewhat smaller, but it is unlikely that variation in methodology can explain all of the difference.

If the U.S. had been included in the European study, it would have ranked sixth in both NGA coverage and rural NGA coverage, behind only five countries. These countries are listed in Table 1, along with some additional information.

The rural household numbers are from the European mapping study. Population density and GDP per capita (adjusted for purchasing power parity) are from Eurostat, with GDP per capita indexed so that the EU average equals 100. Prices for 12–30 Mbps service are the median prices reported in the European study of broadband pricing as of February 2012 (EC 2012b).

TABLE 1:**Comparison of Countries with the Highest Total NGA Coverage, Rural NGA Coverage, 2012**

	Total NGA Rank	Rural NGA Rank	Pct. Rural HHs	Pop. Density (pop./km ²)	GDP per capita	Price 12–30 Mbps	Avg. speed Mbps
Malta	1	1	1%	1327	86	42 €	n/a
Netherlands	2	3	8%	497	128	30 €	8.6
Belgium	3	4	5%	367	120	34 €	6.7
Switzerland	4	5	15%	200	158	43 €	8.7
Luxembourg	5	2	13%	205	263	46 €	4.7
U.S.	6	6	19%	34	152	36 €	7.4

Sources: EC (2012b, 2013a); Eurostat (2014a, 2014c); NTIA and FCC (2013a, 2013b); Akamai (2013).

Average download speed is from Akamai, which, in light of the fact that SamKnows did not report download speeds for individual countries, represents the best source of country-level data on download speeds (Bauer, Clark, and Lehr 2011).

The countries that achieved higher NGA coverage than the U.S. are significantly more urban and compact than the U.S. In fact, the top three countries are the most urban countries in the European mapping study (Malta, Belgium, Netherlands), and the other two countries are in the top eleven in terms of urbanization and two of

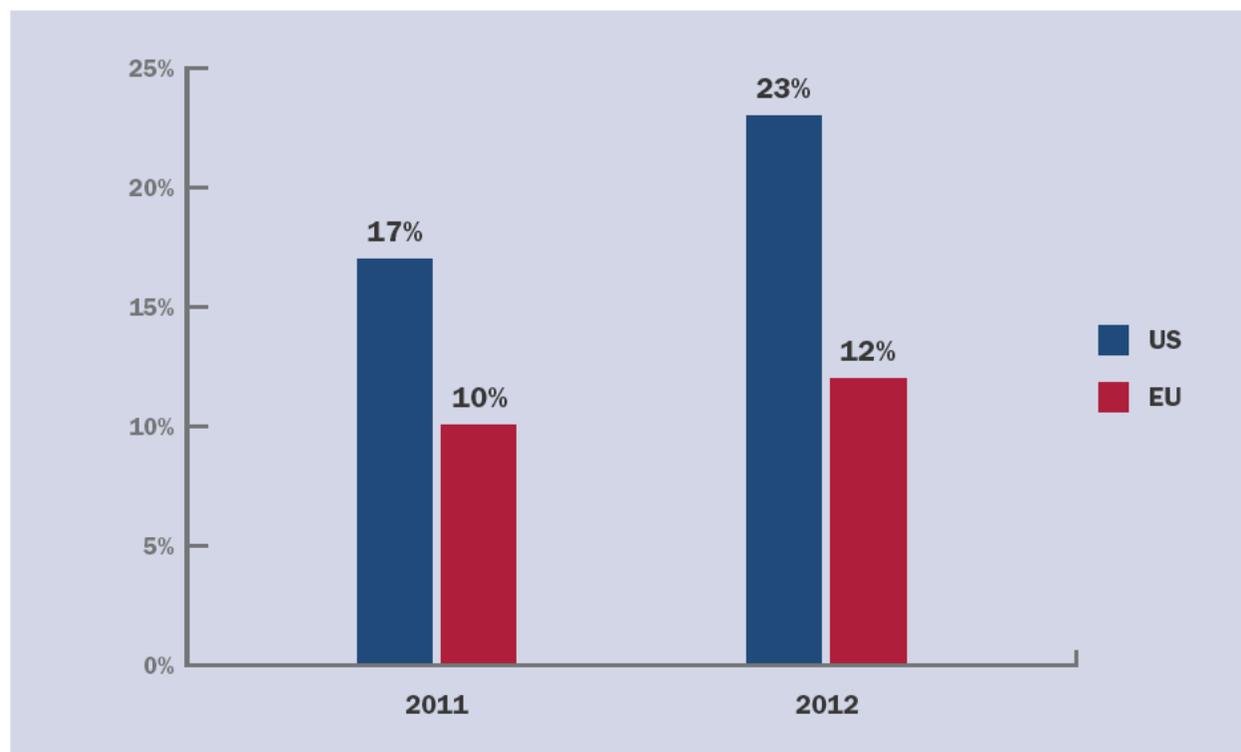
the top three countries in Europe in terms of per capita GDP (Luxembourg, Switzerland). Furthermore, with the exception of Malta, all of the top NGA countries have per capita GDPs that far exceed the European average. In Malta, Switzerland, and Luxembourg, the price of 25 Mbps service is substantially higher than in the U.S., and in Luxembourg, the average download speed is substantially lower.

The U.S. would have thus stood close to the top of the list if it had been included in the European study of NGA coverage. The fact that the U.S. compares favor-

TABLE 2:**Percentage of Households covered by NGA, FTTP, DOCSIS 3, and VDSL and Rank for the Top Five NGA Countries, 2012**

	NGA	Rank	FTTP	Rank	DOCSIS 3	Rank	VDSL	Rank
Malta	99.9%	1	1%	27	99.9%	1	75%	3
Netherlands	98%	2	18%	16	98%	2	60%	4
Belgium	97%	3	0.3%	30	96%	3	85%	2
Switzerland	94%	4	17%	17	93%	4	53%	5
Luxembourg	94%	5	32%	12	61%	6	88%	1

Source: EC (2013a).

FIGURE 3:**FTTP Coverage in the U.S. and Europe, 2011 and 2012**

Sources: EC (2013a); NTIA and FCC (2012a, 2013a).

ably with countries that are much more urban and with significantly higher GDPs per capita is actually quite remarkable.

2.3 Fiber-to-the-Premises (FTTP)

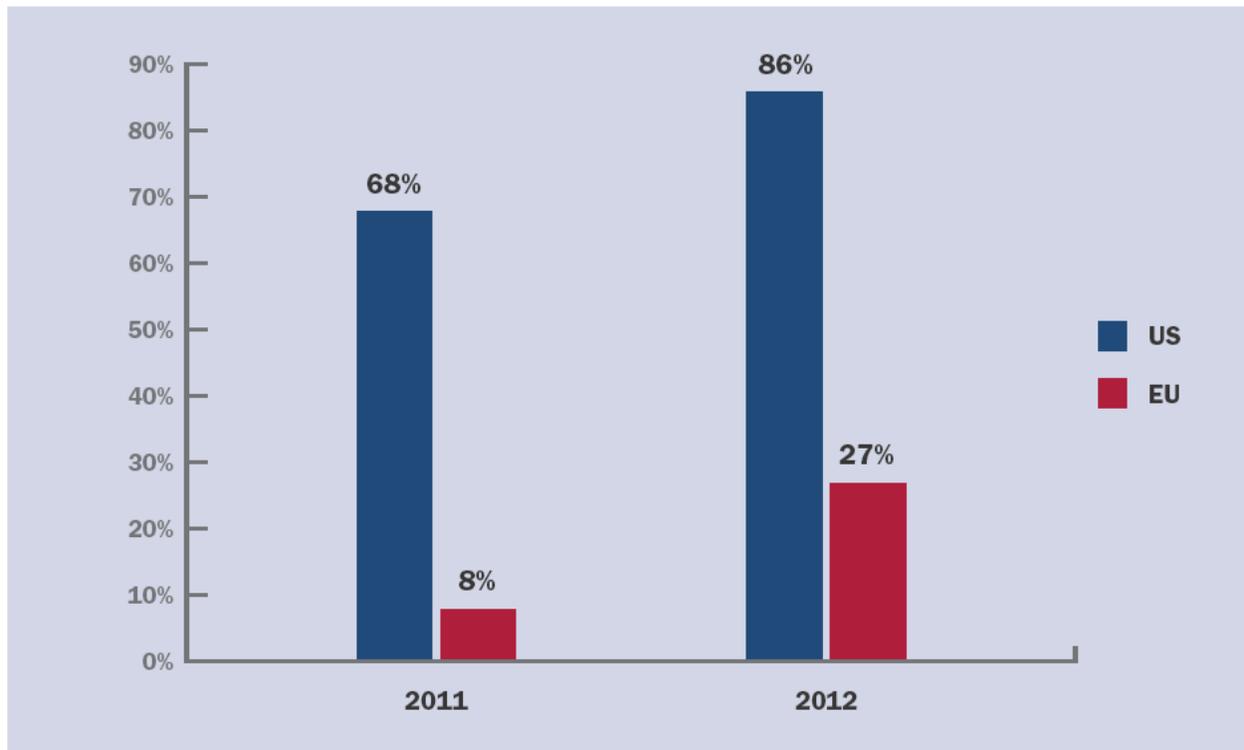
The mapping studies also provide insights into which technologies make the largest contribution to NGA coverage. Although many advocates regard FTTP as the primary platform for NGA, the data suggest otherwise. In Europe, DOCSIS 3 (39% as of 2012) and VDSL (25%) both contribute more to NGA coverage than does FTTP (12%). In terms of actual NGA subscriptions, the distribution skews even more heavily towards DOCSIS 3, with 57% of subscribers, followed by FTTP at 26%, and VDSL at 15% (EC 2013, 43, 52).

An analysis of the countries with the broadest NGA coverage reveals a similar pattern. Five European countries enjoyed NGA coverage that exceeded the

U.S. level of 82%. Interestingly, FTTP did not play a major role in any of these countries. In fact, two of them ranked near the bottom of FTTP coverage, and the other three fell somewhere in the middle of the pack. In contrast, all five of these countries ranked at the top for both DOCSIS 3.0 and VDSL coverage. The 2012 data thus do not support the critical role that many commentators assign to FTTP.

Even if one were to focus exclusively on FTTP coverage, the data clearly give the edge to the U.S. As of the end of 2011, FTTP service was available in 17% of U.S. households and 10% of European households. By the end of 2012, FTTP service increased to 23% of U.S. households and 12% of European households.

A paired *t*-test indicates that this difference is statistically significant at the 94% confidence level. If the U.S. were included in the European study, it would rank 12th, behind a number of Scandinavian countries, Eastern Europe countries, Luxembourg, and Portugal.

FIGURE 4:**LTE Coverage in the U.S. and Europe, 2011 and 2012**

Sources: EC (2013a); FCC (2013a).

2.4 LTE

The European study also collected data on LTE coverage as of the end of 2011 and 2012. The U.S. study did not collect LTE coverage data. However, LTE coverage data is available from the FCC's most recent Wireless Competition Report (2013a), which reported LTE coverage by population (instead of household) as of January 2012 and October 2012. Although these dates and measures do not correspond precisely with the data in the European mapping study, they are close enough to permit a useful comparison to the year-end 2011 and 2012 numbers reported for Europe.

With respect to LTE coverage, the data confirm the conventional wisdom that the U.S. is far ahead of Europe. As of the end of 2011, LTE covered 68% of the U.S. population and 8% of European households. By the end of 2012, LTE coverage increased to 86% of the U.S. population and 27% of European households.

A paired t-test indicates that this difference is statisti-

cally significant at the 99.8% confidence level. If the U.S. had been included in the European study, it would have ranked third in LTE coverage, trailing only Sweden and Portugal.

Because European coverage is measured based on households and U.S. coverage is based on population, this comparison should be approached with some caution. The wide disparity in these numbers makes it unlikely that this difference can be explained by the way coverage is defined. If anything, given the rapid buildout in the last two months of 2012, the fact that the U.S. data reflects coverage as of October 2012 instead of December 2012 means that if anything, the data understate the magnitude of the difference between U.S. and European LTE coverage rates.

* * *

A comparison of the U.S. and European mapping studies thus contradicts claims that the U.S. has fallen behind Europe in the broadband race. On the contrary,

the data convincingly show that it is Europe that has fallen behind the U.S. in terms of NGA, rural NGA, FTTP, and LTE coverage. If the U.S. had been included in the European study on these measures, it would have ranked in the top six for every measure discussed above except for FTTP, and the only countries it would have trailed would have been compact, highly urbanized nations with high per capita GDPs and thus have a much easier time delivering high-speed broadband. The only exception is with respect to FTTP, and the data suggest that FTTP is the technology that contributes the least to NGA coverage.

2.5 Regression Analysis of Facilities-Based vs. Service-Based Competition

The European mapping studies also provide insight into one of the central debates in broadband policy. In the 1990s, as part of the Federal Communications Commission's *Computer Inquiries* and the Telecommunications Act of 1996, the U.S. developed the policy of permitting competitors to share incumbent providers' networks through local loop unbundling and wholesale access. The U.S. soon soured on this idea in part because the type of competition induced by infrastructure sharing is quite thin, with competitors being unable to innovate with respect to services and being limited to competing by squeezing their own margins, and in part because sharing can create disincentives to invest in infrastructure. As a result, the U.S. abandoned local loop unbundling in favor of a regulatory approach that focused on facilities-based competition.

European regulation, in contrast, has continued to emphasize the service-based competition by requiring carriers with significant market power to share their facilities through mechanisms such as local loop unbundling, shared access, and bitstream access. This regime was not designed only to permit competitors to share those network elements that exhibited natural monopoly characteristics and thus could not be replicated economically. It was also intended to permit new entrants to climb the "ladder of investment" by gradually replacing the network elements leased from the incumbent with their own infrastructure (Cave 2006). These access obligations apply generally to VDSL and FTTP services provided by incumbent telephone companies, but except for Denmark do not apply to cable broadband services.

As the International Telecommunications Union (2001)

has recognized, the arguments for and against local loop unbundling and wholesale access are theoretically ambiguous. An extensive literature has emerged evaluating the impact of access regulation on investments in traditional voice service and standard broadband service (see Cambini and Jiang 2009 for a survey). The empirical literature evaluating the impact of access obligations on investments in NGA is somewhat smaller and uniformly concludes that access regulation deters investments in NGA (Wallsten and Hausladen 2009; Briglauer, Ecker and Gugler 2012; Bacache, Bourreau and Gaudin 2013; Briglauer 2014).

The European mapping study provides fresh data collected that can be used to test these propositions. Although the number of observations is quite limited, the dataset reflects sufficient heterogeneity to support regression analysis of the impact of service-based and facilities-based competition on NGA coverage.

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The primary measure for service-based competition is the new entrants' market share of DSL lines, which are presumably served by sharing the incumbent's network (EC 2014b). The primary measure of facilities-based competition is broadband coverage by standard cable (EC 2013a). Standard cable broadband coverage would seem to be a good measure of the full scope of potential facilities-based competition to incumbent telephone companies because of the ease with which standard cable can be upgraded to DOCSIS 3. In any event the difference between standard cable broadband coverage and DOCSIS 3 coverage is not material: 94% of all standard cable broadband in Europe and 92% of all standard cable broadband in the U.S. had already been upgraded to DOCSIS 3 by the end of 2012. Although the results are reported in terms of standard cable, replacing standard cable coverage with DOCSIS 3 coverage does not materially change the results of the regressions.

The regressions also include controls for the percentage of the rural households as reported in the European mapping study. The percentage of rural households represents a better measure of urbanization (and thus costs of providing broadband) than population density. This is because the most important consideration from the standpoint of NGA coverage is what percentage of a country's population resides in nonrural areas. The fact that a country may have large tracts of unoccupied land lowers its population density, but does not make providing NGA service to the vast majority of the population any more difficult.

Take Sweden, for example. With 23 people per square kilometer, it has one of the lowest population densities in Europe, well below the EU average of 116 people per square kilometer and even below the U.S. average of 34 people per square kilometer. At the same time, 85% of the Swedish population is clustered in cities along the coast and another 3% live in small towns (PTS 2013), which are typically places with sufficient density to make NGA service feasible. This places Sweden in the middle of the pack in terms of urbanization (13th among 28 EU countries) despite having the second lowest population density in the EU (behind only Finland). Population density thus overstates how difficult it would be for Sweden to achieve strong levels of NGA coverage.

Conversely, other countries have relatively low levels of urbanization despite having relatively strong population densities. For example, only 68% of Hungarians live in nonrural areas, which places Hungary 26th of 28 EU countries in terms of urbanization, despite the fact that Hungary's population density ranks 13th out of 28 EU countries. Population density thus understates how difficult it would be for Hungary to achieve strong levels of NGA coverage. The statistic contained in the European mapping study reporting the proportion of households that are rural (i.e., residing in areas with population density less than 100 people per square kilometer) thus represents a better control than population density.

The regressions also include controls for year fixed effects and per capita GDP, adjusted for purchasing power parity and normalized so that the EU average equals 100 (Eurostat 2014). Because the errors are not randomly distributed, standard errors are clustered by country. To make sure that small countries do not exercise a disproportionate impact on the results, the regressions weight each country by population. One could also regard each country as an independent

policy experiment deserving of equal weight. If so, the regressions should not be weighted by population. Running the regression without weighting by population does not materially change the results.

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The fact that a country may have large tracts of unoccupied land lowers its population density, but does not make providing NGA service to the entire population any more difficult.

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To test the impact of service-based and facilities-based competition on NGA coverage, specification (1) regresses the percentage of DSL provided by new entrants against NGA coverage; specification (2) regresses the degree of standard cable coverage against NGA coverage; and specification (3) regresses both variables against NGA coverage. These regressions confirm that service-based competition has a strong negative effect on NGA coverage and that facilities-based competition has a strong positive effect on NGA coverage. All of these variables are statistically significant despite the fact that the lack of observations limits the analytical power of the regression.

There are, however, two potential ambiguities in these results. First, as noted earlier, DOCSIS 3 is the primary NGA platform, contributing more than any other technology to NGA coverage. Because cable networks were deployed to deliver multichannel video, it is arguable that NGA coverage is not the product of either facilities-based competition or service-based competition, but is rather the path dependent outcome of different forces. Second, because NGA coverage is the combination of DOCSIS 3 coverage, VDSL coverage, and FTTP coverage, NGA coverage and DOCSIS 3 coverage are likely to be highly correlated. Rather than indirectly spurring telephone-based broadband providers into action, or cable broadband could contribute directly by serving as a platform for NGA coverage in and of itself.

The statistically significant results for specification (1) suggest that cable modem coverage is not the only important driver of NGA coverage, but specifications (2) and (3) are arguably ambiguous in this regard, although it is possible to address this con-

TABLE 3:**Impact of Service-Based and Facilities-Based Competition on Total NGA Coverage**

	(1)	(2)	(3)	(4)
Dependent variable	Total NGA coverage	Total NGA coverage	Total NGA coverage	VDSL+FTTP coverage
Percentage DSL by new entrants	-0.809*** (0.247)		-0.244† (0.167)	-0.770*** (0.219)
Standard cable coverage		0.845*** (0.84)	0.818*** (0.093)	0.288** (0.115)
Percentage rural households	-1.477* (0.792)	-0.617*** (0.218)	-0.655* (0.367)	-1.283** (0.473)
GDP per capita	0.0028* (0.0015)	0.0014* (0.0008)	-0.0004 (0.0010)	0.0019† (0.0014)
Year	0.050*** (0.013)	0.046*** (0.012)	0.036** (0.015)	0.084*** (0.021)
Observations	55	55	55	55
R²	0.38	0.89	0.88	0.66

*** Significant at the 99% level;

** Significant at the 95% level;

* Significant at the 90% level;

† Significant at the 80% level.

cern by reinterpreting specification (3) by treating standard cable coverage as a control rather than as an independent variable. If so, it shows that service-based competition induced by access obligations still has a negative effect on NGA coverage. Another approach is reflected in specification (4), which isolates the competitive impact of cable broadband on incumbent telephone companies by eliminating Total NGA coverage as the dependent variable and replacing it with the sum of VDSL and FTTP. This new dependent variable does not include DOCSIS 3 coverage as one of its components and reflects only those aspects of NGA coverage that are spurred on by competition from cable.

Specification (4) confirms that that service-based competition has a statistically significant negative impact on NGA coverage provided by telephone companies, while facilitates-based competition from cable broadband has a statistically significant positive impact on telephone companies. Alternatively, cable broadband coverage may also be treated as a con-

trol. Either way, service-based competition has as a statistically significant negative correlation with NGA coverage.

Conducting the same analysis on the rural data leads to the same conclusions.

The data collected by the European mapping study thus provides empirical support for claims that facilities-based competition promotes investment in NGA architectures and that regulation-induced service-based competition discourages such investments. That these regressions were able to yield such strong results based on so few observations underscores the strength of these effects. Indeed, many European leaders have indicated that the time may have arrived when Europe should shift its focus away from promoting service-based competition and towards promoting investment if it is to achieve the goal of 100% NGA coverage by 2020 (Kroes 2013c; Süddeutsche Zeitung 2013 (quoting Angela Merkel)). The European experience also provides a real-world example of the

TABLE 4:**Impact of Service-Based and Facilities-Based Competition on Rural NGA Coverage**

	(1)	(2)	(3)	(4)
Dependent variable	Rural NGA coverage	Rural NGA coverage	Rural NGA coverage	Rural VDSL+FTTP coverage
Percentage DSL by new entrants	-0.635*** (0.199)		-0.208* (0.112)	-0.254* (0.139)
Standard cable coverage		0.774*** (0.075)	0.765*** (0.078)	0.297** (0.108)
Percentage rural households	-1.391*** (0.429)	-0.635** (0.258)	-0.590** (0.267)	-0.720** (0.303)
GDP per capita	0.0028** (0.0012)	-0.00006 (0.00071)	0.0011 (0.0008)	0.0010 (0.0009)
Year	0.045*** (0.016)	0.058*** (0.019)	0.030** (0.013)	0.031** (0.015)
Observations	55	55	55	55
R²	0.50	0.90	0.84	0.58

*** Significant at the 99% level;

** Significant at the 95% level;

* Significant at the 90% level.

consequences of subjecting the Internet to the regulatory regime that governs traditional telephone service. This example should inform a wide range of current issues, including the debate over reclassifying

broadband Internet access as a Title II telecommunications service, the IP transition, and House Energy and Commerce Committee's ongoing initiative to update the U.S. communications laws.

3. EUROPEAN AND U.S. STUDIES ON INVESTMENT, ADOPTION, DOWNLOAD SPEEDS, UTILIZATION, AND PRICING

In addition to the mapping study, the EC has collected a great deal of other important information. First, the Commission collects investment data from the National Regulatory Agencies (NRAs). Second, the EC and the FCC collect information on broadband adoption. Third, the EC and the FCC have commissioned studies of broadband quality as measured in download speeds (including a comparison to advertised speeds), upload speeds, latency, and packet loss. Fourth, the EC and the FCC have commissioned studies of broadband pricing. In addition, commercial entities have collected data on the amount of bandwidth the average user consumes in different countries. Together these data enrich the picture pro-

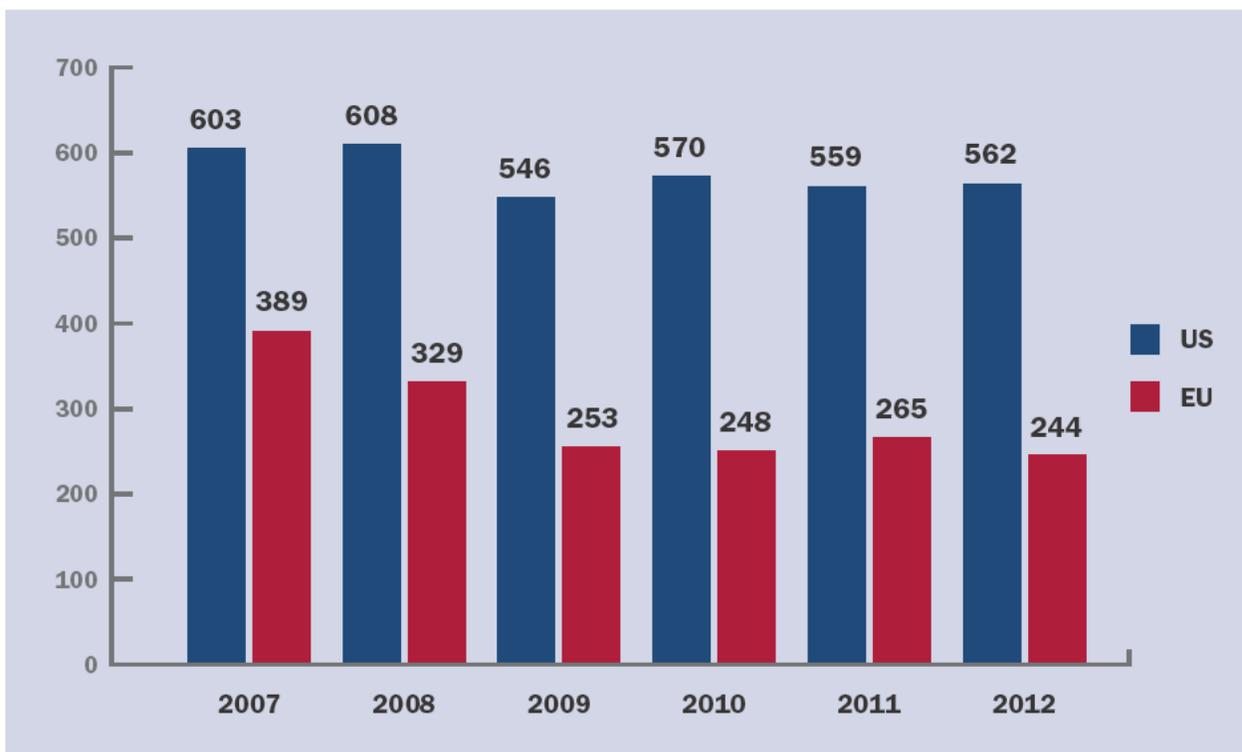
vided by the studies on broadband coverage. On the whole, they tend to confirm the conclusion that the U.S. is doing somewhat better than Europe with respect to broadband.

3.1 Investment

The EC collects data on revenue and investment in the electronic communications sector, which includes fixed-line telecommunications, mobile telecommunications, and pay television, among other things (EC 2009, 2010, 2014c). Although the U.S. government does not collect similar data, the U.S. Telecom Association (2013) compiles total broadband investments based on financial reports filed by leading providers. Household data from Eurostat (2014b) and the U.S. Census Bureau (n.d.) can permit examining investment levels on a per-household basis.

FIGURE 5:

Investment per Household in the Electronic Communications Sector in the U.S. and Europe, 2007–2012



Sources: EC (2009, 2010, 2014c); Eurostat (2014b); U.S. Census Bureau (n.d.); U.S. Telecom Association (n.d.).

The data on broadband investment reveals a stark disparity between the U.S. and Europe. From 2007 to 2012, per household investment in the U.S. more than doubled per household investment levels in Europe.

A paired t-test indicates that this difference is statistically significant at the 99.99% confidence level. The difference between the U.S. and European per-household investment levels has widened following the financial crisis in 2008. At the same time, revenue in the European electronic communications sector has declined by 1% to 2% each year since 2007 (EC 2009, 2010, 2014d).

The data also report investment levels on a per-country basis. If the U.S. were considered along with the European data, it would rank third in terms of per-household investment behind only Luxembourg at

\$759 per household and Ireland at \$584 per household (almost double the investment level in 2011) and just ahead of Denmark at \$457 per household.

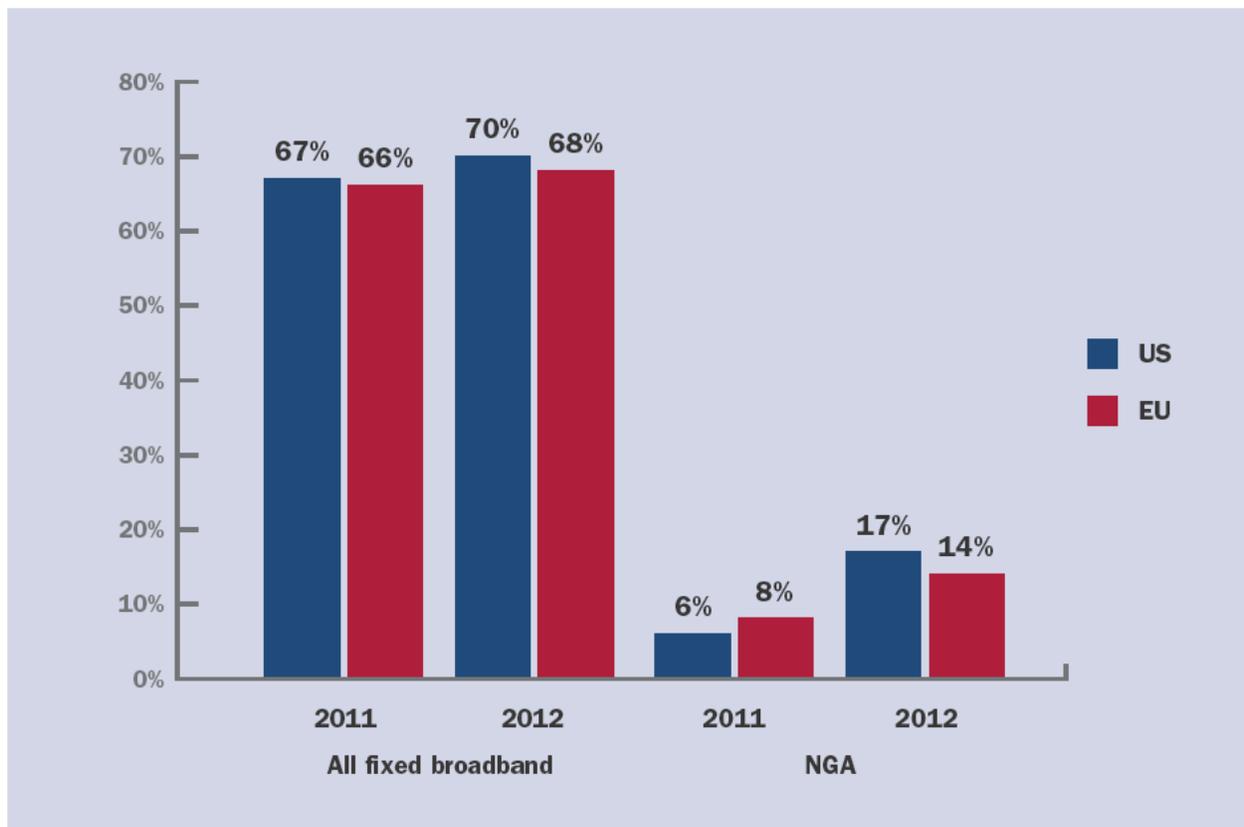
The investment data thus seem to confirm the effectiveness of the U.S. regulatory approach in providing incentives to invest. Unless European investment numbers rise sharply, Europe runs the risk of falling farther behind in high-speed broadband coverage.

3.2 Adoption

In addition to collecting information on NGA coverage, both the European Commission and the FCC collect data on NGA adoption. The FCC (2013b) reports subscription numbers directly, which can be combined

FIGURE 6:

Standard Broadband and NGA Adoption per Covered Household in the U.S. and Europe, 2011 and 2012



Sources: EC (2013b, 2014a); Eurostat (2014b); FCC (2013b); U.S. Census Bureau (n.d.).

with coverage numbers to determine the percentage of households where standard broadband and NGA service are available actually subscribe. The European Commission (2013c) reports information about total broadband subscribership and the percentage of broadband lines that are NGA, which makes it possible to calculate the number of NGA subscribers. The NGA subscription data can be combined with data on the number of households to calculate the rate NGA adoption by household.

In terms of standard broadband, household adoption numbers in the U.S. and Europe are very high and very similar, with the U.S. being slightly ahead. Given the slow growth, it would appear that standard broadband adoption was nearing saturation in 2012.

With respect to NGA, adoption is still in its nascent stages. The U.S. lagged slightly behind Europe in 2011, but surged ahead in 2012, reaching 17% of households as compared with 14% NGA penetration in Europe. The primary driver was an increase in the penetration in mobile wireless broadband providing NGA speeds from 0% of U.S. households to 7% of U.S. households.

The fact that adoption rates fall so far below coverage rates indicates that the impediments to adoption do not consist solely of lack of availability. This is confirmed by studies indicating that lack of interest and perceived need are more important obstacles than price or availability (EC 2013b, 13; Ofcom 2013a, 368; Pew Research Center Internet Project 2013). This underscores that supply-side initiatives are not enough and that policymakers should also continue to pursue demand-side programs for stimulating adoption of broadband.

3.3 Download Speeds and Other Measures of Broadband Quality

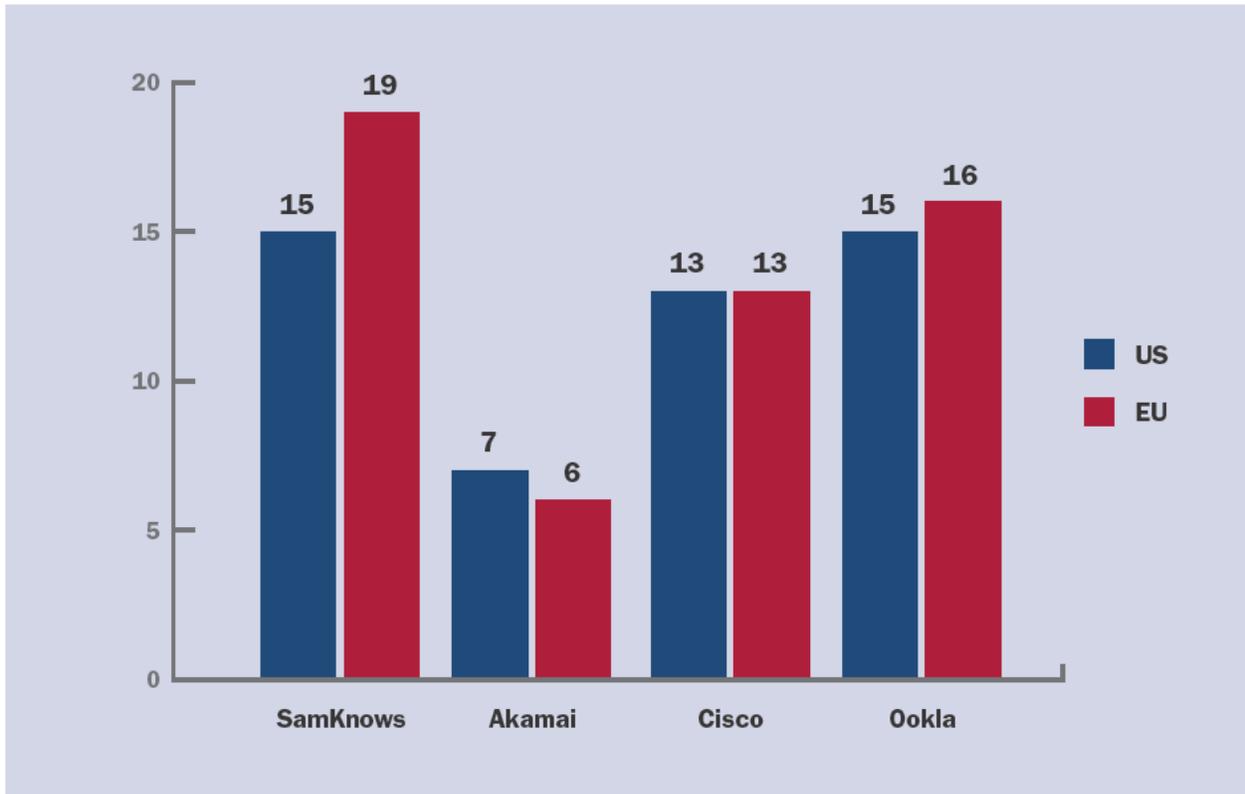
Both the EC and the FCC have recently sponsored studies of broadband quality that produced data that are significantly better than the data collected by the OECD, which relies entirely on advertised speeds. Academic studies indicate that the data produced by the government studies are also better than the widely cited data collected and reported by entities such as Akamai, Cisco, and Ookla. Ookla's NetIndex speed test runs as an application on end-users' computers, which means that the results depend as

much on the configuration of the end users' system, such as the operating system and the quality of the computer hardware, as the quality of the broadband network. Ookla also relies on crowd sourcing to provide its data, which means that its data may not be recruited from a representative sample and vary depending on the location of the server being used for the test. Akamai relies on data generated when end users access web content hosted on its content distribution network. Akamai's strong position in delivering web content (i.e., estimated at one fifth to one third of the world's web content) gives it sufficient scope to observe a broad range of lines in action, which avoids Ookla's potential self-selection and server-selection problems. Akamai still runs as an application on end-users' computers and thus is affected by differences in each end-user's setup. Akamai focuses on a single application (web browsing) and measures total connection speed between the end user and the Akamai servers. This means that it cannot account for connections to non-Akamai servers. The Akamai test cannot distinguish congestion in the access link caused by heavy utilization by the end user (Bauer, Clark and Lehr 2013; ITIF 2013).

Fortunately for our purposes, the European Commission and the FCC both relied on a company called SamKnows to collect data on broadband quality. Instead of relying on the configurations end users' computers, SamKnows recruits panels of consumers who allow SamKnows to attach specially configured monitoring units to their broadband connections that periodically test download speeds, upload speeds, latency, and packet loss. Unlike crowd-sourced tests, SamKnows is able to ensure that its panel is unbiased and conducts checks to guard against sample bias. Because SamKnows employs its own hardware, its results do not vary with the configuration of individual end users' computers.

The consensus is that the SamKnows methodology is superior to other commercially available measures of average download speed, and that Akamai is likely the second best source of data (Bauer, Clark and Lehr

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The difference between the U.S. and European per-household investment levels has widened following the financial crisis in 2008.
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FIGURE 7:**Average Download Speeds in the U.S. and Europe, 2012**

Sources: EC (2013d); FCC (2012b); Akamai (2013); Cisco (n.d.); Ookla (n.d.).

2013; ITIF 2013). In fact, although the FCC used Ookla data in its international broadband comparison, it explicitly acknowledged that it would have preferred to use SamKnows data, which at the time did not exist for any European countries outside the UK (FCC 2012a App. F at 1 n.1). Moreover, the SamKnows studies commissioned by the European Commission and the FCC were conducted only one month apart, with the European study occurring in March 2012 and the U.S.

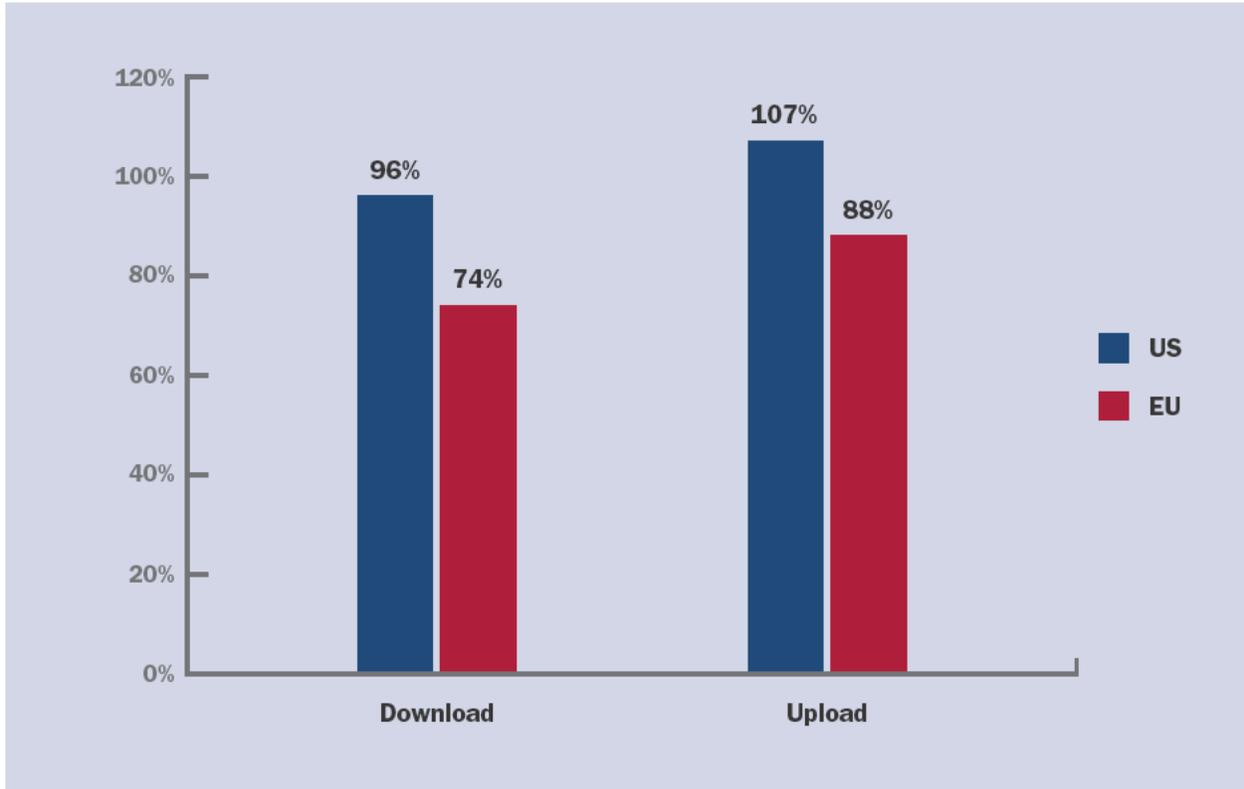
In terms of average download speeds during peak usage times (weekdays from 7:00-10:00 p.m.), U.S. providers deliver 96% of the advertised speeds, while European providers deliver only 74%.

study occurring in April 2012. The results from these studies for average download speeds during peak times (weekdays 7:00-10:00 p.m.) are reported in Figure 7. The average download speeds reported by Akamai, Cisco, and Ookla's NetIndex for the end of 2012 are also provided for comparison.

The SamKnows studies indicate that average download speeds were somewhat faster in Europe than in the U.S. in 2012. The SamKnows data indicate that average upload speeds during peak times were also somewhat faster in Europe (6.2 Mbps) than in the U.S. (4.3 Mbps). Similar measures collected by other sources suggest that U.S. average download speeds were more or less the same as Europe's, although the Akamai results are somewhat lower than the other measurements. As noted above, all of these other measures are subject to at least some degree of methodological criticism. For the purposes of this study, however, the relative difference between U.S.

FIGURE 8:

Actual Speeds as a Percentage of Advertised Speeds During Peak Times in the U.S. and Europe, 2012



Sources: EC (2013d); FCC (2012b).

and European download speeds are what is important, not the absolute magnitude.

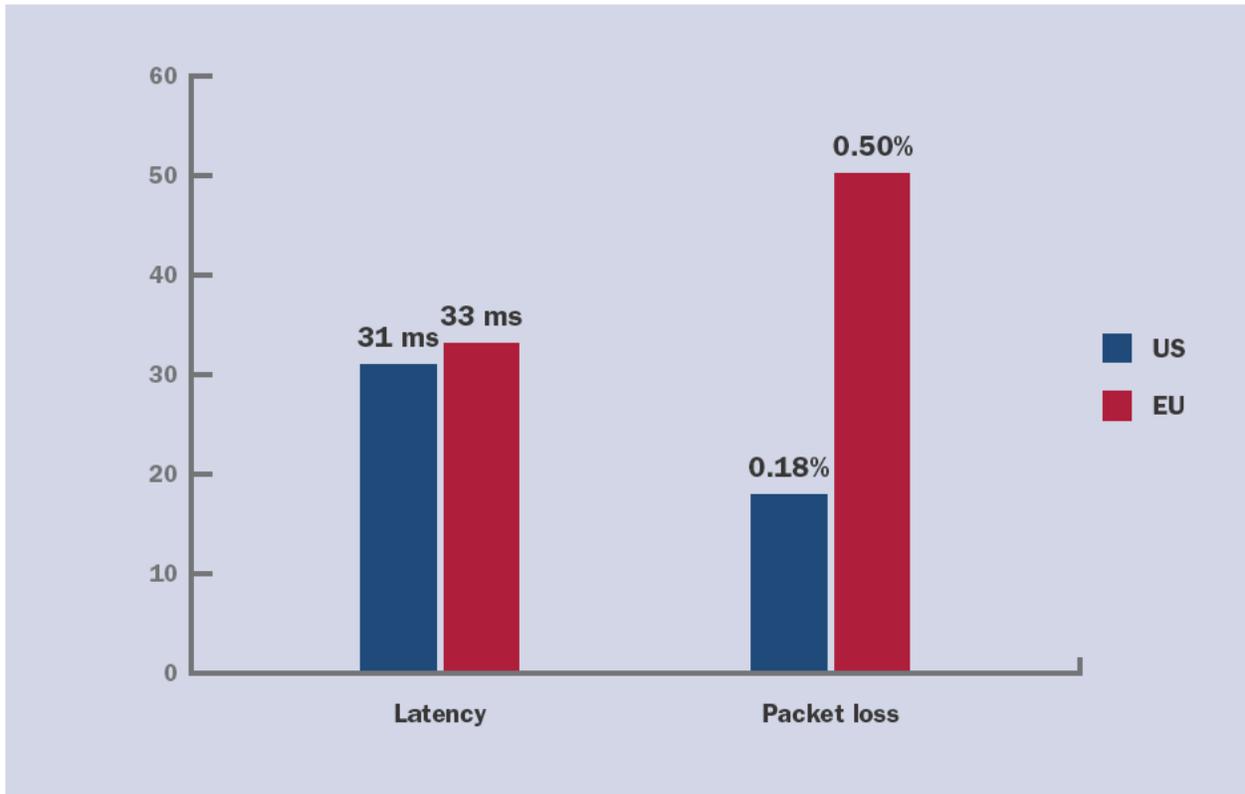
The European study was designed to compare actual to advertised speeds. As a result, the European study does not report country-level data for download speeds, although Akamai, Cisco, and NetIndex do. Under the Akamai data, which reports data for twenty-one EU countries plus Iceland and Norway, the U.S. would rank third in terms of average download speeds behind only the Netherlands and the Czech Republic as of the end of 2012. Cisco reports average download speeds for five Western European countries and for Western Europe as a whole. If the U.S. were compared with these other countries, it would rank third of six as of the end of 2012. NetIndex's country-level data is less flattering to the U.S. If the U.S. were ranked along with the twenty-six EU countries for which Net Index provides data as of the end of 2012, it would rank eighteenth.

In terms of actual and advertised speeds, U.S. ISPs fare better than their European counterparts. In terms of average download speeds during peak usage times (weekdays from 7:00-10:00 p.m.), U.S. providers deliver 96% of the advertised speeds, while European providers deliver only 74%. In terms of upload speeds, U.S. providers exceed their promises, providing actual upload speeds that average 107% of advertised

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This is particularly so because actual download speeds in Europe average 74% of the advertised speeds, whereas U.S. broadband services averages 96% of advertised speeds.

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FIGURE 9:**Latency and Packet Loss in the U.S. and Europe, 2012**

Sources: EC (2013d); FCC (2012b).

speeds during peak times, while European ISPs only provide 88% of their advertised speeds.

The European and FCC studies also included two other measures of broadband quality. First, latency is the amount of time that a packet takes to reach its destination. Note that latency is different from bandwidth. Bandwidth determines how much volume an end user can send; latency determines how long it takes to arrive at its destination. If the Internet were analogized to a pipe, bandwidth would be determined by the diameter of the pipe, while latency would be determined by its length (although other factors such as router configuration, firewalls, network protocols, and reliance and dispersion of data centers also have an impact). Latency and bandwidth are both critical to a good end-user experience. Unlike bandwidth, lower latency numbers represent better performance.

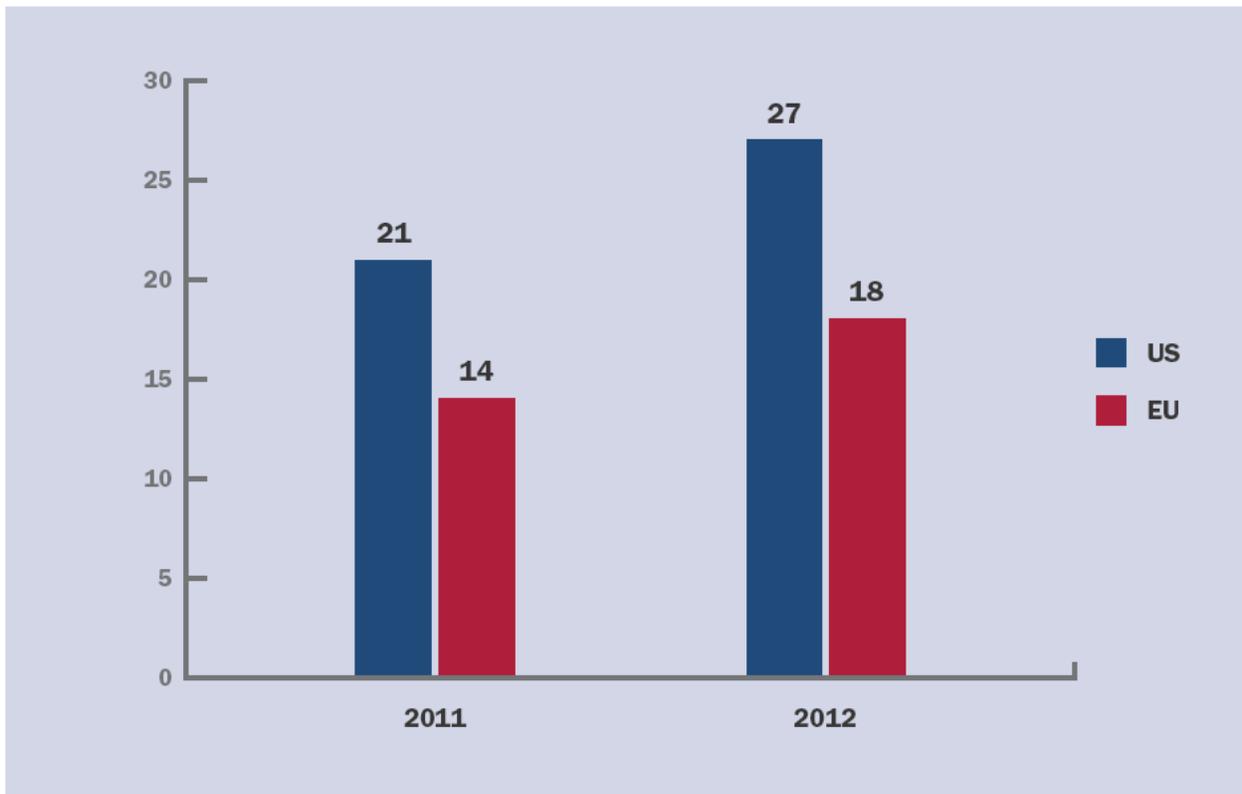
Second, packet loss is the percentage of packets that fail to reach their destination. Packet loss also affects the end-user experience, as any packets sent using TCP that are dropped must be resent, which slows down applications and adds additional burdens on the network. As with latency, for packet loss a lower number means better performance.

On both of these additional metrics, the European study indicates that U.S. ISPs outperformed their European counterparts in 2012. During peak times (weekdays from 7:00-10:00 p.m.), average latency is lower in the U.S. (31 milliseconds) than in Europe (33 milliseconds). Similarly, packet loss during peak times is lower in the U.S. (0.18%) than in Europe (0.50%).

The data suggest that average download and upload speeds may be somewhat faster in Europe, but that the gap is reasonably small. On other measures of broadband quality, such as actual as a percentage of

FIGURE 10:

Monthly IP Traffic per User in the U.S. and Europe (GB/month), 2011 and 2012



Sources: Cisco (n.d.).

advertised speeds, latency, and packet loss, the U.S. fares better than Europe.

3.4 Utilization

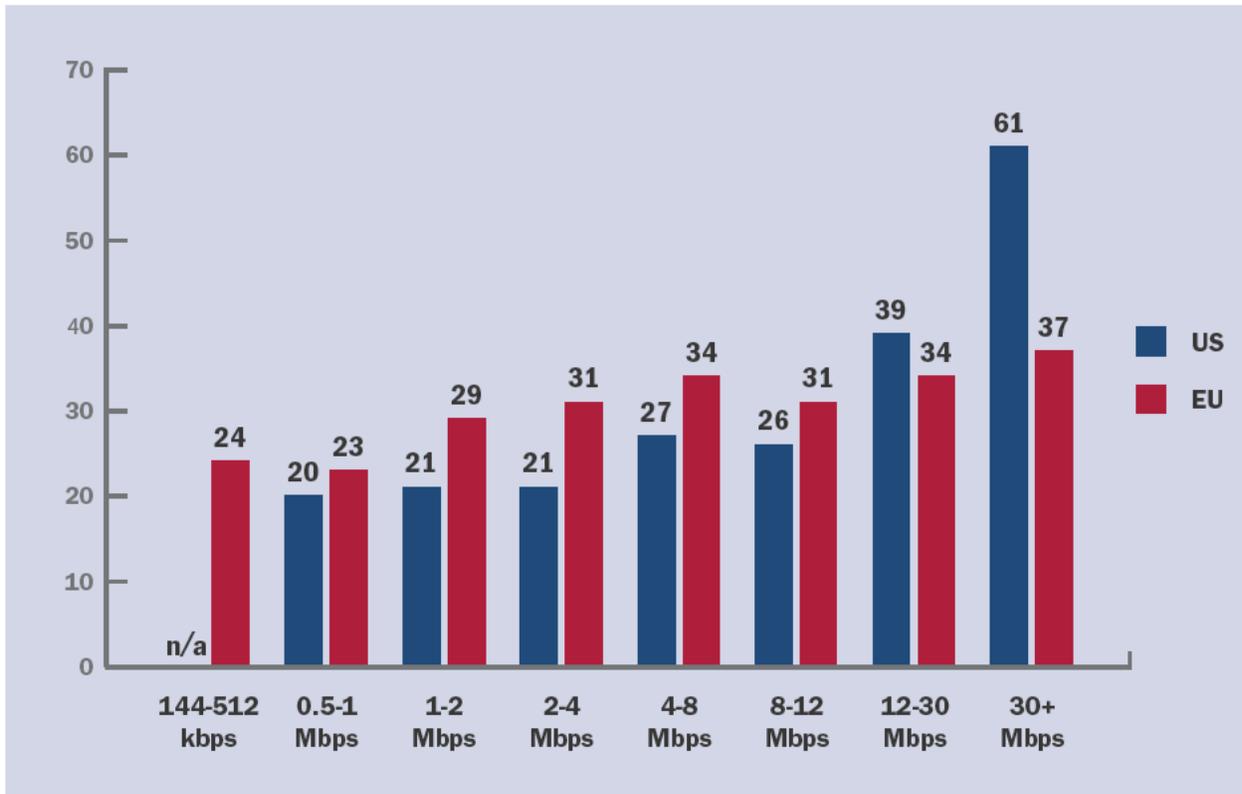
In some ways, download speeds and the other metrics of broadband quality are secondary measures of the value of broadband service. It is arguable that the better metric is total traffic per user, as a real measure of the value of a broadband connection is total amount of usage. Neither the European Commission nor the FCC reports data on bandwidth usage. Cisco does report data on the amount of traffic that each user generates each month for the United States, the five largest Western European countries, and for a category it calls the “Rest of Western Europe,” which includes thirteen other countries. While the overlap with the European Union is not perfect, the European

utilization data can be aggregated and weighted to provide the basis for a comparison of utilization.

These data reveal that in both 2011 and 2012, U.S. users consumed 50% more bandwidth than European users. Evaluating the same data on a per household basis does not materially change the analysis. The heavier utilization suggests that U.S. users are deriving greater value from their Internet connections than European users, as a fast connection only provides value to the extent it is used.

3.5 Pricing

The EU also commissioned a study of broadband pricing that was conducted in February 2012. The study identifies large ISPs representing 90% of subscribers up to a maximum of 8. It looks at the lowest and

FIGURE 11:**European Study of Pricing of Standalone Broadband in the U.S. and Europe, 2012**

Sources: EC (2012b).

median advertised price for all EU countries; other European countries, including Iceland, Liechtenstein, Macedonia, Norway, Switzerland and Turkey; and the states of California, Colorado, and New York. In so doing, it attempts to take into account contract length, data caps, nonrecurring costs, promotions, differences in volume and other services, VAT, and purchasing power parity. The study tracks standalone broadband as well as two-product and three-product bundles, although prices for bundles that include television typically reflect the high cost of program acquisition and not just the cost of Internet service. Unlike other studies that have received recent attention (see, e.g., New America Foundation 2012), the European study looks at pricing nationwide instead of particular cities and reports data for standalone broadband in addition to bundles, which reflect content acquisition costs for video.

Despite these refinements, the resulting methodology is still subject to a number of caveats. The study is

based on advertised prices, but discounts and other measures can cause actual prices to differ. Although the study takes advertised discounts into account, it does not reflect any special discounts that may be extended. In addition, the study is based on advertised speeds, which only imperfectly reflect actual speeds. This is particularly so because actual download speeds in Europe average 74% of the advertised speeds, whereas U.S. broadband services averages 96% of advertised speeds. In addition, broadband pricing can obscure important differences in utilization. Finally, with respect to all of these measures, simply choosing the median fails to take into account the fact that some providers have many more subscribers and thus are more representative. Pricing data should thus be regarded as suggestive rather than definitive.

To isolate the cost of Internet service and to eliminate the impact of program acquisition costs for television or universal service subsidies and other similar sur-

charges for voice, the discussion that follows focuses on the price of standalone broadband. Figure 11 reports the median EU price for standalone broadband in each speed tier included in the European study. The U.S. price is a simple average of the prices reported for California, Colorado, and New York.

The data indicate that U.S. broadband prices are lower than European prices for all service tiers up to 12 Mbps. Even for services between 12 Mbps and 30 Mbps, the price difference is relatively small. Only for speeds greater than 30 Mbps were U.S. prices significantly higher. The fact that the average U.S. user consumes 50% more capacity than the average European user will inevitably show up in the pricing. Indeed, the price difference for 30+ Mbps service (\$61 in the U.S. vs. \$37 in the EU) matches almost exactly the difference in monthly household bandwidth usage (60 GB in the U.S. vs. 40 GB in Western Europe) (Cisco n.d.).

Thus, for lower speeds, the European study provides reason to question whether U.S. prices are in fact higher than European prices. Data collected by the ITU (2013, table 3.2) and the Berkman Center (2010, 75) similarly indicate that U.S. entry-level broadband pricing is lower than European entry-level broadband pricing, while other studies found it to be roughly comparable (OECD 2013 fig. 7.6; FCC 2012a fig. 2a). The higher levels of utilization in the U.S. provide a strong justification for the price difference for higher-speed tiers. Indeed, there is a strong argument that charging low-volume users less and charging high-volume users more may represent a fairer and more efficient allocation of costs.

The European pricing study thus undercuts claims that high U.S. prices are discouraging potential end users from adopting broadband. The FCC and ITU data confirm that U.S. broadband prices are lower for lower speeds. Indeed, the ITU indicates that the U.S. has the third cheapest entry-level price in the world. U.S. prices are somewhat higher than European prices for speeds greater than 30 Mbps. In fact, this is precisely the type of pricing structure that would best promote broadband adoption and alleviate the digital divide. Even the higher prices for higher speed services can be justified by the fact that U.S. users consume 50% more bandwidth than their European counterparts.

* * *

The data reported in the European mapping study thus contradict claims that U.S. broadband service is falling behind Europe in terms of availability. In addition, regression analysis of these data indicate that the U.S. approach of promoting facilities-based competition is more effective in stimulating the buildout of high-speed networks than the European approach of promoting service-based competition. Moreover, the data on investment, average download speed, utilization, and pricing are thus all at odds with blanket assertions that U.S. broadband is too slow and too costly, since U.S. investment levels are higher, average download speeds are slightly below or comparable, entry-level pricing is lower, and utilization levels are higher. On the whole, the data are more consistent with the position that the U.S. is ahead of Europe in the broadband race and well positioned to extend its lead.

The widescale availability and relatively affordable pricing in lower speed tiers underscores the fact that price is not the primary barrier to broadband adoption. Indeed, studies indicate that households who have fast service would only pay \$3 more for very fast service (Rosston, Savage, and Waldman 2011). Both U.S. and European studies have consistently shown that lack of interest and lack of skills are far greater barriers to broadband adoption than are pricing and coverage (EC 2013b, 13; Ofcom 2013a, 368; Pew Research Center Internet Project 2013). Any true welfare metric should also determine the relationship between broadband

4. COUNTRY CASE STUDIES

The data provided by the European and U.S. mapping studies provide a fairly compelling basis for concluding that the U.S. is not behind Europe in the broadband race. That said, bare statistics often do not tell the full story. The eight country case studies presented in this section add insight to the top-level statistical analysis. These case studies focus on the more established economies of Western Europe, including the five largest EU countries (France, Germany, Italy, Spain, and the United Kingdom) and three additional countries of particular interest (Sweden, Denmark, and the Netherlands).

Spain followed a more conventional pattern, in which competition from cable modem service has spurred the incumbent telephone provider to invest in upgrading its network.

The analysis organizes the countries into three categories based on (1) the level of development of the cable modem industry, measured by whether cable modem coverage exceeded coverage levels of the EU as a whole, and (2) the primary broadband strategy pursued by the telephone industry, determined by whether FTTP coverage was greater than VDSL coverage or vice versa. The resulting categories are:

- Countries where telephone companies faced *weak* competition from cable and emphasized *FTTP over VDSL* (Sweden, France, and Italy),
- Countries where telephone companies faced *weak* competition from cable and emphasized *VDSL over FTTP* (none),
- Countries where telephone companies faced *strong* competition from cable and emphasized *FTTP over VDSL* (Denmark and Spain), and
- Countries where telephone companies faced *strong* competition from cable and emphasized *VDSL over FTTP* (the Netherlands, UK, and Germany).

A close analysis of these country case studies reveals an interesting pattern that raises serious doubts about certain countries' continuing emphasis on FTTP. First,

the group of countries that did not face significant facilities-based competition from cable (all of which emphasized FTTP over VDSL) reported the three lowest NGA coverage levels of all the countries included in this study and ranked 20th, 25th, and 28th out of 28 EU countries in this regard even though Sweden and France are often held up as role models that other countries should follow. NGA coverage in Sweden was only slightly above EU coverage levels despite the presence of strong FTTP deployments (with 40% to 50% of these lines being government owned) and remains well below the NGA coverage levels in the U.S. The emphasis on FTTP also had an adverse impact on rural NGA deployments. The high cost of FTTP is leading France and Italy to consider shifting their focus to VDSL.

In contrast, all of the countries in which cable broadband was highly developed achieved NGA coverage rates that exceeded EU coverage levels. Indeed, most of these countries report that cable broadband constituted the primary driver of NGA coverage. Among these, two countries have historically emphasized FTTP over VDSL (Denmark and Spain). Denmark is unusual in that it is the only country in which the incumbent telephone operator was permitted to continue to be the primary cable operator. As a result, competition came from energy companies deploying FTTP instead of cable modem service, although these new entrants have struggled financially. Spain followed a more conventional pattern, in which competition from cable modem service has spurred the incumbent telephone provider to invest in upgrading its network. The primary emphasis has been on FTTP although the Spanish regulator has recognized that VDSL is likely to play an important role outside of the largest cities.

Countries with strong cable modem systems and where incumbent telephone companies emphasized VDSL also exceeded EU benchmarks for NGA coverage. An underappreciated gem is the Netherlands, which had the second highest NGA coverage rates in the EU. The Netherlands achieved this based on nearly universal DOCSIS 3 coverage, based on its legacy of municipally subsidized cable television systems, and a recognition that it must balance the financial risks associated with FTTP with investments in VDSL. The other two countries in this group (the UK and Germany) have embraced VDSL largely to the exclusion of FTTP. In both cases, strong competition from cable is the primary driver of VDSL investment, with both countries regarding VDSL as being able to deliver sufficient bandwidth to justify postponing the more significant investments associated with FTTP for the time being.

With respect to LTE, early deployments typically depended on two key considerations. The first was the timing of the auction to allocate the 2.6 GHz licenses. The second was a willingness to allow current providers to reallocate their 2G spectrum in the 1.8 GHz band initially allocated to GSM to LTE.

A few comments on the data sources for the tables are in order. The primary data sources are the mapping studies commissioned by the EC and the U.S. government measuring coverage as of the end of 2012 (EC 2013a; NTIA and FCC 2013a and 2013b). Data on European investment levels are from the data collected by the EC (2014b). Pricing data are from the EC pricing study (2012b). Download speed data is from Akamai (2013). Bandwidth usage data are from Cisco (n.d.). Population density and GDP per capita (measured in terms of purchasing power parity) are from Eurostat (2014a, 2014c).

4.1 Weak Competition from Cable and FTTP over VDSL

Three study countries faced DOCSIS 3 penetration that fell below EU levels: Sweden, France, and Italy. All of these countries have historically emphasized FTTP over VDSL. Strikingly, these three countries represent the lowest NGA coverage rates of any countries included in this study. In fact, Italy had the lowest NGA coverage of any country in the entire EU, and France had the fourth lowest. Only Sweden enjoyed NGA coverage that

exceeded NGA coverage levels for the EU as a whole, and even that advantage was relatively minor (57% vs. 54%) and ranked it 20th among 28 EU countries.

4.1.1 Sweden

Sweden is often regarded as a leader in broadband infrastructure, having issued the first national broadband plan and established the first LTE network. Sweden remains one of Europe's strongest advocates for FTTP. Media articles often identify Sweden as a country the U.S. should consider emulating, owing primarily to the prevalence of FTTP. These commentators assert that services are much faster and cheaper in Stockholm than in the U.S. (see, e.g., *New York Times* 2014b; *USA Today* 2014). Sweden is accomplishing this even though their population density is lower than the United States' (*NPR* 2014).

Sweden has FTTP coverage rates that far exceed the FTTP coverage rates in the EU as a whole, driven by large public subsidies of FTTP. This advantage has not translated into significantly greater availability of high-speed broadband services, however. NGA coverage was 53% in 2011 and 57% in 2012, which was only slightly above the EU NGA coverage rates of 48% in 2011 and 53% in 2012 and far below the U.S. NGA coverage rates of 72% and 81%. Sweden's 57% NGA coverage rate ranked it 20th among 28 EU countries, and among the countries in this study, Sweden trailed every country except for France and Italy. Thus, even though Sweden is generally seen as a leader in broadband

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Sweden	57%	6%	35%	17%	46%	93%	37%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Sweden	\$280	\$18.15	7.3	n/a	17%	23	125
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

technology, it is actually lagging behind countries that have emphasized VDSL, such as the UK and Germany, and other countries that have pursued more balanced strategies, such as the Netherlands, Denmark, and Spain. Because of its fiber-oriented strategy, NGA coverage is projected to grow very slowly through 2018, at which time Sweden will lag every major European country except Italy (Analysys Mason 2013).

The problem was even more pronounced in rural areas. Swedish rural NGA coverage reached only 5% in 2011 and 6% in 2012. This fell short of the EU rural NGA coverage rates of 9% and 12% and fell far short of the U.S. rural NGA coverage rates of 38% and 48%. Thus, while the emphasis on FTTP did support world-class service in Sweden's largest cities, it also caused the urban-rural digital divide to become worse.

Broadband prices remain quite affordable, and download speeds are close to those of the U.S., although investment levels are somewhat lower. Sweden did enjoy a sharp increase in LTE coverage from 48% in 2011 to 93% in 2012, which allowed it to surpass LTE coverage rates in the U.S.

One brief observation about population density is in order. Although some commentators point out that Sweden has a lower population density (23 people per square kilometer) than the United States (34 people per square kilometer), a higher percentage of Swedes live in urban areas than Americans. As noted above, the low Swedish population density figures reflect the fact that large amounts of Swedish territory are unoccupied and need not be covered by broadband. The European mapping study indicates that only 17% of Swedes live in rural areas, a statistic corroborated by Sweden's national broadband plan, (Government Offices of Sweden 2013). Furthermore, NGA buildout is further facilitated by the

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The Swedish regulator (PTS) has not supported upgrading the copper network to VDSL because of its belief that VDSL will achieve 100 Mbps download speeds only in densely populated areas that are already likely to receive service from FTTP (PTS 2013b).

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fact that half of all Swedes live in apartment buildings (ITIF 2013).

VDSL

VDSL has represented a fairly minor technology in Sweden, covering only 17% of the country in both 2011 and 2012, somewhat below the EU benchmarks of 19% and 25%. Swedish Rural NGA coverage was nominal at 0.2% both years, again below the EU benchmarks of 3% and 5%.

Although telephone service was initiated by private companies, by 1918 the service had become a state-owned monopoly. The incumbent Telia was partially privatized in 1990 and merged with the Finnish incumbent Sonera in 2003. The Swedish government still owns 37% of Telia Sonera, and the Finnish government still owns 13.2%.

DSL was commercially introduced in Sweden around 1999 and quickly became the leading broadband technology through subscriptions provided by the incumbent Telia and by competitors such as Telenor, who leased lines following the Swedish regulator's decision to impose local loop unbundling. Sweden was also an early pioneer in VDSL, with new entrant Bredbandsbolaget (now part of Telenor) conducting tests as early as October 2005 and Telia Sonera providing service starting in March 2008 and pledging SEK 500 million to expand the service in 2012.

The Swedish regulator (PTS) has not supported upgrading the copper network to VDSL because it believes that VDSL will achieve 100 Mbps download speeds only in densely populated areas that are already likely to receive service from FTTP (PTS 2013b). Particularly given the government's continued ownership of a large stake in Telia Sonera, Sweden is likely to continue to emphasize FTTP over VDSL.

DOCSIS 3

Cable broadband has been an important contributor to NGA coverage in Sweden, but has not been the leading NGA technology. DOCSIS 3 was available in 31% of Swedish households in 2011 and 35% in 2012. This fell slightly short of the EU benchmarks of 37% and 39% and well below the U.S. coverage rates of 72% and 81%. Rural DOCSIS 3 coverage was almost nonexistent at 0.1% in both 2011 and 2012.

Television in Sweden was provided exclusively through public broadcasters until 1981, when local master antenna television systems began retransmitting international satellite programming. In 1983, the government agency responsible for telecommunications in Sweden established Televerket Kabel-TV, which would ultimately occupy 75% of the cable television market. The company was named Svenska Kabel-TV during the 1993 divestiture that created Telia and later rebranded as Telia InfoMedia TeleVision in 1996. Telia prepared to spin off its cable properties in 1999 in anticipation of its proposed but ultimately unsuccessful merger with Telenor and finally sold the business to private equity firm EQT as part of its 2003 merger with Sonera. Since that time, it has been acquired by a succession of private equity funds, including the Carlyle Group and Providence Equity Partners (2006) and BC Partners (2011).

Cable has remained a relatively minor broadband technology, representing 18% of the market for fixed broadband. Moreover, the number of cable broadband subscriptions began to decline slightly in 2012 in the face of vigorous competition from FTTP and LTE (PTS 2013b). As a result, the Swedish regulator PTS does not consider DOCSIS 3 technology as playing a critical role in helping Sweden reach the speed and coverage targets established by the Digital Agenda.

FTTP

FTTP covered 46% of Swedish homes in 2011 and 2012, well above EU coverage levels of 10% and 12% as well as U.S. coverage levels of 17% and 23%. Sweden is thus one of Europe's leaders in FTTP, ranking behind only Lithuania, Latvia, and Romania.

Unsurprisingly, FTTP has focused on urban areas. FTTP reached only 5% of Swedish rural households in 2011 and 6% in 2012. This was slightly above the EU benchmarks of 2% and 5%, but slightly below the U.S. benchmarks of 6% and 8%.

Government subsidies have long played a key role in promoting FTTP in Sweden. For example, Government Bill 1999/2000:86, entitled "An information society for all," provided for SEK 5.6 billion (\$640 million) in government funding to defray the SEK 40 billion (\$4.6 billion) to extend optical fiber to rural areas, with the total cost of extending fiber to all of Sweden reaching SEK 57 billion (\$6.6 billion). Government Bill 2004/05:175, entitled, "From an IT policy for society

to a policy for the information society," allocated €525 million (\$76 million) for infrastructure funding and €57.5 million (\$7 million) for structural funds and other regional grants. The result was pervasive government ownership of broadband facilities. According to the Swedish national broadband plan, central government agencies and government-owned companies owned 15% to 20% of the nation's fiber infrastructure as of 2008, and another 25% to 30% was owned by municipalities (Government Offices of Sweden 2009, 22, 25).

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One of the primary reasons that LTE has deployed so quickly in Sweden is the speed with which it conducted its spectrum auctions. In May 2008, Sweden became the second country (behind only Norway) to auction its 2.6 MHz spectrum. The licenses were technology and service neutral.

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The central government has continued to provide public support for FTTP. For example, from 2010 through 2012, PTS has provided SEK 178.5 million (\$27 million) in funding to provide 35,000 homes and businesses in rural areas with broadband via fiber, which represents a cost of roughly \$800 per location. PTS allocated an additional SEK 160 million (\$25 million) for 2013. During the same period, municipalities continued to invest SEK 8–9 million (\$1.2–1.3 million) each year. Private companies have invested roughly SEK 8–9 billion (\$1.1–\$1.2 billion) annually since 2005. In 2012, Telia Sonera announced that it would invest SEK 5 billion (\$800 million) to extend FTTP to 1 million additional homes.

PTS made clear in 2013 that it regards FTTP as the only technology capable of achieving the 100 Mbps targets established by the Digital Agenda. Moreover, PTS has an ongoing proceeding that would include FTTP in the product market for network infrastructure. If finalized, this proceeding would require Telia Sonera to provide unbundled access to its FTTP network as well as its copper network. The proceeding is scheduled for completion in spring 2014.

Although these efforts provided Sweden with strong FTTP coverage rates, they did not translate into NGA coverage levels that significantly exceeded the prevailing levels in the EU or the U.S. In addition, the emphasis on FTTP had an adverse impact on rural coverage, where FTTP is unviable.

LTE

Sweden has long been a global leader in LTE. Swedish LTE coverage surged from 48% in 2011 to 93% in 2012, well above the EU benchmarks of 8% and 27%. During this time, Sweden appears to have passed the U.S. in terms of LTE coverage, which was 68% in January 2012 and 86% in October 2012. Rural LTE coverage rates made even more impressive gains, skyrocketing from 7% in 2011 to 71% in 2012, far exceeding the EU benchmarks of 5% and 10%

One of the primary reasons that LTE has deployed so quickly in Sweden is the speed with which it conducted its spectrum auctions. In May 2008, Sweden became the second country (behind only Norway) to auction its 2.6 MHz spectrum. The licenses were technology and service neutral.

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In March 2011, Sweden became the second country (behind only Germany) to auction its 800 MHz digital dividend spectrum.

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In December 2009, Telia Sonera used this spectrum to deploy the world's first LTE service. Telia Sonera executives acknowledged that the early deployment was mostly to gain prestige and that the company recognized that the lack of devices meant that subscriptions would be predictably slow to develop until 2013. In November 2010, Tele2 and Telenor began offering LTE through a spectrum-sharing joint venture known as Net4Mobility, which achieved its goal of 99% coverage by early 2013.

3 Sweden would enter the fray shortly, albeit following a somewhat different strategy. In December 2010, 3 Sweden acquired the unpaired block that Intel won in the 2.6 GHz auction and combined it with the paired block 3 Sweden acquired in the same auction. The

company then used the combined spectrum holdings to launch a multimode LTE service in December 2011. 3 Sweden plans to cover 95% of the country by the end of 2014.

In March 2011, Sweden became the second country (behind only Germany) to auction its 800 MHz digital dividend spectrum. A spectrum cap of 2x10 MHz per bidder was imposed by a decision by PTS. In addition, the recipient of one designated license (won by Net4Mobility, which is a joint venture of Tele2 and Telenor) would bear the obligation to cover the permanent homes and fixed places of business identified as lacking 1 Mbps broadband service. The government provided a subsidy of SEK 300 million (\$47 million) to support the buildout of these homes. The 800 MHz spectrum is now being used to complement the LTE networks deployed at 2.6 GHz and to provide rural coverage, although the 2x10 MHz cap means that each 800 MHz licenses provides only half of the spectrum required for maximum LTE performance.

In October 2011, Sweden auctioned off spectrum in the 1.8 GHz band that had previously been allocated to GSM. Telia Sonera and Net4Mobility each acquired licenses, although neither would deploy service until 2013. In addition, 900 MHz and 1800 MHz will be gradually developed for 4G network for the future as well, with the transition for 1800 MHz starting in 2013.

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Sweden has chosen to emphasize FTTP over VDSL and has achieved impressive level of FTTP coverage. It achieved these coverage numbers through large government subsidies. In the aftermath of the 2008 financial crisis, other countries would no doubt find it difficult to follow the same path. More importantly, these large public investments in FTTP failed to create any significant advantages in terms of NGA coverage. At 57%, Sweden's NGA coverage is only slightly above the 2012 EU benchmark of 54% and ranks 20th among 28 EU countries.

The shortcomings of emphasizing FTTP without the support of collateral technologies are manifest in Sweden's poor NGA coverage in rural areas. The high cost of FTTP means that it is not commercially viable in many rural areas. As a result, Sweden's rural NGA coverage is roughly half that of the rest of Europe and one eighth that of the U.S. Thus, while Sweden's commitment to FTTP has no doubt yielded impressive service in Stockholm and other cities, those benefits

are not available on a nationwide basis. This stands in stark contrast to other countries, where greater reliance on DOCSIS 3 and VDSL has supported more extensive rural coverage.

4.1.2 France

France is another country that is often identified as a broadband leader and is often lauded for having fast service and cheap prices. As was the case with Sweden, France has emphasized FTTP over other NGA technologies, and companies such as Free are renowned for offering low-cost service.

The data on NGA coverage paint a very different picture. France achieved only 23% NGA coverage in 2011 and 24% in 2012, both of which were less than half the EU benchmarks of 48% and 54% and far below the U.S. benchmarks of 73% and 82%. Indeed, French NGA coverage is the fourth worst in the entire EU. French rural NGA coverage is virtually nonexistent, checking in at 0% in 2011 and 1% in 2012, far short of EU levels of 9% and 12% and U.S. levels of 38% and 48%. French LTE coverage was 0% in 2011 and only 6% in 2012, as compared with 8% and 27% in the EU and 68% and 86% in the U.S. Although prices are low and investment levels are above average, download speeds lag behind European norms.

Consistent with the tradition of strong government involvement in shaping battles between business

rivals that dates back to 17th-century finance minister Jean-Baptiste Colbert, the central government has asserted greater control over the French telecommunications industry than was the case in other countries, beginning with the government's assertion of a monopoly over the optical telegraph system in 1792 (Millward 2005, 104; *New York Times* 2014a). For example, after initially permitting private development of the telephone system in 1879, the French subsequently nationalized the phone system in 1889. Not only did the central government insist on building the phone system itself. Because the French government lacked the funds to expand the system, citizens who wished to have service had to raise the funds to cover the costs of construction and loan them to the government interest free, with the principal to be repaid out of the profits if the system proved successful. This forced consumers to bear all of the risk of extending telephone service but receive none of the potential benefits (Brock 1981).

This legacy of top-down planning caused French telephone coverage to lag behind the rest of Europe well into the 1970s and is reflected in the well-known state-run Internet forerunner known as Minitel. In addition, the French were unenthusiastic supporters of liberalization during the 1990s and instead favored maintaining the telephone system as a government-owned monopoly. Indeed, the French government continues to own 27% of Orange, 13.5% directly and 13.5% indirectly through the French Sovereign Fund (*Fonds stratégique d'investissement*).

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
France	24%	1%	21%	0%	7%	6%	56%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
France	\$326	\$24.25	4.8	12	18%	103	109
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

VDSL

ADSL service appeared in France 1999 and soon saw vibrant service-based competition emerge through unbundling. Somewhat surprisingly, VDSL was slow to develop, with coverage rates of 0% in both 2011 and 2012, well below EU coverage rates of 19% and 24%.

The reason is simple: consistent with its tradition of centralized control over the infrastructure, the French regulator, ARCEP, refused to approve VDSL as a standard. As a result, it focused instead on promoting FTTP and ADSL+. Even as late as 2010, Orange was continuing to invest in improving ADSL coverage from 98.6% to 99% by 2013.

It was not until April 2013 that ARCEP finally approved VDSL2, and even then it offered the pessimistic assessment that VDSL2 would benefit only 16% of all lines in France and would provide 30 Mbps service in only 6% of French homes. ARCEP thus saw VDSL2 as a complementary technology that it would support with public funding only if it represented an intermediate step towards FTTP. Orange, Free, and SFR formally launched VDSL2 service in October 2013, although the firms had conducted small-scale field trials before that date. Orange has begun to deploy vectoring technologies that can support download speeds of 50 Mbps in many areas and download speeds of up to 100 Mbps under optimal conditions.

In February 2014, ARCEP opened a consultation on a new VDSL technology known as Fiber to the Distribution Point (FTTDP) that will push fiber even closer to the consumer. Many see FTTDP as a way to deliver 100 Mbps in a more affordable manner than FTTP. Given the high costs of FTTP, these observers believe that France may well switch focus away from FTTP and towards VDSL.

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French rural NGA coverage is virtually non-existent, checking in at 0% in 2011 and 1% in 2012, far short of EU levels of 9% and 12% and U.S. levels of 38% and 48%.

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DOCSIS 3

French cable broadband has also tended to lag behind the rest of Europe as well. DOCSIS 3 was available in only 21% of French homes in 2011 and 2012. These coverage rates were well below the EU rates of 37% and 39% and the U.S. rates of 72% and 81%. French rural DOCSIS 3 coverage was 0% in both 2011 and 2012.

As was the case with telephony, French television has long been characterized by strong government influence and slow development. Initially, the French government restricted cable operators to retransmitting over-the-air broadcast signals. It was not until 1982 that the National Cable Plan dissolved the broadcasters' monopoly over video programming. This program, which was fully funded by public money, allowed municipalities to grant monopoly licenses to selected companies, all of which were built by France Télécom. As was the case with telephony, municipalities were expected to help finance the buildout by providing interest-free loans. Water companies, which were able to leverage their relationships with municipal governments, were particularly successful in attracting licenses. The lack of funds caused the cable buildout to proceed very slowly. In 1986, France began to allow greater entry by private firms. France Télécom remained the dominant player until the mid 2000s, when it divested its cable business as well as its investment in major cable companies such as Noos. By 2006, a series of mergers consolidated the vast majority of regional cable companies in the hands of a single company, Numericable. As of February 2014, Numericable had reached 5 million homes and was targeting 8.5 million by 2016.

Despite this consolidation, cable remains a minor player in the French broadband industry. As of September 2013, ADSL was the leading broadband technology (22.4 million subscribers), followed by FTTP (1.4 million subscribers). Cable providers served only 0.5 million NGA subscribers and likely served a significant proportion of the 0.4 million standard broadband subscribers in the category marked "other broadband access," giving it at most 0.9 million subscribers. Interestingly, Numericable's recent presentations of its financial results clearly indicate that it is focusing on FTTP for future growth. Its FTTP-oriented strategy is likely to increase following completion of its acquisition of telephone provider SFR announced in April 2014.

FTTP

Despite all of the emphasis placed on FTTP, French FTTP coverage has continued to lag well behind the rest of Europe. FTTP coverage was 4% in 2011 and 7% in 2012, which fell far short of the EU benchmarks of 10% and 12% and the U.S. benchmarks of 17% and 23%. French rural FTTP increased from 0% in 2011 to a mere 0.6% in 2012. Again, these fell short of EU coverage levels of 0% and 3% and U.S. coverage levels of 6% and 8%.

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This legacy of top-down planning caused French telephone coverage lagged behind the rest of Europe well into the 1970s and is reflected in the well-known state-run Internet forerunner known as Minitel.

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FTTP has performed poorly in France despite the fact that it has long been the target of government subsidies. Perhaps the most controversial example is THD92, the FTTH subsidy program for Hauts-de-Seine targeted at one of the wealthiest suburban Paris departments, which already had a healthy broadband infrastructure. Initiated by Nicolas Sarkozy in 2004 when he was President of the Hauts-de-Seine's General Council, the project became bogged down in litigation when competitors challenged the €59 million subsidy as a violation of the EU's prohibition of state aid. The EU rejected these challenges in September 2009 and September 2013, and the project was finally permitted to proceed.

The French government continued to endorse FTTP in its public pronouncements. In February 2010, President Sarkozy announced France's "National Investment Program," which promised €4.5 billion for the digital economy including €2 billion to promote FTTP. The government set the goal of providing 70% of the French population with access to fiber by 2020 and 100% by 2025. The estimated cost was around €25–€30 billion. Because of the lack of political support, these funds were never allocated.

In February 2013, shortly after the European Union announced that it was reducing its Connecting Europe

Facility from €9 billion to €1 billion, President Holland committed €3 billion in public funding (with an additional €3 billion to come from local governments) and €20 billion in public loans to provide 30 Mbps service to the entire country by 2022 and half the country by 2017, with FTTP being the primary means for doing so. Government officials continued to assert that FTTP represented the best technology for the future.

The companies have signaled some degree of commitment to FTTP. For example, in 2010, Orange resumed fiber deployments in several cities and in July 2011 announced that it would move outside what the French government has classified as "very dense areas," spending €2 billion to cover 60% of French households by 2020. Orange reaffirmed that commitment in 2013. New entrant Free began offering service in 2008, although many regard its efforts at providing FTTH to be somewhat disappointing. In addition, Orange, Free, and SFR entered into agreements in 2011 to share FTTH infrastructure in low-density areas.

Unfortunately, the rhetoric far outstripped actual performance. Despite the ambitious plans, to date French FTTP coverage remains quite disappointing. Given the high cost of FTTP and the needs to extend coverage to more French citizens, Orange has already signaled its preference for shifting away from an FTTP-oriented strategy, and industry analysts predict that the financial realities make such a shift quite likely. ARCEP's FTDP consultation may ultimately prove to be the means for effecting a change in emphasis away from FTTP.

LTE

French deployment of LTE has also lagged well behind the rest of Europe. French LTE coverage was 0% in 2011 and 6% in 2012. This falls far short of the EU benchmarks of 8% and 27% and the U.S. benchmarks of 68% and 86%. French rural LTE coverage was nonexistent at 0% in both 2011 and 2012.

The reasons for the late deployment of LTE in France are myriad. As an initial matter, France did not allocate the 2.6 GHz spectrum until September 2011, which was later than countries that achieved higher LTE penetration. Even more problematic is the relatively limited coverage of French providers' third-generation HSPA+ networks. Only the second leading provider, Vivendi-owned SFR, has nearly global coverage at 98% of the population. In contrast, the HSPA+ coverage of market leader Orange was only 60% as of the end of 2012.

The HSPA+ coverage of the number three provider, Bouygues, was even lower at 50%. As a result, the market leaders initially placed greater emphasis on upgrading their third-generation networks than on building out LTE.

As a result, French providers did not initiate LTE trials until June 2012, and Orange and SFR did not offer commercial LTE service until November 2012. Although Bouygues did not enter until October 2013, several months after the market leaders, it offered the greatest coverage, due in part to the French regulator's March 2013 decision to allow Bouygues to reallocate its 1.8 GHz spectrum designated for GSM to LTE so long as it divested part of that spectrum to new entrants. As a result, Bouygues covered 63% of the population as of its October 2013 launch and claimed 69% coverage as of March 2014. Neither Orange nor SFR have requested permission to refarm their 1.8 GHz spectrum, opting instead to operate LTE exclusively in the 2.6 GHz band. As a result, the LTE coverage provided by both companies is more limited than Bouygues's, with each carrier covering only 40% of the population as of the end of 2013. Bouygues's strategy also benefits from the fact that the iPhone operates in the 1.8 GHz band and does not support service in the 2.6 GHz band. Bouygues also plans to launch LTE Advanced in June 2014.

Free Mobile launched its long awaited LTE service in the 2.6 GHz band in December 2013. Free Mobile's coverage remains more limited, although the company has not yet revealed any specific statistics about the extent of its network coverage. Free Mobile does compete aggressively on price, including LTE service in its existing 3G plans without any additional charge.

Orange and SFR have begun experimenting with LTE Advanced, which would allow them to combine spectrum across multiple bands.

In December 2012, the government auctioned the 800 MHz portion of the digital dividend. Each 800 MHz licensee was subject to an obligation to cover 98% of the population in mainland France within 12 years from license issued, and 99%+ within 15 years. In this auction, only three of the country's operators acquired spectrum, Free failed to win any blocks at all. Instead, it was given the option of sharing SFR's network.

The market is still undergoing change. In April 2014, Numericable won a bidding war with Bouygues to acquire SFR. In the aftermath, Bouygues and Free are rumored to be in merger negotiations.

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On close analysis, claims about France as a leader in Internet service do not hold up. NGA coverage is languishing at half the EU rate and well behind the U.S. Rural NGA and LTE coverage are virtually nonexistent. These poor results undermine claims that the French approach that centers on strong government intervention and mandated infrastructure sharing and emphasizes FTTP is something that should be emulated. Indeed, ARCEP's recent approval of VDSL and ongoing proceeding on VDSL2 may indicate that France may be preparing to place less emphasis on FTTP and more emphasis on VDSL.

4.1.3 Italy

The third study country with weak facilities-based competition from cable is Italy. Italy is one of the largest countries in Europe, with a high level of urbanization and per capita GDP in line with the rest of Europe. It was also an early leader in deploying FTTP

That said, Italy's NGA deployment is disappointing, with only 11% NGA coverage in 2011 and 14% NGA coverage in 2012 despite the country's early leadership position in FTTP. These NGA coverage rates are by far the worst in Europe and far below the EU benchmarks of 48% and 54% and U.S. coverage rates of 73% and 82%. Rural NGA coverage rates are 0% for both 2011 and 2012, far below EU rates of 9% and 12% and U.S. rates of 38% and 48%. Subscription prices are also high, and download speeds and total bandwidth consumption are low.

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... Italy's NGA deployment is disappointing, ... despite the country's early leadership position in FTTP.

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The government's efforts to promote broadband coverage have been largely unsuccessful. For example, in March 2003, the government established a "Program for the Development of Broadband in the South" allocating €2 billion over a five-year period to close the existing gap in broadband infrastructure between the north and south of Italy. By August 2013, the company

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Italy	14%	0%	0%	5%	12%	17%	47%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Italy	\$291	\$34.96	4.0	12	13%	198	101
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

charged with overseeing these funds had invested only €329 million.

Similarly, in 2009, the Italian Ministry for the Economic Development (MISE) developed a “National Broadband Plan” aimed at providing the entire Italian population the opportunity to access broadband service providing download speeds of at least 2 Mbps by the end of 2013. The total budget for period 2009–2012 was initially set for €1.5 billion, but was later cut to €1.1 billion.

Finally, in 2012, the Italian Government defined the Italian Digital Agenda (*Agenda Digitale Italiana – ADI*), translating the goals identified by the Digital Agenda for Europe to the national level. With regards to NGA, the Strategic Project for Ultra-broadband (*Piano Strategico Banda Ultralarga*) was intended to help Italy to achieve the European objective of broadband coverage at a speed of not less than 30 Mbps with at least 50% of households having access to broadband at a speed of at least 100 Mbps by 2020. The first step aimed to bring ultrabroadband to the 15 biggest Italian cities (roughly 17% of the population) within 5 years, investing about €2.5 billion. The second step focused on covering all cities with more than 20,000 people (roughly 50% of the population) at a cost of about €8.5 billion.

These investments would receive both public and private financing, with public interventions initially focused on those areas of market failure in the southern regions of Italy where current providers have found service to be uneconomical (Basilicata, Calabria,

Campania, Molise, Sicily), although other regions could participate in 2014–2020. The Italian Cohesion Action Plan (*Piano Azione Coesione – PAC*), organized in conjunction with the European Commission in 2011, has directed €383 million in funding (co-financed by the EU) towards this end.

Italian regions and autonomous provinces play a central role in achieving the objectives set out in the Digital Agenda. Almost all have initiated plans to ensure wider 8 Mbps coverage, usually integrated by agreements with the Ministry of Economic Development. For example, in 2011 Lombardy planned to deploy ultra-broadband networks to cover 50% of its population, investing €1.1–€1.5 billion within 5–7 years, while Trentino Alto Adige already bridged the digital divide before the end of 2013.

In early 2013, the Ministry of Economic Development announced its intent to launch three calls for tenders, for a total of €900 million (including €237 million in private co-financing) in order to fulfill the objectives of the Broadband Action Plan and the first phase of the Strategic Project for Ultra-broadband.

VDSL

Italian VDSL coverage has been very low, reaching 0% of Italian households in 2011, rising to 5% in 2012, well below the EU benchmarks of 19% and 25%. Signs

indicate, however, that VDSL may be becoming the centerpiece of Italian broadband strategy.

Although Italian companies initially showed interest in FTTP, their focus in recent years has shifted to VDSL. As discussed in greater detail below, new entrant Fastweb abandoned FTTH in favor of a VDSL-based strategy in 2005. Telecom Italia experimented with VDSL2 as early as 2007 and conducted trials through a service known as Alice Phibra.

Moreover, in February 2012, following the collapse of the 2010 proposal for FTTH infrastructure sharing advanced by FTTH pioneer Fastweb, Vodafone, and Wind, Telecom Italia and Fastweb announced a collaboration to use VDSL2 as the last segment in an FTTC architecture. The project sought to provide 100 cities (20% of the population) with theoretical download speeds of 400 Mbps by 2014.

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Italian VDSL coverage has been very low, reaching 0% of Italian households in 2011, rising to 5% in 2012, well below the EU benchmarks of 19% and 25%.

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In September 2012, Fastweb announced its commitment to expanding NGA access by investing an additional €400 million in VDSL infrastructure, which is expected to extend 100 Mbps service to 20% (5.5 million) of Italian homes and firms by the end of 2014. In March 2013, Fastweb launched its VDSL service, extending its VDSL network to 1.5 million homes and enterprises in 14 cities.

In December 2012 Telecom Italia began offering *Ultra Internet Fibra Ottica* at 30 Mbps in three cities: Rome, Turin, and Naples. In June 2013, Telecom Italia obtained regulatory approval to launch VDSL2 nationwide, targeting 6.1 million homes in 100 cities by 2014. All of Telecom Italia's recent corporate presentations confirm that its primary focus is now on VDSL.

DOCSIS 3

In Italy, DOCSIS 3 is nonexistent, covering 0% of the country in both 2011 and 2012. This is necessarily well below the EU benchmarks of 37% and 39% and the U.S. benchmarks of 72% and 81%.

The total absence of cable television is the result of two statutes: a 1936 fascist-era postal statute requiring authorization of the state before anyone can conduct wire-based communications and a 1954 enactment giving public broadcaster RAI (*Radio Audizioni Italiane*) a monopoly over television broadcasting. The success of cable television in other countries during the 1970s prompted some private entrepreneurs to test the limits of these restrictions. Noting that RAI's monopoly extended only to broadcast television and that the postal law did not mention cable television specifically, these entrepreneurs created local cable operations. The government regarded these systems as a threat to public television and in 1973 formally extended RAI's monopoly to all forms of television regardless of the means of transmission. The Italian Constitutional Court declared that action unconstitutional the following year.

Even though the court decision legalized cable, cable operators were still subject to strict and onerous obligations, such as being limited to a single urban area unless the served population was less than 150,000 inhabitants. More importantly, each cable system infrastructure could carry only one channel from the same broadcaster. These regulations limited cable operators' ability to compete with over-the-air broadcasters. Thus, when television services were fully liberalized at local and national level during the 1980s, the Italian cable infrastructure had still not yet developed.

In 1995, Telecom Italia launched Project Socrates (*Progetto Socrate*), which was intended to bring a hybrid fiber coaxial network to 19 Italian cities at a cost of 13 trillion lire (~\$8 billion), of which only 5 trillion lire (~\$3 billion) was actually spent to cover roughly 2 million homes. The program was abandoned in 1997 due to prohibitive cost, concerns about permitting Telecom Italia to establish what would amount to a monopoly over multichannel video, and a change in leadership following the privatization of Telecom Italia.

The absence of cable encouraged the Italian government to use the digital video transition to experiment with an ultimately unsuccessful attempt to generate a broadband alternative to ADSL. Rather than turning to FTTP or cable broadband, the government attempted to promote Digital Video Broadcasting-Terrestrial (DVB-T) as a platform for distributing text, news, weather, text messaging, and other interactive services. The

government pledged to develop e-government services by means of DVB-T, which it called “t-government.” It also provided a €220 million subsidy in 2004 and 2005 for the set-top boxes needed for DVB-T.

The effort was largely unsuccessful. Ten years later, t-government services still had not yet appeared, and Italians used DVB-T only to watch television, with the only pay-per-view and interactive services being offered by Mediaset, controlled by the family of Prime Minister Silvio Berlusconi. Decoders with a smart-card slot for interactive services were eligible for grants. However, the European Commission, the General Court of the European Union, and the Court of Justice of the European Union ruled that the government grants to subsidize the purchase of these DVB-T decoder boxes constituted unlawful state aid. This dalliance with DVB-T further forestalled the possibility that cable networks would emerge as an alternative source of NGA.

FTTP

Italy was an earlier leader in FTTP having begun to deploy FTTP during the 1990s. The country would soon abandon this strategy, and its initial advantage eroded over time. As of 2011, Italy’s 11% national FTTP coverage only slightly exceeded the 10% coverage levels of the overall EU. By 2012, Italy’s 11.8% coverage rates slightly trailed the EU coverage rate of 12.3%. As with other technologies, Italy’s rural coverage remained at 0% as of the end of 2012.

The leading Italian FTTP pioneer was Fastweb. In 1999, Fastweb began providing FTTP in Milan, utilizing some of the resources initially built for Project Socrates. The initial plan was to spend \$6 billion to build a nationwide FTTP network, with a primary emphasis on business customers. By 2002, Fastweb finished the buildout of Milan and began operations in Rome, Genoa, Turin, Naples, and Bologna. After offering FTTP to 2 million homes (representing 10% of the Italian population) and years of unprofitable operations, the company pared back its buildout plans, limiting its fiber rollout to these six large cities and relying on ADSL service provided through local loop unbundling to serve the rest of the country.

In 2005, Fastweb entered a new expansion phase, backed by €800 million in new capital. The new plan sought to reach 10 million homes or 45% of the

Italian population not through FTTP but rather through a less ambitious VDSL strategy based on fiber-to-the-street-cabinet (FTTS) based on subloop unbundling. Thus, only the 2 million homes representing 10% of the Italian population that Fastweb served during the first phase are served by FTTP. In 2007, Swisscom acquired 82% of Fastweb and acquired the remaining shares in November 2010, after which it took the company private.

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At the present, an FTTH network covering 50% of the Italian population is expected to require capital expenditures of no less than €13 billion.

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In May 2010, Fastweb exhibited renewed interest in FTTP when it joined Vodafone and Wind in submitting a proposal that would have devoted €2.5 billion (\$3 billion) to create a shared FTTP network in 15 Italian cities. Telecom Italia countered with a €7 billion (\$9 billion) plan to extend FTTP to six cities by end of 2010 and expand it to 13 cities by the end of 2012 and 138 cities (50% of the population) by 2018. Fastweb and its partners withdrew their proposal the following September after Telecom Italia’s repeated disavowals of any interest in participating in a shared FTTP infrastructure and because of its belief that the advisory committee created by the Italian regulator (AGCOM) to facilitate NGA deployments was favoring the incumbent. Telecom Italia also did not proceed with its plans. Fastweb’s subsequent expansion plans to cover 50% of the Italian population have been based on FTTS. Even with the advantage of obtaining resources from Project Socrates at a discount, Fastweb has operated at a loss every year except for one.

At the present, an FTTH network covering 50% of the Italian population is expected to require capital expenditures of no less than €13 billion. Telecom Italia has begun to show renewed interest in FTTP but only on a limited basis. In January 2012, it received regulatory approval to begin deploying FTTP subject to certain conditions. Specifically, in cities where a competing FTTP exists, Telecom Italia must limit its operations to 40,000 subscribers and must offer competitors access to its network on an unbundled or wholesale basis. The company rolled out FTTH in

Milan in June 2013, reaching around 455,000 homes and scheduled to reach 564,000 homes by 2015. In November 2013, Telecom Italia announced a strategic action plan for 2014 to 2016, committing €1.8 billion for FTTP. This minor investment is widely regarded as a token gesture towards FTTP, and the major providers remain focused primarily on VDSL. In May 2012, the Fondo Strategico Italiano (Italian Strategic Fund) announced that it would invest in up to €500 million in FTTP provider Metroweb to bring FTTP to the thirty largest Italian cities. In the meantime, the ambitious FTTH projects launched by regional governments, such as the one in Lombardy, appear to have ground to a halt.

Thus, even though Italy was once an FTTP leader and has long favored FTTP over VDSL, it appears to be shifting towards emphasizing VDSL. The low current levels of NGA coverage argues strongly in favor of such a move.

LTE

Italy's deployment of LTE began relatively late, but coverage substantially improved during 2012. LTE coverage was 0% as of the end of 2011, but reached 17% by the end of 2012. This impressive achievement closed the gap with EU benchmarks of 8% and 27%, but still trailed U.S. benchmarks of 68% and 86%. Rural LTE coverage remained at 0%, however.

Italy completed its 4G auction in September 2011, encompassing both the 800 MHz and 2.6 GHz spectrum as well as spectrum in the 1.8 GHz band. (A block in the 2.0 GHz band failed to sell.) Vodafone began offering LTE service in the 1.8 GHz in October 2012, followed by Telecom Italia Mobile and 3 Italy in November 2012.

Italy's LTE coverage has improved still further since the end of 2012. Telecom Italia Mobile's LTE network now covers 384 municipalities, representing 41% of the population. Vodafone's network is more limited, covering only 46 of the most important Italian cities and tourist locations. Both companies intend to cover 90% of the population in 2017, and Telecom Italia Mobile aims at reaching 60% of the population by the end of 2014. 3 Italia currently covers only Rome and Milan, but has the goal of covering all of the provincial capitals by the end of 2014. Wind is lagging even farther behind, as its 4G network only covers some areas of Rome and Milan.

* * *

All in all, despite promising early efforts in FTTP, Italian broadband policy must be considered something of a disappointment. As far as January 2014, the objective of ensuring that all Italian citizens had access to standard broadband by the end of 2013 was not achieved. Indeed, standard broadband (defined as 144 kbps) was available in only 91% of rural areas. NGA coverage has lagged even farther behind. Hopefully, the Italian government's most recent subsidy program will help close the gap.

On a more general note, countries that relied on FTTP in the absence of strong cable competition appear to have performed worse than Europe as a whole. The weak performance of these countries on key metrics raises serious questions as to whether the reputations that Sweden and France enjoy as Internet leaders are fully deserved.

Moreover, both Italy and France appear to be considering shifting focus away from FTTP and towards VDSL as a more cost-effective way to achieve the Digital Agenda goals established by the European Commission. One industry analyst usefully frames the decision between VDSL and FTTP as a choice between speed and coverage: "Is it better to provide 75–100 Mbps to 80–90 percent of the population or 1 Gbps to 10–20 percent of the population? Especially when that 10–20 percent is already enjoying faster speeds than the rest" (Broadband Trends 2013).

This is not to say that FTTP does not have an important role in a broadband deployment strategy. Where new infrastructure is being deployed, FTTP represents the best long-term option. These results do suggest that VDSL and DOCSIS 3 also play important roles, either as bridge technologies that allow fiber to be deployed ever deeper into the network or as ways to serve rural areas that lack sufficient population density to support FTTP. In short, rather than favoring any one technology, as France did when promoting FTTP to the exclusion of VDSL, these data suggest that policymakers should seriously consider a balanced strategy that takes the unique legacy and circumstances of each country into account.

4.2 Strong Competition from Cable and FTTP over VDSL

Two other countries whose telephone companies also pursued FTTP over VDSL strategies faced strong competition from cable broadband. Both of these countries exhibited NGA coverage levels that exceeded that of the EU. They were also characterized by DSL sharing levels that fell below EU averages, underscoring the importance of facilities-based competition over service-based competition.

4.2.1 Denmark

Denmark represents an NGA success story, undeservedly overshadowed by its more celebrated neighbor to the north. NGA coverage reached 62% in 2011 and 73% in 2012, well above the EU benchmarks of 48% and 53%, but slightly below the U.S. benchmarks of 72% and 81%. In addition, Denmark enjoyed strong LTE coverage of 54% in 2011 and 61% in 2012, significantly higher than the EU coverage levels of 8% and 27%, although again short of U.S. coverage levels of 68% and 86%. Denmark also enjoyed strong download speeds, low prices, and healthy investment rates.

The only blemish is with respect to rural NGA coverage, which languished at 0% in 2011 and 3% in 2012, below EU levels of 9% and 12% and well

behind U.S. levels of 38% and 48%. Despite the strong nationwide coverage levels for LTE, rural LTE coverage was only 1% in 2011 and 2% in 2012.

Denmark also has an unusual market structure in that the incumbent telephone provider is also the owner of the leading cable provider, a situation that was rectified in other countries. Denmark is also the only country in the study to see a new entrant to become the market leader in FTTP instead of the incumbent. Aside from some early support for cable and some minor initiatives in municipal broadband, Denmark has largely eschewed public subsidies.

VDSL

VDSL covered only 2% of the country in 2011, before surging to 21% in 2012, reaching levels close to the EU benchmark of 25%. Rural VDSL service was 0% in both years, in contrast to the 3% and 5% coverage achieved in the EU as a whole.

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Aside from some early support for cable and some minor initiatives in municipal broadband, Denmark has largely eschewed public subsidies.

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	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Denmark	73%	3%	61%	21%	43%	65%	25%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Denmark	\$457	\$23.40	7.0	n/a	17%	130	126
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

As was the case in most European countries, telephone service in Denmark began as a state-owned monopoly, but unlike many other countries, the initial providers were small regional telephone companies instead of a national PTT. In 1990, the Danish Parliament enacted legislation authorizing these small regional companies to merge in order to help compete against other international telecommunications providers. A holding company known as Tele Danmark (later known as TDC) acquired these companies and consolidated their operations in 1995. The government began the process of privatizing TDC in 1994, and the company became completely private in 1998. TDC was subsequently acquired by a series of private equity firms, although that does not seem to have adversely affected the company's willingness to invest.

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Although there were some early experiments with cable television during the late 1950s and 1960s, the industry did not take off as a technology until 1985, when the government authorized the four then-regional telephone companies to enter the cable market and provided some funding to enable them to do so.

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TDC was not the first provider to deploy DSL, largely out of concern that DSL would cannibalize TDC's ISDN business. Instead, DSL was first offered by a new entrant known as Cybercity in 1999, which was later acquired by Telenor, establishing a recurring pattern in Danish telecommunications. TDC soon followed in 2000, and soon three roughly evenly sized companies shared the market. Over time, TDC became the dominant DSL provider, in no small part from its practice of acquiring companies that successfully employed local loop unbundling to establish service (such as Fullrate and A+ in 2010). As of the end of 2012, TDC controlled 74% of the DSL market, well above the levels of the typical European incumbents and only trailing the levels of the incumbents in Cyprus and Luxembourg.

TDC's only significant competitors are Telenor, the Norwegian incumbent, and Telia Sonera, the company formed by the merger of the Swedish and Finnish incumbents. Neither provider owns any copper infra-

structure, and both appear to be focusing more on wireless broadband than on competing for fixed-line customers.

The fact that TDC provided both DSL and cable modem service appears to have led it to emphasize cable modem service over both VDSL and FTTP. Indeed, in 2009, it stopped marketing its 50 Mbps VDSL service in favor of a triple-play service based around its 20 Mbps cable product. In recent years, TDC has begun to show greater interest in VDSL, emphasizing the potential of vectoring and remote DSLAMs in its annual reports. In addition, because vectoring is inconsistent with unbundling, the Danish regulator relieved TDC of unbundling obligations in areas where it has upgraded its VDSL network to use vectoring, opting instead for a wholesale access requirement.

DOCSIS

DOCSIS 3 contributed more than any other technology to Denmark's strong NGA coverage. DOCSIS 3 was available in 54% of Danish households in 2011 and 61% of Danish households in 2012. These coverage levels were significantly higher than the EU benchmarks of 37% and 39%, but below U.S. benchmarks of 72% and 81%. In rural areas, however, Danish DOCSIS 3 coverage was a disappointing 0% in both 2011 and 2012, trailing EU rural coverage levels of 4% and 6% and well behind U.S. rural coverage levels of 37% and 40%.

Although there were some early experiments with cable television during the late 1950s and 1960s, the industry did not take off as a technology until 1985, when the government authorized the four then-regional telephone companies to enter the cable market and provided some funding to enable them to do so. The goal was to form a hybrid network that would provide radio and video programming to private households as well as high-speed data to private companies and public institutions.

As a platform for distributing video programming, the initiative was a rousing success, with Denmark enjoying the highest level of cable television subscribership in the world. As a platform for high-speed data, the hybrid network was essentially a failure. When TDC integrated the regional companies into a single operation in 1995, it shut down the hybrid network and integrated it into a single national cable television network known as Tele Danmark Kabel TV. Even after NTC acquired

TDC in 2005, it continued to operate TDC Kabel TV as a separate company and renamed it YouSee in 2007 to emphasize its independence.

TDC remains the largest cable television operator, offering service to 1.5 million (56%) of Danish households and providing service to 1.2 million (46%) Danish households. Stofa is the second largest provider of cable, with 414,000 subscribers as of 2011. Stofa's service area focuses on Jutland and Funen. The lack of overlap with TDC's cable network means that for the most part the two companies do not compete directly. Stofa, which was acquired by Telia in 1995, first offered cable modem service in 1996. TDC began providing broadband service in 1999, half a year after ADSL. By 2003, most of the cable infrastructure was upgraded to provide broadband services. Cable modem service is now available in 63% of Danish households, with the vast majority (62% of households) having already been upgraded to DOCSIS 3. Interestingly, in 2012, Stofa was acquired by energy company Syd Energi (SE), which is also a major provider of FTTP.

One of the most striking aspects of Danish broadband is that the telephone system and the cable system are both owned by TDC, which controls 74% of the DSL market and 66% of the cable modem market. This led the Danish NRA in 2009 to order TDC to open its cable broadband infrastructure to other operators. As a general matter, the European Commission does not recommend including fiber and cable broadband networks in the definition of the market for broadband access (market 5). Danish telecommunications legislation does not distinguish between different types of fixed communication networks, however, and thus applies equally to copper, cable, and optical networks. Although eleven other EU countries include cable modem service in the market for broadband access, Denmark is the only country to mandate access to cable broadband systems, although to date no provider has attempted to utilize this right.

FTTP

Denmark also enjoys strong FTTP coverage. As of 2011, FTTP was available in 37% of Danish homes, well over the 10% coverage rate for the EU as a whole and the 17% coverage rate for the U.S. By 2012, Danish FTTP coverage had risen to 43%, well above the EU coverage rate of 27% and the U.S. coverage rate of 23%. Rural FTTP coverage rates were disappointing in Denmark, however, registering at 0% in 2011 and 3% in

2012, which was in line with EU rates, but below U.S. rates of 6% and 8%.

In contrast to other countries that have emphasized fiber, the incumbent TDC has shown little interest in pursuing FTTP. Its annual reports instead emphasize increasing the capacity and speed of its cable modem product and improving DSL through vectoring and making greater use of remote DSLAMs to deploy fiber closer to the home. TDC's November 2009 acquisition of DONG Energy and its 15,000 FTTP customers raised the possibility that it might be preparing to place greater emphasis on FTTP. Subsequent press reports do not find that the acquisition effected any change in TDC's approach.

Instead, the Danish FTTP market is dominated by regional energy companies. Since 2000, energy companies have invested heavily in fiber networks, and their networks now pass 700,000 households. The most important player among the electricity companies is Syd Energi (SE), the electricity provider in South Jutland. This region is one of the least densely populated regions in Denmark, but due to SE, it nonetheless enjoys the best FTTP coverage in the nation. As noted above, in 2012, SE acquired Stofa, Denmark's second largest cable company and the only cable provider in Jutland. In addition, in September 2010, fourteen energy companies formed Wao! in order to promote broadband via FTTP.

Unfortunately, these energy companies' large investments in FTTP have not been financially successful, losing DKK 5.3 billion (€700 million) on these activities through 2012. As a result, the energy companies have scaled back further investments in the aftermath



In contrast to other countries that have emphasized fiber, the incumbent TDC has shown little interest in pursuing FTTP. Its annual reports instead emphasize increasing the capacity and speed of its cable modem product and improving DSL through vectoring and making greater use of remote DSLAMs to deploy fiber closer to the home.



of the 2008 economic downturn and have focused instead on connecting more customers to the existing infrastructure.

Thus, Denmark's strong FTTP coverage is the product of private investment by a facilities-based entrant, in stark contrast to the government subsidies used in Sweden. Unfortunately, to date the financial performance of these services has been disappointing. Even so, since June 2011, TDC has received some requests to open its FTTP network to other operators and service providers. Any household within 30 meters of TDC's optical network can request access regardless of whether they are a TDC customer or not. The costs of connection, which are estimated to be around €2,000, must be borne by TDC even if the customer wants to subscribe to a competing operator.

LTE

Denmark is one of the stronger LTE countries in Europe, achieving 54% national coverage by the end of 2011 and 65% national coverage by the end of 2012, well ahead of the EU levels of 8% and 27% respectively, but behind the U.S. levels of 68% and 86%. Rural coverage has been more disappointing, with LTE reaching only 1% of Danish rural households by the end of 2011 and 2% of Danish rural households by the end of 2012, as compared with EU coverage levels of 5% and 10%.

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The fact that the 7% increase in DOCSIS 3 coverage and the 6% increase in FTTP coverage both contributed to the 11% increase in NGA coverage suggests that the bulk of these investments do not overlap and thus are not driven by competitive forces.

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Denmark completed its auction of the 2.6 GHz on May 6, 2010, which among the countries studied in this study trailed only Sweden. The early 2.6 GHz auctions permitted Denmark to enjoy the widespread early deployment of LTE. Telia launched LTE service in December 2010, relying on the 2.6 GHz band and reaching 75% coverage by May 2013. TDC launched

LTE in October 2011, again relying on the 2.6 GHz band. TDC's LTE network covered 40% of the Danish population by the end of 2012 and is forecast to cover 99% of the population by the end of 2015.

In addition, the Danish regulator, the National IT and Telecom Agency (NITA), decided in December 2009 to permit providers to reallocate 900 MHz and 1.8 GHz spectrum from GSM to LTE. NITA did so notwithstanding the EU's initial preference for deploying LTE in the 800 MHz spectrum or in the 2.6 GHz flexible spectrum, although in 2011 the EU directed member states to permit LTE operations in the 1.8 GHz spectrum in an attempt to promote roaming through harmonization. NITA did require Telia to divest spectrum in both bands and also required TDC to reduce its spectrum holdings in the 1.8 GHz band. The recovered spectrum was refarmed into a 2x5 MHz block in the 900 spectrum and a 2x10 MHz block in the 1.8 GHz spectrum. In October 2010, these blocks were sold at an auction at which incumbents were not allowed to bid and at which 3 Denmark was the only participant.

In June 2011, Telia and Norwegian incumbent Telenor entered into an infrastructure-sharing joint venture called TT-Netværket, which was approved by Danish regulators in March 2012. The flexibility provided by the Danish regulator to provide LTE service in the 1.8 GHz band permitted Telenor to use the TT-Netværket infrastructure to launch LTE service in Denmark in March 2013. Moreover, at launch, Telenor was able to cover 75% of the Danish population, which allowed it to leapfrog over the coverage provided by TDC. Telia was also able to expand its LTE service to include both the 1.8 GHz and 2.6 GHz bands.

In June 2012, Denmark allocated more spectrum to LTE when it completed its digital dividend auction of 800 MHz spectrum. TDC acquired a 2x20 MHz license, which is widely regarded as the optimal block size for implementing LTE. TT-Netværket acquired 2x10 MHz licenses which can be used to reach an estimated 98% of the population. These licenses carry no rural coverage requirements, although they are subject to tower-siting restrictions to prevent interference with television broadcasting. Both 800 MHz licensees must cover 99% of the Danish population with 10 Mbps service.

Denmark's fourth wireless provider, 3 Denmark, missed out in its bid for 800 MHz spectrum. However, in September 2012, it launched its 4G network across fifteen of Denmark's largest cities, covering 38% of the population using a combination of 1.8 GHz and 2.6

GHz spectrum at launch and later expanding its coverage to 75% of the population by the end of 2013. Because Apple's iPhone 5 LTE operates only in the 1.8 GHz band, it is compatible with Telia, Telenor and 3 Denmark, but not TDC.

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The precise bases for Denmark's success are hard to unravel. On the one hand, the fact that the incumbent telephone company was also the leading cable broadband provider undercuts the traditional story of facilities-based competition between cable and DSL. On the other hand, the presence of vibrant FTTP-based entry by energy companies raises the possibility of facilities-based competition between cable and FTTP, although to date FTTP has been unprofitable. The fact that the 7% increase in DOCSIS 3 coverage and the 6% increase in FTTP coverage both contributed to the 11% increase in NGA coverage suggests that the bulk of these investments do not overlap and thus are not driven by competitive forces.

In any event, recent years have witnessed a fundamental change in the political discourse about broadband policy. Debates during 2013 witnessed increasing calls for public subsidies, as many became concerned that private companies would not be able to meet the increasing demand for bandwidth. These proposals did not specify how such public funding would be financed.

4.2.2 Spain

That Spain would emerge as an above-average performer in terms of NGA coverage comes as something of a surprise. Not only does Spain have a greater rural population than is generally true in Europe; its GDP per capita (adjusted for purchasing power parity) is slightly below the EU average. Notwithstanding these demographic disadvantages, Spain has achieved high levels of NGA coverage, reaching 56% of households in 2011 and 64% of households in 2012. These coverage levels exceed the NGA coverage levels of 48% and 54% for Europe as a whole, although they fall short of U.S. coverage levels of 73% and 82%.

Rural NGA coverage levels are also respectable by European standards, reaching 7% in 2011 and 13% in 2012 as compared with 9% and 12% EU-wide, although these fall short of U.S. rural NGA coverage of 38% and 48%.

There are some areas for improvement, however. As of 2012, LTE coverage still languished at 0%. Prices remain relatively high, and download speeds, bandwidth usage, and investment levels remain low.

VDSL

To date, VDSL has played a minor role in supporting Spain's impressive NGA coverage numbers. VDSL was available in only 11% of Spanish households in both 2011 and 2012, well below EU coverage levels

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Spain	64%	13%	50%	11%	18%	0%	41%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Spain	\$255	\$47.11	4.9	13	18%	92	96
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

of 19% and 25%. Rural VDSL coverage was 0% both years, in contrast to EU rural VDSL coverage rates of 4% and 5%.

DSL service was launched in 1999. Several new entrants took advantage of local loop unbundling to compete with Telefónica, with the leading DSL competitors including Jazztel, Vodafone and Orange. Telefónica launched VDSL2 in April 2008, the earliest launch of any country included in this study. Jazztel followed suit in April 2010, with Telefónica increasing its download speeds from 30 Mbps to 50 Mbps in 2011 and Vodafone launching VDSL2 in May 2013.

The service initially failed to gain traction with subscribers, but over time became an important component of NGA coverage, although not as important as FTTP. A study of NGA technologies by city size conducted by the Spanish regulator revealed that FTTH represented the most important NGA technology in Madrid and Barcelona and had begun expanding in medium-sized cities as well. DOCSIS 3 was the most important technology in medium-sized cities. VDSL played an important role in medium-sized cities and has remained the most important technology in smaller cities (CMT 2013).

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More recently, other providers have begun to show greater interest in FTTP. In June 2012, Orange announced its intention to invest €300 million to bring FTTP to 1.5 million Spanish homes.

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DOCSIS 3

Cable broadband has played the leading role in allowing Spain to achieve its impressive NGA coverage rates. DOCSIS 3 was available in 46% of Spanish households in 2011 and 50% of Spanish households in 2012, well above the EU benchmarks of 37% and 39%, but below the U.S. benchmarks of 72% and 81%. Moreover, DOCSIS 3 was the only NGA technology in Spain that was available in rural areas. Rural DOCSIS 3 coverage was 7% in 2011 and 13% in 2012, versus EU coverage rates of 4% and 6% and U.S. coverage rates of 37% and 39%.

The progress of cable broadband is all the more impressive in light of the fact that private television channels did not exist until 1987 and the Spanish cable television industry did not exist until the mid-1990s. All of this changed in 1998, when the government used a competitive tender process to create thirty-seven new cable operators in different regions of the country. The access to local capital provided by Spanish savings banks and the regional governments' inherent opposition to the central government helped get these fledgling operations off the ground. Because cable television did not develop until relatively late, they were able to deploy modern equipment that was easy to upgrade for more advanced services. To compete with these new pay TV services, Telefónica created Telefónica Cable in 1997, although regulatory and commercial problems led Telefónica to focus its efforts on ADSL and pay television through its satellite-based Via Digital platform.

A series of mergers in 2004 and 2005 consolidated many of the regional cable operators into a single company called ONO, which emerged as the largest cable operator in Spain. On March 17, 2014, ONO announced that it was being acquired by Vodafone. Smaller operators, such as Euskaltel (País Vasco), R (Galicia), and Telecable (Asturias), continue to operate on a regional level.

Cable operators upgraded their networks in 2012 so that 96% of all cable broadband connections belonged to a node updated to DOCSIS 3. As of 2012, ONO controlled 51% of NGA connections, and regional cable operators controlled another 21%, although their cumulative share dropped 9% from the previous year due primarily to the growth of FTTP.

FTTP

Spanish FTTP deployments run at or slightly above the EU average. In 2011, FTTP was available in 10% of Spanish households in 2011 and 18% of Spanish households in 2012. This was compared with EU coverage rates of 10% and 12% and U.S. coverage rates of 17% and 23%. Rural FTTP coverage remains at 0%.

Telefónica has provided FTTP since 2009, but the service did not begin to take off until 2011. As of now, FTTP falls outside the scope of any obligations to provide unbundled or indirect wholesale access, although Telefónica asserts that the overhanging threat of such regulation deters FTTP investments.

More recently, other providers have begun to show greater interest in FTTP. In June 2012, Orange announced its intention to invest €300 million to bring FTTP to 1.5 million Spanish homes. The high cost of FTTP has led providers to experiment with higher degrees of cooperation. In October 2012, Telefónica and Jazztel agreed each to deploy fiber to 1.5 million households and to provide each other with reciprocal access to the interior wiring needed to reach those customers. Jazztel anticipates that the project will cost €590 million, with €450 million coming from Chinese investors and the rest from the European Investment Bank. Orange and Vodafone reached a similar agreement shortly thereafter, committing to extend FTTP to 6 million households at a cost of €1 billion. The parties have submitted these agreements to CMT for review.

A recent CMT study of NGA deployments based on city size has also raised questions about FTTP's potential in smaller Spanish cities. Limited public funding (€333 million) is being used to support initiatives such as Asturcon, which is designed to bring FTTP to the economically disadvantaged principality of Asturias.

LTE

Spain got off to a late start in LTE deployments, having 0% LTE coverage as of the end of 2012 despite the fact that it auctioned both its 800 MHz and 2.6 GHz spectrum in July 2011. Although this satisfied the EC's requirement that the spectrum be allocated by January 1, 2013, Spain nonetheless invoked the exception permitting states to postpone the deadline until 2015 under exceptional circumstances. Following a change in the government in November 2011, the new administration committed to release the digital dividend frequencies by January 1, 2014. However, a December 2012 Supreme Court decision invalidated the new digital television channel assignments for their failure to comply with the Audiovisual Communication General Act. This cast doubt on whether the 800 MHz frequencies would in fact be available in January 2014.

Spanish law nonetheless gave mobile providers the flexibility to deploy LTE in other frequency plans. Rather than wait for these issues to be resolved, mobile providers initiated LTE service in the 1.8 and 2.6 GHz frequency bands. By July 2013, Vodafone, Orange, and Yoigo had deployed LTE, with Movistar following suit in September 2013.

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Spain's ability to achieve such strong NGA coverage in light of its demographic characteristics and the weak legacy of cable television is impressive. Spain is a good example of a country where cable made the primary contribution to NGA coverage, but the increase from 2011 to 2012 was driven primarily by FTTP. The Spanish regulator has raised the possibility that VDSL may play an important role in smaller metropolitan areas.

4.3 Strong Competition from Cable and VDSL over FTTP

Three other countries faced strong competition from cable, but unlike the other five countries in this study chose to emphasize VDSL over FTTP. All three of these countries exceeded the EU benchmark for NGA coverage. Indeed, at 98% NGA coverage, the Netherlands enjoyed the second highest level of NGA deployment in the EU.

4.3.1 Netherlands

European broadband success stories typically do not mention the Netherlands, but they should. Netherlands is one of Europe's leaders in NGA coverage, second only to Malta. NGA was available in 97% of Dutch households in 2011 and 98% of Dutch households in 2012. The Netherlands thus far exceeded the EU benchmarks of 48% and 54% and was the only country in this study to surpass the U.S. benchmarks of 73% and 82%. Dutch rural NGA coverage was also outstanding, serving 73% of Dutch homes in 2011 and 85% in 2012, well above the EU levels of 9% and 12% and exceeding the U.S. levels of 38% and 48%. The Netherlands also enjoys healthy investment, good prices, and strong download speeds. The only area where the Netherlands lags is LTE, which had not been deployed as of the end of 2012.

The Netherlands also enjoys healthy investment, good prices, and strong download speeds. The only area where the Netherlands lags is LTE, which had not been deployed as of the end of 2012.

Perhaps the Netherlands strong NGA coverage comes as no surprise, since the Netherlands has the lowest percentage of rural households of any country in this study, a strong per capita GDP, and a relatively flat topography. What is most striking is that the Netherlands was able to achieve such high coverage rates without significant contributions from FTTP. Instead, competition from cable is credited in spurring the incumbent KPN to invest in VDSL (Analysis Mason 2013).

VDSL

VDSL played an important contributing role in promoting Dutch NGA coverage. In 2011, VDSL covered 47% of all Dutch households, and that number increased to 60% in 2012. These coverage rates far exceeded the EU coverage rates of 19% in 2011 and 25% in 2012. Rural VDSL rates check in at 28% both years, higher than the EU rates of 19% and 25%.

The fixed line broadband market has long been dominated by DSL technologies provided via the traditional copper local loop of KPN. Kicked off in late 1990s, ADSL rapidly became the market leader, surpassing cable broadband in the early 2000s. After the introduction of ADSL, several alternative providers entered the market using the access network of KPN.

In 2007, these parties began negotiations with KPN about subloop unbundling to support VDSL. The leap to

VDSL and increased competition meant that KPN and new entrant Tele2 were the only substantial facilities-based DSL providers in the Netherlands. In August 2009, Tele2 (formerly Versatel) deployed CO-VDSL to launch a 60 Mbps product called "Fiber Speed." With this approach Tele2 expected to reach out to 1 million households less than 1 kilometer away from the central office by the end of 2010 and eventually reach 2 million homes without having to incur the high cost of FTTP. KPN initiated VDSL2 service in 2009, CO-VDSL in 2010, and VDSL-Outer Ring service in 2011. Vodafone also launched VDSL in 2011. Like Tele2, these companies regard VDSL as a defensive strategy against cable broadband used to postpone the need to invest in FTTP.

DOCSIS 3

DOCSIS 3 represents the dominant NGA technology in the Netherlands. In 2011, DOCSIS 3 was available in 97% of Dutch households, well over EU coverage levels of 36% and even higher than the U.S. coverage level of 72%. By 2012, Dutch DOCSIS 3 coverage had inched up to 98%, while EU coverage remained at 39% and U.S. coverage increased to 81%. Rural DOCSIS 3 coverage was also quite strong at 66% in 2011 and 80% in 2012, compared with 4% and 6% in the EU and 37% and 39% in the U.S.

The Dutch cable industry emerged during the late 1950s and 1960s as a series of community antenna television systems, with larger systems being operated

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Netherlands	98%	85%	98%	60%	18%	0%	27%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Netherlands	\$450	\$23.95	8.6	n/a	8%	495	128
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

as part of the PTT. In 1969, the government abandoned plans to unify all of the cable systems under a PTT monopoly and opted instead to license private cable systems that gave preferential rights to the municipalities. Other amendments to the telecommunications statute permitted the incumbent telephone provider to build cable television networks through a subsidiary called CASEMA.

The result was that during the 1970s and 1980s, thousands of small cable networks were built, financed primarily by local municipalities, housing corporations, or third parties often acting on behalf of municipalities and spurred in part by these municipalities' decisions to bar rooftop antennas. By the mid-1990s, cable television covered 94% of Dutch homes. Municipalities generally divested their cable networks following the mandate of liberalization in the late 1990s. This triggered a wave of consolidation that ultimately created two dominant, but nonoverlapping cable operators, Ziggo and Liberty Media-owned UPC. Together these companies serve close to 90% of all cable subscribers. Liberty Media is in the process of acquiring Ziggo. The transaction is subject to approval by the European competition authority, which may require remedies including access obligations.

During the merger wave of the 1990s and 2000s, cable companies continued to invest in keeping their networks technologically up to date, which left Dutch cable operators well positioned to roll out broadband Internet services. These companies first deployed cable broadband during the late 1990s using proprietary technologies, but later switched to DOCSIS during the early 2000s. These companies have subsequently upgraded their networks to DOCSIS 3.

Despite their near universality, cable broadband networks are not regarded as possessing significant market power and thus remain largely unregulated. During a limited period of time, the regulator considered mandating access to cable facilities, but these decisions were challenged in court and were never implemented. Recently, the Dutch parliament introduced amendments to the Telecommunications Act and to the Media Act that would have mandated wholesale access to the so-called "analogue basic package." However, these provisions have been challenged by the European Commission. A Dutch court annulled the provisions, and the Dutch government has announced that they will withdraw the provisions. This will also end the European case.

FTTP

Despite being one of the leading European nations in terms of NGA coverage, Dutch FTTP coverage is surprisingly pedestrian. In 2011, FTTP was available in 13% of all Dutch households, as compared with 10% coverage for the EU as a whole and 17% coverage for the U.S. By 2012, Dutch FTTP coverage had increased to 18%, while EU coverage increased to 12% and U.S. coverage had increased to 23%. Dutch rural FTTP coverage was 9% in both 2011 and 2012, compared with 0% and 3% for the EU and 6% and 8% for the U.S. In short, Dutch FTTP coverage is nothing more than merely solid despite the presence of well-publicized initiatives such as *Kenniswijk* and *Reggefiber*.

The Netherlands has a unique fixed line access infrastructure. Thanks to municipal subsidies, it is among the most densely cabled countries in the world, which made two fixed-line connections available in 92% of Dutch homes.

Dutch FTTP began in the early 2000s, as some municipalities and smaller operators began to deploy fiber optic networks in Rotterdam and Amsterdam. In addition, in 2000, the government initiated the *Kenniswijk* (smart city) project in the area around Eindhoven, which provided €9 million in annual funding to promote the rollout of FTTP

Dutch FTTP deployments received a jolt in the arm in 2005 when a private investor founded *Reggefiber*. *Reggefiber* began acquiring small-scale fiber networks, such as a 40,000-subscriber FTTP network in Amsterdam. The company also targeted small and mid-sized cities for rolling out full blown FTTP. *Reggefiber* leases the fiber connection on a wholesale basis to retail service providers and does not begin construction until at least 30% of households in the targeted area have committed to subscribe to one of the retail service providers. KPN acquired a 41% stake in *Reggefiber* in December 2009 and increased its stake to 51% in November 2012 and again to 60% in January 2014, which gave it full control over *Reggefiber*. Approval by the national competition authority is pending.

Because Reggefiber is likely to come under the full control of KPN, its FTTP networks are subject to unbundling and wholesale access obligations. The fact that Reggefiber's business model is wholesale access and the lack of alternative providers has minimized the impact of this obligation.

In 2008, the Communications Infrastructure Fund (CIF), a large investment group largely supported by Dutch pension funds, also became interested in FTTP although it decided to pursue a strategy that is quite different from Reggefiber's. CIF started to acquire the remaining cable connections from independent cable operators, who owned approximately 12.5% of all connections, with the other connections being in the hands of Ziggo and UPC. CIF owns an estimated 60% of these once independent connections. After acquisition, CIF and overbuilds their coaxial networks with FTTP. It then upsells services to promote migration from coaxial cable to fiber with the aim of eventually retiring the coaxial network. Because of this strategy, CIF-based FTTP does not face competition from cable broadband providers. Reggefiber and CIF FTTP deployments tend not to overbuild each other. Despite these efforts, Dutch FTTP coverage remains quite modest, with incumbent KPN continuing to take a balanced approach between VDSL and FTTP.

LTE

The Netherlands was slow to deploy LTE, having 0% LTE coverage in both 2011 and 2012. This, of course, was well below the 2012 EU coverage rate of 27% or the U.S. coverage rate of 86%.

The primary reason for the delay in deploying LTE is that the Netherlands did not auction its 2.6 GHz spectrum until April 2010. The delay was mostly the result of Lower House of the Dutch Parliament's insistence that the auction create new mobile broadband providers by placing spectrum caps on the incumbents. Ironically, only two new entrants entered the auction, and some blocks did not receive any bids. The result was a spectrum allocation that was far from optimal, and the auction generated a disappointing €2.7 million. Ziggo launched LTE service using its 2.6 GHz spectrum in May 2012, but it targeted only the business market.

A December 2012 auction allocated the 800 MHz digital dividend spectrum as well as the 900 MHz and 1.8 GHz spectrum reformed from GSM. Although spectrum was again set aside for newcomers, only one player

entered the wireless market, Tele2, and it in the end decided not to build its own network but instead opted to team up with T-Mobile. All three operators—KPN, Vodafone and T-Mobile—were offering LTE using the 800 MHz or 1.8 GHz spectrum before the end of 2013.

* * *

The Netherlands has a unique fixed line access infrastructure. Thanks to municipal subsidies, it is among the most densely cabled countries in the world, which made two fixed-line connections available in 92% of Dutch homes. Both were more or less government financed/owned. The privatization of these networks resulted in today's market with strong competition between cable television operators and the incumbent KPN that is driving the NGA rollout. Two high-profile FTTP ventures have garnered a fair amount of attention, but have yet to have a significant impact.

4.3.2 United Kingdom

With high levels of urbanization and a per capita GDP that exceeded the EU average, it is perhaps unsurprising that the UK has exceeded EU coverage levels for NGA. NGA in the United Kingdom reached 58% of households in 2011 and 70% of households in 2012, which was higher than the EU levels of 48% and 54%, but below the U.S. levels of 73% and 82%. Rural NGA coverage registered a respectable 4% in 2011 and 18% in 2012, as compared with 9% and 12% in the EU and 38% and 48% in the U.S. LTE coverage was quiet modest at 0% in 2011 and 17% in 2012, while in the EU LTE coverage was 8% and 27% and in the U.S. LTE coverage was 68% and 86%. Rural LTE was 0%.

The UK government has one of the most significant public broadband subsidy programs in Europe. Between 2003 and 2006, the government spent more than \$2 billion on building public sector networks. More recently, the government allocated £530 million to the Broadband Delivery UK (BDUK) to support broadband buildout by local authorities on a technology-neutral basis, with an additional £250 million set aside for "super connected" cities.

VDSL

British VDSL registered a sharp gain during 2012, increasing from covering 26% of households in 2011

to covering 47% of households in 2012, accounting for almost all of the 12% growth in NGA coverage. This exceeded the EU rates of 19% and 25%. VDSL was also available in 4% of rural households in the UK during 2011 and 14% of rural households in 2012, a substantial improvement over EU levels of 3% and 5%.

These numbers are likely to improve even more in the near future. BT announced in April 2013 that it had reached its target of passing 50% of UK homes with VDSL, eighteen months ahead of schedule, and announced in October 2013 that it reached 57% of UK homes. BT was confident that it would reach its target of passing 66% of UK households by spring 2014.

The strong performance of VDSL in the UK is a direct reflection of the business strategies being pursued by BT. Although the company initially regarded DSL as a short-term bridge solution until it could deploy optical fiber, the company soon began to question the business case for FTTP.

Instead, BT is pursuing a VDSL strategy based on fiber-to-the-cabinet (FTTC). As BT Managing Director Mike Galvin said in May 2012, “Our FTTC delivers 80Mbit/s downstream and 20Mbit/s upstream and FTTH currently delivers 100Mbit/s downstream and 10Mbit/s upstream. I don’t think customers see it as a huge step between FTTC and FTTH. There is a subset of people who believe that FTTH is a pure answer and that it is ‘engineeringly elegant’ and something that everyone should go forward with. Our view is that we will be led by our customers and what we think

best meets their needs” (*Computing 2012*).

Consequently, BT has developed an aggressive plan to use FTTC to upgrade its DSL connections to VDSL. The figure on the next page shows the FTTC status of each city’s exchanges, according to BT’s current roll-out plans.

DOCSIS 3

DOCSIS 3 joined VDSL in playing a key role in supporting strong NGA coverage during both of the years covered in this study. In 2011, DOCSIS 3 was available in 46% of UK households, well above the 37% coverage achieved across the EU as a whole, but below the 72% coverage achieved in the U.S. By 2012, DOCSIS 3

The strong performance of VDSL in the UK is a direct reflection of the business strategies being pursued by BT. Although the company initially regarded DSL as a short-term bridge solution until it could deploy optical fiber, the company soon began to question the business case for FTTP.

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
U.K.	70%	18%	48%	47%	1%	17%	61%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
U.K.	\$215	\$27.29	6.5	31	9%	259	105
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

Current and Planned Upgrades to VDSL in British Cities

	Total exchanges	Already upgraded	Pct.	Scheduled for upgrade	Cumulative pct.
London	208	176	84%	20	94%
Birmingham	41	16	39%	14	73
Manchester	24	21	88%	3	100%
Cambridge	7	2	29%	0	29%
Exeter	5	1	20%	0	20%
Glasgow	33	10	30%	12	67%
Inverness	3	0	0%	1	33%
Cardiff	14	10	71%	4	100%
Bangor	1	1	100%	0	100%
Belfast	15	15	100%	0	100%
Derry-Londonderry	10	10	100%	0	100%

Source: Ofcom (2013).

coverage had crept upwards to 48% in the UK, as compared with 39% in the EU, and 82% in the U.S. Rural DOCSIS 3 coverage remained disappointing, reaching 0% of rural UK households in 2011 and only 5% of rural UK households in 2012, which was below the EU coverage rates of 4% and 6%.

Cable television emerged relatively late in the UK, but by the late 1990s, cable television service was available in 50% of the country. A series of mergers concentrated 90% of the industry in the hands of two companies, NTL and Telewest, which served nonoverlapping territories. The two companies merged with each other in 2006 and eventually joined with Virgin Mobile in 2006 to form a new company known as Virgin Media.

Cable modem service launched in 1997, three years prior to the launch of ADSL in 2000. Technical considerations limited the availability of cable modem service to 45% of the country at the time of launch and to 48% of the country as of 2012, in contrast to DSL, which was available in 60% of the country by 2001 and 99% of the country by 2006. Despite having greater bandwidth and being the first to deploy, the limited geographic reach of cable modem service caused it to be overtaken by ADSL in 2003.

The deployment of VDSL has caused cable modem's market share to stagnate. The cable industry has continued to invest in higher speeds, with the average speed on Virgin Media's network nearly doubled from May 2012 to May 2013 from 18 Mbps to 34 Mbps.

FTTP

The UK's FTTP coverage remains quite low, reaching only 0.2% of British households in 2011 and 0.7% of British households in 2012. Studies generally indicated that the business case for FTTP was relatively weak (Analysys Mason 2013). Consequently, as noted in the discussion on VDSL, BT has prioritized VDSL over FTTP as a matter of business strategy. That said, BT recognized that FTTP may have some appeal to small and medium sized enterprises. Thus, in July 2012, BT initiated trials in a handful of central offices. Deployment plans are limited, covering at most 25% of the country, and as Ofcom noted (2013a, 320), the high cost of FTTP means that its appeal will be predominantly limited to business customers. BT would not expand its FTTP service so long as customers indicate they remain satisfied with its 80 Mbps VDSL service. The relative weakness of FTTP did not seem to impair the UK's overall NGA coverage.

LTE

The UK got off to a late start in LTE deployments, having 0% LTE coverage as of the end of 2011, as compared with 8% in the EU and 68% in the U.S. Since that time, UK LTE providers have made steady progress, achieving 17% coverage by the end of 2012, as compared with 27% in the EU and 86% in the U.S. Rural LTE coverage continued to be 0%.

One of the primary reasons for delay in deploying LTE was the inability of the UK's largest wireless providers to agree on the design of the auction delayed completion of the digital dividend auction until February 2013. Despite the delays, LTE did appear in the UK in February and March 2012 courtesy of failed-WiMax provider UK Broadband. UK Broadband used spectrum in the 3.5 and 3.6 GHz bands originally auctioned in 2003 for fixed wireless and authorized for mobile wireless in 2007 under an alternative standard known as TD-LTE.

Moreover, in August 2012, the UK regulator approved EE's plan to redeploy some of its 1.8 GHz GSM spectrum for LTE on the condition that it sell 25% of its spectrum to the country's smallest wireless operator, 3 UK. EE launched LTE service in this band in October 2012 despite the fact that the UK had not yet completed its digital dividend auction. By June 2013, EE reached 55% of the UK population and forecast 98% coverage by the end of 2014.

In addition, all four of the leading UK wireless providers won licenses in the auction completed in February 2013. The block acquired by O2 requires that it provide indoor coverage for at least 98% of the UK population (including at least 95% of each to England, Northern

Ireland, Scotland, and Wales) by the end of 2017.

Telefónica-owned O2 and Vodafone launched their 800 MHz service in August 2013. By November 2013, EE launched service in the 2.6 GHz band to supplement its existing 1.8 GHz service. Finally, 3 UK launched service using its 800 MHz license as well as service in the 1.8 GHz spectrum it acquired from EE the previous year. Thus, by the end of 2013, all of the leading UK wireless providers were providing service in the bands that the EU had allocated for LTE.

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The UK was thus able to achieve fairly strong NGA coverage with roughly balanced contributions from VDSL and DOCSIS 3 and without any meaningful contribution from FTTP. BT remains committed to emphasizing VDSL over FTTP, and the explosive growth of VDSL appears to confirm the wisdom of this approach.

4.3.3 Germany

As a country with a low percentage of rural households, high population density, and high per capita GDP, Germany is a clear candidate for strong NGA coverage. German NGA coverage increased modestly from 64% to 66% from 2011 to 2012, rates that exceeded the 48% and 54% benchmarks of the EU, but fell short of the 73% and 82% benchmarks of the U.S. In terms of rural coverage, NGA was available in 22% of German households in 2011 and 26% of German households in 2012. This was considerably higher than the 9% and 12% levels in the EU, but fell below the 38% and 48% levels in the U.S. LTE, which was languishing at 22% in 2011, increased sharply to 52% in 2012, which is above the 8% and 27% coverage rates in the EU as a whole.

The primary driver of VDSL investments is facilities-based competition from cable broadband. There are some causes for concern, however. Investment per household is well below EU averages, and bandwidth usage per user is low.

VDSL

VDSL represented a significant determinant of the high levels of NGA coverage enjoyed by Germany. VDSL covered 41% of German households in 2011 and 46%

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The UK was thus able to achieve fairly strong NGA coverage with roughly balanced contributions from VDSL and DOCSIS 3 and without any meaningful contribution from FTTP. BT remains committed to emphasizing VDSL over FTTP, and the explosive growth of VDSL appears to confirm the wisdom of this approach.

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of German households in 2012. This was significantly higher than the EU coverage rates of 19% and 25%. In rural areas, VDSL coverage was 13% in 2011 and 22% in 2012, both significantly higher than the EU rates of 3% and 5%.

Begun as a government-owned monopoly, the German telephone system was included as part of the Deutsche Bundespost as the post-war successor to the Reichspost. The 1989 postal reform separated it into a separate entity (along with the Deutsche Post and the Deutsche Postbank). In 1995, a subsequent round of reform renamed the company Deutsche Telecom and privatized it, although the German government still owns 32% of the company (15% directly and 17% through the government bank, KfW).

The German Federal Government adopted its “Broadband Strategy Paper” in February 2009. It includes two major objectives: increasing coverage of 1 Mbps service from 92% to 100% by 2010 and increasing 50 Mbps service from 20% to 75% by 2014.

Competition from cable broadband has forced telephone companies to invest to upgrade their networks. Vodafone deployed its VDSL network in the summer of 2010, and in December 2012, Deutsche Telecom announced that it is committing €6 billion to deploy VDSL2 with vectoring over an FTTC architecture, with plans to deliver vectored VDSL to 24 million households (65% of the population) by 2016. The German regulator approved vectoring in April 2013. In May 2013, Telefónica and Deutsche Telecom signed

an agreement permitting Telefónica to use Deutsche Telecom’s VDSL network.

The advent of vectoring and other technologies that permit VDSL to deliver speeds in excess of 30 Mbps are thus giving VDSL a more central role in delivering high-speed broadband.

DOCSIS 3

DOCSIS 3 was the other major technology contributing to strong German NGA coverage. DOCSIS 3 reached 46% of German households in 2011 and 52% in 2012, well above EU coverage levels of 37% and 39%, but behind U.S. coverage levels of 72% and 81%. DOCSIS 3 was substantially weaker in rural areas, reaching only 4% of German households in 2011 and 6% in 2012, which was right in line with EU benchmarks, but behind U.S. rural coverage of 37% and 40%.

The German cable television industry began in 1970, when a cooperative known as Senne TV began using master antenna cable systems to engage in private broadcasting, although the government fairly quickly shut down that operation. In 1971, the Bundespost initiated trials in Nuremberg and Hamburg. A December 1975 report issued by a blue-ribbon commission endorsing cable and urging that it be a federal monopoly was rejected by the government in 1977, which opted to authorize cable television only where there was an “acute public demand.”

	Total NGA	Rural NGA	DOCSIS 3 cable	VDSL	FTTP	LTE	Pct. DSL shared
Germany	66%	26%	52%	46%	3%	52%	47%
Europe	54%	12%	39%	25%	12%	27%	46%
U.S.	82%	48%	81%	10%	23%	86%	n/a

	Investment per HH	Price 12-30 Mbps	Avg. speed Mbps	Bandwidth per user	Rural HHs	Population density	GDP per capita
Germany	\$197	\$19.12	6.0	14	11%	229	123
Europe	\$244	\$27.64	5.7	18	15%	116	100
U.S.	\$562	\$28.76	7.4	27	19%	34	152

Eventually, the early prototype projects initiated during this period became part of Deutsche Telecom. Because the incumbent also owned cable system, cable broadband deployed slowly until 1999, when Deutsche Telecom spun off its cable assets into nine operating companies. A series of consolidations left the majority of the industry in the hands of two companies: Unity Media Kabel BW and Kabel Deutschland, although Vodafone acquired Kabel Deutschland in September 2013.

Cable modem service was introduced in 2003. By 2010, Kabel Deutschland had upgraded 85% of its connections to DOCSIS 3. In Germany, cable broadband can reach only 75% of all households nationwide, with the coverage being particularly low in states such as Saxony-Anhalt and Thuringia. Standard cable modem service is available in only 59% of German households and only 9% of German rural households, and cable providers are focusing their attention on upgrading their networks rather than expanding their footprints.

FTTP

FTTP has been slow to deploy in Germany, reaching only 2.4% of households in 2011 and 2.6% of households in 2012. These coverage levels were far below the EU-wide coverage rates of 10% in 2011 and 12% in 2012 as well as the U.S. coverage rates of 17% and 23%. Rural FTTP coverage was even lower at 0.4% in 2011 and 0.7% in 2012.

As discussed in the section on VDSL, Germany has chosen to deemphasize FTTP. A 2011 study by *Wissenschaftlichen Institut für Infrastruktur und Kommunikationsdienste* (WIK) (Scientific Institute for Infrastructure and Communication Services) concluded that a nationwide FTTP rollout would cost €70–€80 billion overall and €1000–€4000 per household. Assuming a 70% penetration rate with an average revenue per user (ARPU) of €38, only 25%–45% of German households could be profitably supplied with FTTP (WIK 2011). A subsequent study commissioned by the German *Bundesministerium für Wirtschaft und Technologie* (Federal Ministry of Economics and Technology) similarly placed the costs of a wide-area development of FTTP at €86–€94 billion (TÜV Rheinland 2013).

For these reasons, Deutsche Telecom has chosen to deemphasize FTTP. In fact, it has made clear that it

would pursue the technology only in areas where 10% of the households commit to adopting it. At the same time, approximately twenty regional network operators, such as NetCologne and NetAachen, are also making limited FTTB deployments in major metropolitan areas. The German *Bundeskartellamt* (2010) (German Federal Antitrust Agency) has taken steps to facilitate the buildout of FTTP by clarifying that cooperation in rural areas that currently lack broadband service is unproblematic under the antitrust laws and might be permissible in other areas if structured in a way unlikely to harm competition. Deutsche Telecom has indicated its willingness to cooperate with NetCologne, 1&1 Internet, and Telefónica Deutschland.

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Begun as a government-owned monopoly, the German telephone system was included as part of the Deutsche Bundespost as the post-war successor to the Reichspost. The 1989 postal reform separated it into a separate entity..

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LTE

In terms of LTE, Germany represents a success story. As of the end of 2011, national LTE coverage was 22% and rural LTE coverage was 33%, well above the EU averages of 8% and 5%. By the end of 2012, German national LTE coverage had soared to 52% and rural LTE coverage had reached 50%, again well above the EU averages of 27% and 10%.

One major reason for the robustness of Germany's LTE deployments is the fact that Germany completed its 4G auctions relatively early. In May 2010, it completed its 4G auction, which included the 800 MHz and 2.6 GHz auctions designed by the EU for LTE as well as the 1.8 GHz and 2.0 GHz spectrum.

The German licenses also included conditions that helped speed the buildout of rural areas. Winners of 800 MHz licenses bore the obligation to focus on rural areas. German communities were categorized by number of inhabitants, with level one including towns

with fewer than five thousand inhabitants and level four including cities with more than 50,000 inhabitants. With each level, each state designated communities that did not receive adequate broadband services. Holders of 800 MHz licenses had to build out 90% of the communities in each level before it could proceed to the next level. The desire to serve the largest metropolitan areas gave licensees strong incentive to buildout rural areas.

Of the four leading German wireless companies, Vodafone began providing LTE in September 2010, followed by Deutsche Telekom in April 2011, O2 (owned by Telefónica) in July 2011, and E-Plus (owned by KPN) in March 2014. By the end of 2013, the main providers served 180 to 200 German cities. O2 has announced plans to acquire E-Plus, which would make the merged company the largest wireless provider in Germany and would likely accelerate upgrading E-Plus's network to LTE.

The future LTE market will be characterized by the next-generation 4G technology known as LTE Advanced, which is capable of providing download speeds of 150 Mbps or even 300 Mbps. Deutsche Telekom has announced plans to introduce LTE Advanced by 2015/16, although Telefónica does not plan to follow suit. Discussions have also begun about reallocating the 700 MHz frequency band to wireless broadband.

5. CONCLUSION

The increasing availability of high-quality data has the promise to effect a sea change in broadband policy. Debates that previously relied primarily on anecdotal evidence and personal assertions of visions for the future can increasingly take place on a firmer empirical footing.

In particular, these data can resolve the question whether the U.S. is running behind Europe in the broadband race or vice versa. The U.S. and European mapping studies are clear and definitive: These data indicate that the U.S. is ahead of Europe in terms of the availability of Next Generation Access (NGA) networks. The U.S. advantage is even starker in terms of rural NGA coverage and with respect to key technologies such as FTTP and LTE.

Empirical analysis, both in terms of top-level statistics and in terms of eight country case studies, also sheds light into the key policy debate between facilities-based competition and service-based competition. The evidence again is fairly definitive, confirming that facilities-based competition is more effective in terms of driving broadband investment than service-based competition.

The empirical record also undercuts the position that the provision of high-speed Internet depends on fiber. In short, FTTP has remained a minor contributor to NGA coverage, and those countries that emphasized fiber represented the worst performers among the eight European countries studied. Even Sweden, an FTTP leader that is often lauded as a paragon of high-speed broadband service, only achieved NGA coverage of 57%, which is only slightly above the EU average. The other countries that emphasized different technologies or used a balanced approach consistently achieved higher NGA coverage rates and are placing increasing emphasis on VDSL, which will play a particularly important role in rural areas. These results suggest that broadband policy should not focus on any particular technology as the definitive solution. Instead, policymakers should recognize that

the viability of broadband technologies varies in urban and rural areas. If so, policymakers would be better served trying to promote a balanced approach that accommodates multiple technologies.

Finally, LTE coverage depended on early deployment of 2.6 GHz spectrum and a flexible approach to 1.8 GHz spectrum. Attempts to configure auctions to stimulate competitors led to considerable delays in deployment.

The empirical evidence produced by the mapping studies thus indicates that the United States is faring better than Europe in terms of broadband coverage and provides a strong endorsement of the regulatory approach taken by the U.S. These data stand as a major landmark with which anyone asserting otherwise must come to grips.

Despite the widespread availability, NGA adoption continues to languish. Studies have consistently shown that availability and cost are not the primary barriers to NGA adoption, but rather that nonsubscribers do not see the need for the service. As a result, ensuring that consumers enjoy the benefits created by the broadband depends as much on demand-side initiatives to encourage adoption, such as those identified by the National Broadband Plan and other similar documents, as it does on supply-side initiatives to upgrade the infrastructure.

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The empirical record also undercuts the position that the provision of high-speed Internet depends on fiber. In short, FTTP has remained a minor contributor to NGA coverage, and those countries that emphasized fiber represented the worst performers among the eight European countries studied.
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About the Report

Both the European Commission (EC) and the U.S. government have recently conducted or commissioned studies providing detailed information about the extent of broadband coverage as of the end of 2011 and 2012. These studies report coverage levels for a wide range of speed tiers and technologies in both urban and rural areas. Although the European mapping study focuses on Next Generation Access (NGA), which it defines to be service providing download speeds of at least 30 Mbps, a close analysis reveals that the study actually reports data for 25 Mbps service. Data from these studies served as the basis for analysis in this report.

These mapping studies were supplemented by other studies conducted or commissioned by the EC or the Federal Communications Commission that examine other key information, such as broadband investment, pricing, and download speeds.

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