APPENDIX G

INTERNATIONAL BROADBAND DATA REPORT APPENDICES

APPENDIX G-1: Country List

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APPX. G-1
Country List

1. The Commission must include "information comparing the extent of broadband service capability (including data transmission speeds and price for broadband service capability) in a total of 75 communities in at least 25 countries abroad for each of the data rate benchmarks for broadband service utilized by the Commission to reflect different speed tiers."[1] We must choose international communities comparable to various communities in the United States with respect to population size, population density, topography, and demographic profile.[2] The Commission is required to include "a geographically diverse selection of countries" and "communities including the capital cities of such countries."[3]

2. In the Figure below, we list the United States and the 35 foreign countries selected for purposes of the *International Broadband Data Report* and identify the countries that are included in an Appendix with an "X." These 35 countries and the United States account for 36 of the 37 Organisation for Economic Co-operation and Development (OECD) Member countries.[4] We refer to these countries as the "comparison countries." For the fixed and mobile broadband price comparisons, we rely on a smaller subset of 25 comparison countries.[5] For the fixed and mobile deployment comparison, we rely on the 26 European comparison countries (EU26).

[1] 47 U.S.C. § 1303(b)(1); *see also* Section 401 of the Repack Airwaves Yielding Better Access for Users of Modern Services Act of 2018 (RAY BAUM'S Act), Pub. L. No. 115-141, 132 Stat. 1087 (codified at 47 U.S.C. § 163) (RAY BAUM'S Act).

[2] 47 U.S.C. § 1303(b)(2). Fig. III.A.8 depicts how the average proportion of the population with coverage by fixed terrestrial services by speed tier varies with median household income, population density, and household poverty rate at the census block group level. On average, deployment is highest in census blocks with the highest median household incomes, the highest population densities and the lowest household poverty rates.

[3] *Id.*

[4] Colombia is the only OECD country not included as a comparison country because of unavailability of the data before it became an OECD member country in April 2020.

[5] The countries excluded from the pricing analysis are: Chile, Hungary, Israel, Japan, Lithuania, Poland, Slovakia, Slovenia, South Korea, and Turkey. Due to the time intensive nature of collecting both fixed broadband and mobile broadband pricing data from multiple providers in each country, we limited the pricing analysis to the same countries analyzed in the *2018 International Broadband Data Report* except for Chile, Japan, and South Korea. *International Comparison Requirements Pursuant to the Broadband Data Improvement Act; International Broadband Data Report*, GN Docket No. 17-199, Sixth Report, 33 FCC Rcd 978 (IB 2018) (*2018 International Broadband Data Report*).

Country	Appx. G-2: Speed and Performance (Ookla)	Appx. G-3: Price	Appx. G-4: Deployment
Australia (AU)	X	X	
Austria (AT)	X	X	X
Belgium (BE)	X	X	X
Canada (CA)	X	X	
Chile (CL)	X		
Czech Republic (CZ)	X	X	X
Denmark (DK)	X	X	X
Estonia (EE)	X	X	X
Finland (FI)	X	X	X
France (FR)	X	X	X
Germany (DE)	X	X	X
Greece (GR)	X	X	X
Hungary (HU)	X		X
Iceland (IS)	X	X	X
Ireland (IE)	X	X	X
Israel (IL)	X		
Italy (IT)	X	X	X
Japan (JP)	X		
Latvia (LV)	X	X	X
Lithuania (LT)	X		X
Luxembourg (LU)	X	X	X
Mexico (MX)	X	X	
Netherlands (NL)	X	X	X
New Zealand (NZ)	X	X	
Norway (NO)	X	X	X
Poland (PL)	X		X
Portugal (PT)	X	X	X
Slovakia (SK)	X		X
Slovenia (SI)	X		X
South Korea (KR)	X		
Spain (ES)	X	X	X
Sweden (SE)	X	X	X
Switzerland (CH)	X	X	X
Turkey (TR)	X		
United Kingdom (GB)	X	X	X
United States (US)	X	X	X

APPX. G-2
Broadband Speed and Performance Comparisons

1. This section of the *International Broadband Data Report* Appendix presents a comparison of fixed broadband and mobile broadband performance metrics in terms of "data transmission speeds" (download and upload speeds) and latency for the United States and 35 other comparison countries. The main analysis relies solely on Ookla Speed Test datasets for both speed and latency. For fixed broadband we consider all technologies, and for mobile broadband we only consider 4G LTE, because it is the baseline industry standard for the marketing of mobile broadband service.[6] Compared to previous *International Broadband Data Reports*, in this report we present a deeper analysis of download and upload speeds, as well as an analysis of latency, with a five-year time horizon for fixed broadband services and a four-year time horizon for mobile broadband services.[7] We also present the data visually with new maps and graphs for more countries. We rank speeds from fastest (1st) to slowest (36th) and latency from shortest (1st) to longest (36th). In section IV, we present additional mobile broadband data on download speeds for 3G/4G and 5G and 5G availability as calculated by OpenSignal.

I. FIXED BROADBAND SPEED AND LATENCY RESULTS

2. *Figure G-1.* U.S. mean download speed rankings improved significantly to a ranking of 5th among the 36 comparison countries for the past two years, up from a ranking of 9th in 2017 and 2016, and 14th (of 35 countries) in 2015.[8] In 2019, the mean download speed for the United States was 119.6 Mbps which almost tripled the mean download speed in 2015 of 40.4 Mbps. Iceland had the fastest mean download speed of the countries in 2019 with a mean download speed of 164.1 Mbps.

3. *Figure G-2.* U.S. mean upload speed rankings were relatively stable for the last five years, with the United States ranking 17th of the 36 comparison countries for the past two years, 16th in 2017, 17th in 2016, and 18th (of 35 countries) in 2015.[9] The mean upload speed in 2019 for the United States was 46.3 Mbps, compared to the fastest mean upload speed of 169.4 Mbps in Iceland.

4. *Figure G-3.* U.S. mean latency rankings were consistent over the comparison period, ranking 24th in 2015 and 2019. The mean latency for the United Sates in 2019 was 23.7 ms, compared to Latvia's mean latency of 14.2 ms in 2019, which was ranked the best among the countries.

5. *Figure G-4.* The mean download speed in Washington D.C. in 2019 was 119.6 Mbps, ranked 30th among the 86 country and state capital cities. The highest ranked U.S. capital city in 2019 was Dover, Delaware which ranked 3rd with a mean download speed of 155.7 Mbps. Other U.S. capital cities in the top ten in 2019 included Austin, Texas at 4th, Raleigh, North Carolina at 5th, Lincoln, Nebraska at 6th, Boston, Massachusetts at 9th and Salt Lake City, Utah at 10th.

6. *Figure G-5.* This graph shows the distribution of download speeds for each country. The top of each color bar represents the corresponding 25th, 50th, and 75th percentiles. The 25th, 50th, and 75th percentiles of download speeds in the United States were 33.2 Mbps, 77.9 Mbps and 159.5 Mbps, respectively.

[6] Prior *International Broadband Data Reports* considered all mobile technologies available. This report has been updated to only present Ookla Mobile—4G LTE data.

[7] We use a shorter time horizon for mobile broadband than for fixed broadband because the Mobile—4G LTE data is only available beginning in 2016.

[8] For fixed broadband download speeds, Luxembourg is excluded in 2015.

[9] For fixed broadband upload speeds, Luxembourg is excluded in 2015.

7. *Figure G-6.* This graph depicts mean download speeds in G7[10] countries and South Korea from 2015 to 2019. U.S. mean download speeds increased at a similar trajectory as other G7 countries, with download speeds increasing from 40.4 Mbps in 2015 to 119.6 Mbps in 2019. South Korea had the fastest mean download speed of these countries at 151.6 Mbps in 2019.

8. *Figure G-7.*[11] Test counts in the United States increased by 36% from 125.6 million in 2015 to 171.3 million in 2019. The number of cities with fixed broadband tests remained roughly constant in the United States during the five-year time horizon.

9. *Figure G-8.* Mean download speeds in 2019 in North America ranged from 31.5 to 119.6 Mbps.[12] The top six countries had a range of download speeds from 118.4 to 164.1 Mbps, whereas the bottom six countries had a range from 22.8 Mbps to 50.4 Mbps. Western Europe and Scandinavia generally had higher download speeds than Eastern and Southern Europe.

10. *Figure G-9.* Mean upload speeds in 2019 in North America ranged from 13.2 to 46.4 Mbps.[13] The top six countries had a range of download speeds from 87.9 to 169.4 Mbps, whereas the bottom six countries had a range from 6.0 to 16.5 Mbps.

11. *Figure G-10.* Mean latency in 2019 was between 20.5 ms and 32.3 ms for North American countries.[14] Mean latency in 2019 was the lowest in the Northern and Eastern European countries of Iceland, Latvia, and Lithuania, which had latencies ranging from 14 ms to 15 ms.

II. MOBILE BROADBAND – 4G LTE RESULTS

12. *Figure G-11.* For mean download speeds, the United States ranked 25th among the 36 comparison countries in 2019, with a mean download speed of 37.0 Mbps, increasing from 21.4 Mbps with a ranking of 35th in 2016. In 2019, Iceland had the highest mean download speed at 78.6 Mbps, whereas Chile had the lowest at 21.2 Mbps.

13. *Figure G-12.* U.S. mean upload speeds consistently ranked 35th among the 36 comparison countries for the past four years, with the speeds increasing from 8.8 Mbps in 2016 to 11.1 Mbps in 2019. Iceland, the country with the fastest mean upload speed in each of the past four years, had a 22.6 Mbps upload speed in 2019--an increase from 19.3 Mbps in 2016.

14. *Figure G-13.* U.S. mean latency ranked 34th among the 36 comparison countries in 2019 at 46.7 ms. Iceland ranked 1st in 2019 with latency of 21.1 ms.

15. *Figure G-14.* The mean download speed in Washington D.C. in 2019 was 44.9 Mbps, which was 25th of the 86 country and state capital cities. The highest ranked U.S. state capital city in 2019 was Annapolis, Maryland which ranked 8th with a mean download speed of 55.6 Mbps. No other U.S. state capitals were among the top ten ranked capital cities.

16. *Figure G-15.* This graph shows the distribution of download speeds for each country. The top of each color bar represents the corresponding 25th, 50th, and 75th percentiles. The 25th, 50th and

[10] The G7 or Group of Seven is an informal group of industrialized democracies whose leaders meet annually to discuss various issues. Council on Foreign Relations, *The G7 and the Future of Multilateralism* (Aug. 20, 2019), https://www.cfr.org/backgrounder/g7-and-future-multilateralism.

[11] In mid-2016, Ookla adjusted the method by which they perform geolocation, resulting in subnational geographies (e.g., cities) being potentially incomparable between 2015 and 2017. This methodological change explains why the number of cities per country varies significantly for some countries between these years.

[12] Each country's mean fixed broadband download speed values are reported in Fig. G-1.

[13] Each country's mean fixed broadband upload speed values are reported in Fig. G-2.

[14] Each country's mean fixed broadband latency values are reported in Fig. G-3.

75th percentiles for download speed in the United States were 10.7 Mbps, 26.6 Mbps, and 52.3 Mbps, respectively.

17. *Figure G-16.* U.S. mean mobile broadband download speed increased at a similar pace as in G7 countries during the past few years, most closely mirroring Japan's trend in download speeds. Canada experienced the fastest growth in mean download speed over the last four years, increasing from 36.2 Mbps in 2016 to 71.3 Mbps in 2019.

18. *Figure G-17.* Test counts in the United States for 4G LTE increased by 25% from 14.3 million in 2016 to 17.9 million in 2019. The number of cities with 4G LTE tests in the United States increased modestly by about 1,900 cities during the same period.

19. *Figure G-18.* Mean 4G LTE download speeds in 2019 in North America ranged from 27.4 to 71.3 Mbps.[15] The top six countries had a range of download speeds from 61.2 to 78.6 Mbps while the bottom six countries had a range from 21.2 to 33.4 Mbps.

20. *Figure G-19.* Mean 4G LTE upload speeds in 2019 in North America ranged from 11.1 to 15.9 Mbps.[16] The top six countries had a range of upload speeds from 17.0 to 22.6 Mbps, whereas the bottom six countries had a range from 9.8 to 12.5 Mbps.

21. *Figure G-20.* Mean 4G LTE latency in 2019 was between 34.1 and 50.0 ms for North American countries.[17] In Europe, the lowest mean latency was concentrated in Eastern European countries, such as Estonia and Hungary.

III. DATA AND ANALYSIS

22. *Data*. The FCC obtains aggregated fixed broadband and mobile broadband speed and latency datasets from Ookla for the United States and the 35 comparison countries. The annual fixed datasets are aggregated to the city-platform level; whereas the annual mobile datasets are aggregated to the city-platform-technology level.[18] Prior to aggregating the data, Ookla applies a set of cleaning and filtering rules to ensure the quality of the data and to further control for certain variables and remove invalid test results.[19] The Ookla Speed Test data are user-generated, meaning the user manually chooses to run each speed test. Therefore, the results from these tests may represent nontypical situations (e.g. when the user is experiencing congestion issues). Because the tests are not taken randomly, they may not represent consumers' typical broadband experience.

23. *Analysis*. In our analysis, we consistently aggregate the data to higher levels using sample counts as a weight.[20] First, we aggregate over platforms for fixed broadband and mobile – 4G

[15] Each country's mean 4G LTE download speed values are reported in Fig. G-11.

[16] Each country's mean 4G LTE upload speed values are reported in Fig. G-12.

[17] Each country's mean 4G LTE latency values are reported in Fig. G-13.

[18] For 2015, the annual fixed broadband dataset is aggregated to the city-level.

[19] We do not report fixed broadband speeds for Luxembourg for 2015, as these values are potentially incomparable with later years. This is due to adjustments in the method by which Ookla performs geolocation, as well as certain methodological changes in their cleaning and filtering rules. Further, for the 2018 and 2019 mobile—4G LTE data, Ookla adopted additional minor changes to their cleaning and filtering methodology. For more information regarding Ookla's methodology, *see* Brian Connolly, *How Ookla Ensures Accurate Reliable Data: A Guide to Our Metrics and Methodology (Updated for 2020)*, Ookla (Apr. 28, 2020), https://www.speedtest.net/insights/blog/how-ookla-ensures-accurate-reliable-data-2020/.

[20] In the *2018 Communications Marketplace Report*, we weighted summary statistics by the number of tests because the sample count was unavailable in earlier datasets. *Communications Marketplace Report et al.*, GN Docket No. 18-231, Report, 33 FCC Rcd 12558, 12560-61, paras. 2-4 (2018) (*2018 Communications Marketplace Report*). Results from prior *International Broadband Data Reports* will not match exactly due to this change in methodology; (continued….)

LTE broadband. Then, we aggregate data over cities to the state or country level. Ideally, we would have an observation for each broadband subscriber or at least a representative sample of all broadband users, but as subscribers choose to opt-in to Ookla's service, this is unlikely to be the case. For example, if the ratio of Ookla users relative to broadband subscribers is greater in urban areas compared to rural areas, it may produce an urban bias in the dataset at the country level.

24. The 2015 fixed broadband speed dataset is aggregated to a higher level (over platforms) by Ookla.[21] Given Ookla's aggregation methodology, the 2015 city-level data are not perfectly comparable to the 2016-2019 city-level data. However, we do not suspect these discrepancies to affect the results significantly. Similarly, our city-level and country-level results are not directly comparable to any city-level and country-level results published by Ookla because Ookla applies their aggregation methodology to the given level of aggregation before calculating statistics, whereas we must weight the lower level of disaggregation by sample count to aggregate the data to higher levels.

however, in the *2018 Communications Marketplace Report Data Update*, we used the new methodology, and those results will be consistent with this report. FCC, *Communications Marketplace Report – Updates*, https://www.fcc.gov/communications-marketplace-report-updates (last visited Oct. 27, 2020).

[21] For fixed broadband, speed tests include technologies such as DSL/Copper, Cable Modem, Fiber, Satellite, Fixed Wireless, and Other (e.g., Electric Power Line).

Fig. G-1: Fixed Broadband Mean Download Speed by Country (2015-2019)

Country	2015		2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	30	17.7	32	18.7	33	23.4	33	30.0	33	38.7
Austria	26	29.5	29	28.4	31	32.2	32	37.4	32	43.8
Belgium	12	41.1	18	43.7	18	51.8	21	59.1	23	72.2
Canada	23	31.3	17	43.8	13	60.6	10	81.9	7	114.3
Chile	31	15.9	31	25.3	30	32.8	26	48.9	19	77.2
Czech Republic	24	31.1	27	32.2	28	34.8	29	41.2	31	50.4
Denmark	8	45.8	10	51.6	10	66.4	13	81.0	12	103.3
Estonia	20	32.4	22	40.2	25	42.4	28	41.8	29	55.4
Finland	15	40.0	20	43.2	23	46.4	25	51.5	25	66.0
France	10	42.7	14	44.6	15	56.5	15	79.1	9	114.0
Germany	19	33.4	24	35.0	21	46.9	22	56.0	24	71.1
Greece	35	10.6	36	11.8	36	13.9	35	18.6	35	23.8
Hungary	13	40.6	12	49.8	6	77.0	3	102.3	3	124.3
Iceland	9	45.3	2	82.4	2	124.1	1	153.5	1	164.1
Ireland	21	32.2	15	44.1	20	50.7	20	59.6	20	76.4
Israel	25	30.5	26	33.0	26	40.6	18	62.2	21	76.3
Italy	34	11.0	34	16.9	32	25.5	31	38.3	30	52.2
Japan	1	85.2	5	60.4	7	72.3	11	81.5	13	97.7
Latvia	6	50.8	8	55.1	17	54.4	19	60.1	16	90.6
Lithuania	7	50.3	6	59.9	3	99.6	9	82.2	17	89.5
Luxembourg			16	43.8	16	56.1	14	79.6	10	109.1
Mexico	32	14.0	33	17.8	34	20.6	34	24.2	34	31.5
Netherlands	5	55.0	7	58.6	8	71.0	12	81.4	14	96.4
New Zealand	27	29.1	21	41.1	14	58.5	16	73.3	15	91.1
Norway	16	38.7	11	49.8	11	65.8	8	85.3	11	105.8
Poland	28	25.7	25	34.7	24	45.7	23	54.5	22	76.0
Portugal	18	35.7	19	43.3	19	51.8	17	69.4	18	88.4
Slovakia	22	31.6	28	31.3	27	38.1	27	45.1	27	58.6
Slovenia	29	24.7	30	28.1	29	33.1	30	39.8	28	57.4
South Korea	2	69.4	1	83.6	1	128.5	2	119.8	2	151.6
Spain	11	41.9	13	48.9	12	61.9	7	87.7	8	114.1
Sweden	3	61.7	3	67.4	4	81.6	4	96.9	6	118.4
Switzerland	4	58.7	4	63.4	5	77.4	6	92.1	4	120.6
Turkey	33	12.6	35	14.8	35	16.0	36	18.4	36	22.8
United Kingdom	17	36.3	23	37.2	22	46.6	24	52.6	26	61.0
United States	**14**	**40.4**	**9**	**52.7**	**9**	**70.1**	**5**	**92.5**	**5**	**119.6**

Fig. G-2: Fixed Broadband Mean Upload Speed by Country (2015-2019)

Country	2015		2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	28	5.9	33	5.2	32	8.2	31	11.6	30	16.9
Austria	24	7.0	27	8.5	28	9.8	32	11.4	33	14.9
Belgium	30	5.4	28	8.3	26	10.4	29	13.0	32	15.8
Canada	21	8.0	23	12.3	21	18.6	18	30.9	16	46.4
Chile	32	3.9	32	5.3	34	7.1	34	10.1	25	20.5
Czech Republic	12	15.7	20	16.5	20	19.3	21	21.2	23	25.9
Denmark	7	30.0	7	35.8	8	49.0	8	61.1	8	80.1
Estonia	11	18.0	13	23.9	15	27.1	19	28.3	19	40.3
Finland	16	13.9	18	17.3	19	19.9	20	22.0	20	29.0
France	15	14.7	16	18.3	18	24.1	15	37.4	12	66.6
Germany	29	5.5	30	7.2	27	9.8	28	13.5	28	18.6
Greece	35	1.5	36	2.2	36	2.9	36	4.2	36	6.0
Hungary	14	14.9	14	20.1	13	29.6	14	39.7	13	61.4
Iceland	5	36.7	2	78.2	1	129.7	1	160.1	1	169.4
Ireland	20	9.6	21	15.4	22	18.3	22	20.8	21	26.9
Israel	31	4.0	31	5.4	33	7.5	27	13.5	29	16.9
Italy	34	2.2	34	5.1	31	8.4	26	13.8	26	20.1
Japan	1	75.6	3	59.5	4	73.9	3	91.5	2	108.9
Latvia	4	45.8	5	54.8	5	54.3	9	60.5	5	92.2
Lithuania	3	46.2	4	55.3	3	85.7	4	74.4	7	82.7
Luxembourg			12	24.8	12	33.2	11	47.6	11	67.9
Mexico	27	6.4	26	8.6	30	8.9	33	10.3	34	13.2
Netherlands	9	23.3	10	27.4	11	33.4	12	41.3	15	48.6
New Zealand	19	12.3	15	18.6	14	29.2	13	40.1	14	55.2
Norway	8	25.2	8	34.5	7	49.4	7	62.2	9	79.0
Poland	22	7.9	24	11.1	24	14.2	23	17.9	22	26.2
Portugal	26	6.6	19	17.3	17	25.7	16	36.6	18	45.0
Slovakia	13	15.0	22	13.6	23	14.7	24	16.2	24	21.3
Slovenia	23	7.9	25	10.2	25	11.9	25	14.1	27	18.8
South Korea	2	60.8	1	80.9	2	127.9	2	98.4	3	105.1
Spain	17	12.9	11	25.9	10	43.4	5	71.3	4	98.9
Sweden	6	34.1	6	40.6	6	53.3	6	68.3	6	87.9
Switzerland	10	21.3	9	31.0	9	43.8	10	58.0	10	77.1
Turkey	33	3.1	35	3.6	35	3.9	35	5.7	35	7.0
United Kingdom	25	6.7	29	8.1	29	9.7	30	11.9	31	16.5
United States	**18**	**12.7**	**17**	**17.9**	**16**	**26.9**	**17**	**34.6**	**17**	**46.3**

Fig. G-3: Fixed Broadband Mean Latency by Country (2015-2019)

Country	2015		2016		2017		2018		2019	
	Rank	ms	Rank	ms	Rank	ms	Rank	ms	Rank	ms
Australia	33	48.5	35	49.6	31	40.0	32	32.3	30	24.7
Austria	20	31.6	23	31.3	26	29.6	27	28.9	28	24.2
Belgium	19	31.2	15	27.0	17	24.8	14	21.4	14	18.3
Canada	22	36.4	21	30.8	21	28.7	19	25.0	18	20.5
Chile	34	53.2	31	43.3	33	40.5	31	31.5	20	22.2
Czech Republic	9	26.4	12	25.5	15	24.0	15	22.4	16	19.4
Denmark	3	23.3	8	21.7	7	19.7	6	18.3	7	15.2
Estonia	12	28.3	6	20.7	8	20.3	17	24.2	12	16.7
Finland	11	27.4	14	26.7	19	27.3	24	27.2	27	24.1
France	28	44.0	32	44.3	32	40.4	35	38.7	34	31.6
Germany	25	37.6	27	34.7	27	29.8	21	26.3	23	23.6
Greece	30	45.5	33	48.2	34	43.8	36	40.4	36	36.8
Hungary	13	28.9	13	26.3	13	22.0	12	20.8	13	17.0
Iceland	2	23.2	1	15.6	1	13.6	1	12.9	2	14.4
Ireland	31	45.6	17	27.4	16	24.7	18	24.7	22	23.3
Israel	17	30.3	19	28.7	14	23.0	10	19.6	15	19.0
Italy	36	65.4	36	57.0	35	43.8	33	35.8	33	29.2
Japan	32	47.3	29	37.8	29	33.6	29	30.8	31	28.1
Latvia	4	23.8	2	17.3	4	18.8	7	18.3	1	14.2
Lithuania	7	24.7	3	18.9	3	17.2	3	17.5	3	14.5
Luxembourg	1	18.6	11	24.8	10	20.6	4	17.5	5	14.5
Mexico	35	55.6	34	48.8	36	44.0	34	38.0	35	32.3
Netherlands	6	24.1	4	19.7	5	19.0	5	18.2	6	15.2
New Zealand	23	36.5	25	32.1	22	28.9	20	25.4	19	21.9
Norway	16	29.9	10	23.3	9	20.4	11	20.0	11	16.6
Poland	27	39.8	24	31.3	20	28.2	23	26.8	26	23.8
Portugal	18	30.6	16	27.2	11	21.2	9	19.4	8	16.0
Slovakia	15	29.4	20	30.7	23	28.9	25	27.5	29	24.3
Slovenia	14	29.0	18	27.5	18	25.8	16	23.8	17	19.5
South Korea	8	26.2	5	20.2	2	15.7	2	15.6	4	14.5
Spain	29	45.1	30	41.7	30	36.3	28	29.4	25	23.7
Sweden	5	24.0	7	21.4	6	19.4	8	19.2	10	16.5
Switzerland	10	27.2	9	23.3	12	22.0	13	21.1	9	16.2
Turkey	21	36.3	28	36.9	28	32.6	30	30.9	32	29.0
United Kingdom	26	37.7	26	33.4	24	29.5	22	26.7	21	22.4
United States	**24**	**37.5**	**22**	**30.9**	**25**	**29.6**	**26**	**28.4**	**24**	**23.7**

Fig. G-4: Fixed Broadband Mean Download Speed by Country Capital and U.S. State Capital Cities (2015-2019)

City, Country/State	2015		2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Canberra, Australia	78	20.0	79	23.9	82	28.7	83	36.8	81	53.2
Vienna, Austria	30	41.9	66	36.9	76	39.1	80	41.6	82	51.7
Brussels, Belgium	56	32.8	69	35.8	72	41.7	76	49.3	79	61.4
Ottawa, Canada	50	35.2	37	48.7	36	65.0	20	101.5	8	147.2
Santiago, Chile	79	18.1	81	23.4	80	30.5	78	42.0	72	71.5
Prague, Czech Republic	34	40.6	57	42.3	69	43.4	75	50.1	78	62.6
Copenhagen, Denmark	23	44.1	25	56.4	32	67.6	39	83.1	35	113.1
Tallinn, Estonia	29	42.1	46	46.7	64	48.0	68	57.3	74	70.8
Helsinki, Finland	25	43.1	53	44.5	70	43.3	72	54.8	76	65.8
Paris, France	2	76.4	2	93.9	5	111.9	8	114.7	2	163.6
Berlin, Germany	66	28.9	70	35.7	71	42.8	65	61.2	65	84.2
Athens, Greece	85	10.8	86	11.6	86	14.0	86	18.4	86	23.5
Budapest, Hungary	14	48.7	15	62.2	14	87.4	10	113.8	18	132.3
Reykjavik, Iceland	15	48.5	4	86.1	3	127.2	1	159.1	1	169.5
Dublin, Ireland	41	38.5	35	50.9	46	57.8	63	64.6	63	87.1
Jerusalem, Israel	70	26.0	78	25.6	78	34.8	81	41.0	83	48.6
Rome, Italy	83	14.5	82	19.7	81	28.8	82	37.2	80	56.5
Tokyo, Japan	4	72.3	10	65.2	23	74.5	62	65.0	48	102.5
Riga, Latvia	7	60.7	14	62.8	45	58.2	52	71.5	45	105.1
Vilnius, Lithuania	6	66.4	6	77.2	1	146.5	19	102.3	47	102.7
Luxembourg City, Luxembourg			41	47.8	49	57.0	42	80.6	36	112.4
Mexico City, Mexico	76	21.6	80	23.6	84	26.3	84	32.1	84	40.7
Amsterdam, Netherlands	24	43.6	30	53.9	35	66.7	47	76.2	56	92.0
Wellington, New Zealand	69	28.5	31	53.4	15	83.1	24	97.7	31	118.1
Oslo, Norway	13	50.7	26	55.3	28	71.9	35	87.1	41	107.7
Warsaw, Poland	67	28.6	52	44.5	42	60.1	66	61.1	55	93.9
Lisbon, Portugal	26	43.1	44	47.1	55	52.3	60	65.4	59	90.4
Bratislava, Slovakia	10	52.2	28	55.0	39	63.2	48	73.4	62	88.8
Ljubljana, Slovenia	62	30.4	68	36.3	74	40.8	73	52.5	75	68.4
Seoul, South Korea	5	68.8	3	87.0	2	136.7	4	127.5	7	150.2
Madrid, Spain	17	46.4	9	65.4	20	77.0	9	114.5	11	140.8

City, Country/State	2015		2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Stockholm, Sweden	3	72.8	5	79.3	9	96.1	14	111.2	21	130.9
Bern, Switzerland	8	56.3	24	56.7	29	71.6	33	89.0	38	110.8
Ankara, Turkey	82	15.3	84	17.0	85	17.9	85	20.0	85	25.3
London, United Kingdom	63	29.7	72	35.1	68	45.1	74	51.8	77	64.3
Albany, New York	72	25.3	75	28.1	77	38.0	50	71.9	54	96.1
Annapolis, Maryland	18	46.1	27	55.3	21	76.5	13	111.8	20	131.0
Atlanta, Georgia	38	39.1	11	65.2	11	89.4	43	79.3	14	138.6
Augusta, Maine	81	16.8	83	19.4	79	30.7	71	56.6	69	73.5
Austin, Texas	1	80.2	1	96.1	4	115.9	2	136.4	4	154.5
Baton Rouge, Louisiana	52	34.0	60	41.8	38	64.1	44	78.0	39	108.8
Bismarck, North Dakota	16	48.3	45	47.0	27	72.2	22	99.9	28	122.4
Boise, Idaho	73	22.9	36	50.3	51	56.3	57	67.0	58	91.2
Boston, Massachusetts	37	39.1	22	57.0	13	87.6	7	115.8	9	142.8
Carson City, Nevada	71	25.7	71	35.3	59	50.9	61	65.1	66	83.3
Charleston, West Virginia	44	37.2	48	45.7	52	53.5	32	93.5	42	107.4
Cheyenne, Wyoming	53	34.0	56	42.3	67	45.2	58	66.6	61	90.1
Columbia, South Carolina	74	22.7	77	25.6	73	41.3	69	57.2	60	90.2
Columbus, Ohio	68	28.5	67	36.6	57	51.3	54	69.3	51	98.4
Concord, New Hampshire	19	44.5	23	56.8	22	75.4	15	110.0	24	129.8
Denver, Colorado	36	39.8	34	51.4	30	71.6	34	88.9	37	111.7
Des Moines, Iowa	59	31.5	49	45.6	50	56.5	56	68.1	57	92.0
Dover, Delaware	9	52.3	17	61.4	10	93.0	6	120.5	3	155.7
Frankfort, Kentucky	84	13.2	85	13.4	83	27.8	77	43.5	71	72.8
Harrisburg, Pennsylvania	47	36.2	39	48.3	33	67.2	21	100.6	32	117.5
Hartford, Connecticut	48	35.9	47	46.2	56	51.4	49	72.3	50	98.6
Helena, Montana	64	29.2	64	37.6	75	39.8	59	65.9	68	77.0
Honolulu, Hawaii	31	41.5	16	61.5	25	73.6	25	97.7	26	126.7
Indianapolis, Indiana	60	31.0	51	45.3	37	64.3	38	83.7	27	123.1
Jackson, Mississippi	54	33.9	8	67.6	48	57.1	40	82.7	52	97.9
Jefferson City, Missouri	65	29.2	74	30.8	62	49.3	67	60.9	70	72.9
Juneau, Alaska	77	21.2	76	25.6	66	45.6	70	56.7	67	80.0

City, Country/State	2015		2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Lansing, Michigan	32	41.0	21	57.3	26	73.1	26	96.9	25	127.5
Lincoln, Nebraska	80	17.3	73	31.2	44	59.2	16	109.4	6	151.1
Little Rock, Arkansas	39	38.8	58	42.1	61	49.9	53	69.7	53	97.7
Madison, Wisconsin	51	34.5	62	38.9	60	50.8	36	86.3	34	113.2
Montgomery, Alabama	55	33.9	59	42.1	54	52.3	45	76.8	46	104.3
Montpelier, Vermont	75	22.0	63	37.9	65	46.7	79	42.0	73	71.1
Nashville, Tennessee	45	36.6	12	64.1	12	88.4	18	108.0	15	138.1
Oklahoma City, Oklahoma	22	44.2	20	57.9	18	79.6	31	93.6	16	135.7
Olympia, Washington	11	51.2	18	61.2	19	78.5	12	112.4	17	133.0
Phoenix, Arizona	40	38.5	29	54.6	31	71.4	29	94.2	29	120.8
Pierre, South Dakota	42	38.2	42	47.8	40	61.4	37	84.2	44	105.2
Providence, Rhode Island	35	40.5	40	48.1	41	60.7	27	95.1	23	129.9
Raleigh, North Carolina	49	35.6	13	63.7	8	99.8	3	127.9	5	153.3
Richmond, Virginia	28	42.4	54	43.8	24	73.8	23	99.0	22	130.1
Sacramento, California	33	40.8	38	48.4	34	67.1	30	94.1	19	131.2
Saint Paul, Minnesota	61	30.8	50	45.3	43	59.5	41	80.7	43	106.7
Salem, Oregon	12	51.1	19	60.3	17	79.8	17	109.2	12	140.4
Salt Lake City, Utah	21	44.2	7	70.8	6	109.6	5	120.7	10	141.5
Santa Fe, New Mexico	43	37.8	43	47.8	47	57.8	55	68.5	64	85.9
Springfield, Illinois	46	36.4	55	43.5	53	52.9	64	62.0	33	115.6
Tallahassee, Florida	57	31.8	61	41.0	63	48.7	46	76.7	40	108.8
Topeka, Kansas	58	31.5	65	37.0	58	51.0	51	71.6	49	101.6
Trenton, New Jersey	20	44.4	33	53.1	7	102.1	11	112.7	13	140.1
Washington, District of Columbia	27	42.8	32	53.4	16	80.8	28	94.9	30	119.6

Fig. G-5: Fixed Broadband Download Speed Percentiles (2019)

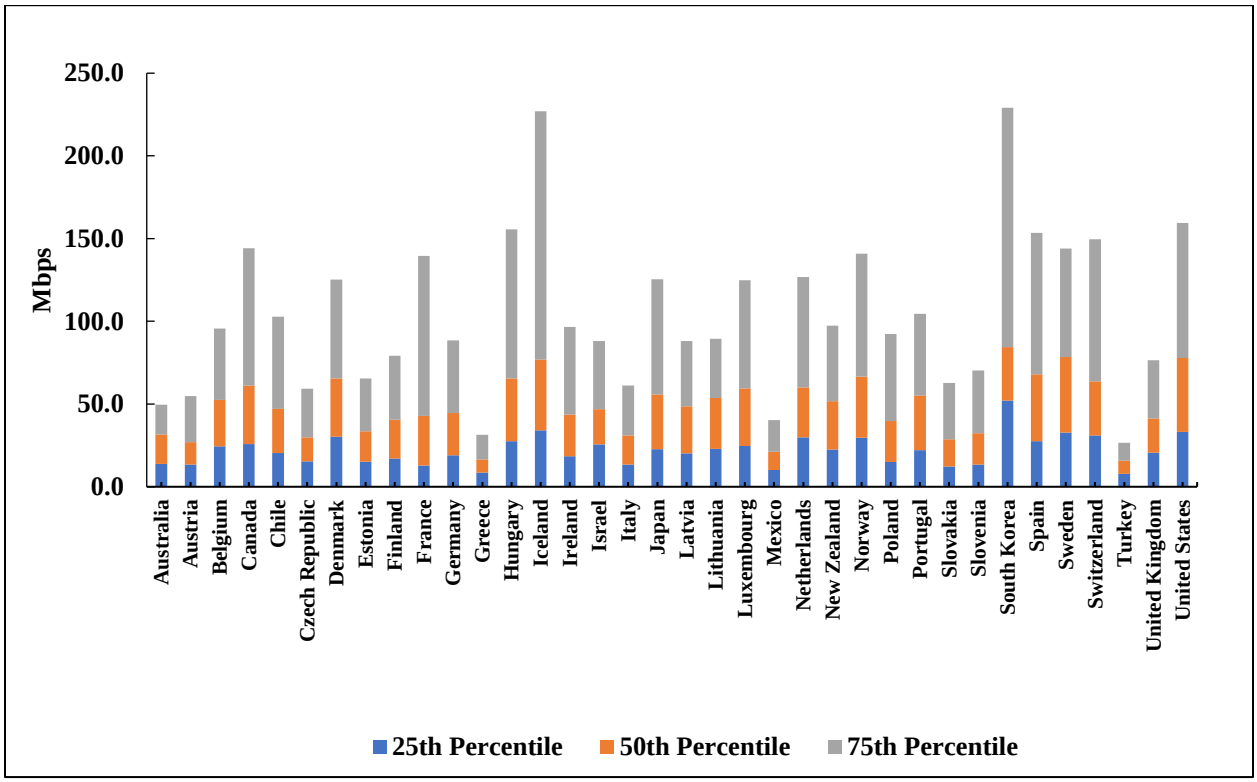


Fig. G-6: Fixed Broadband Mean Download Speed (2015-2019)

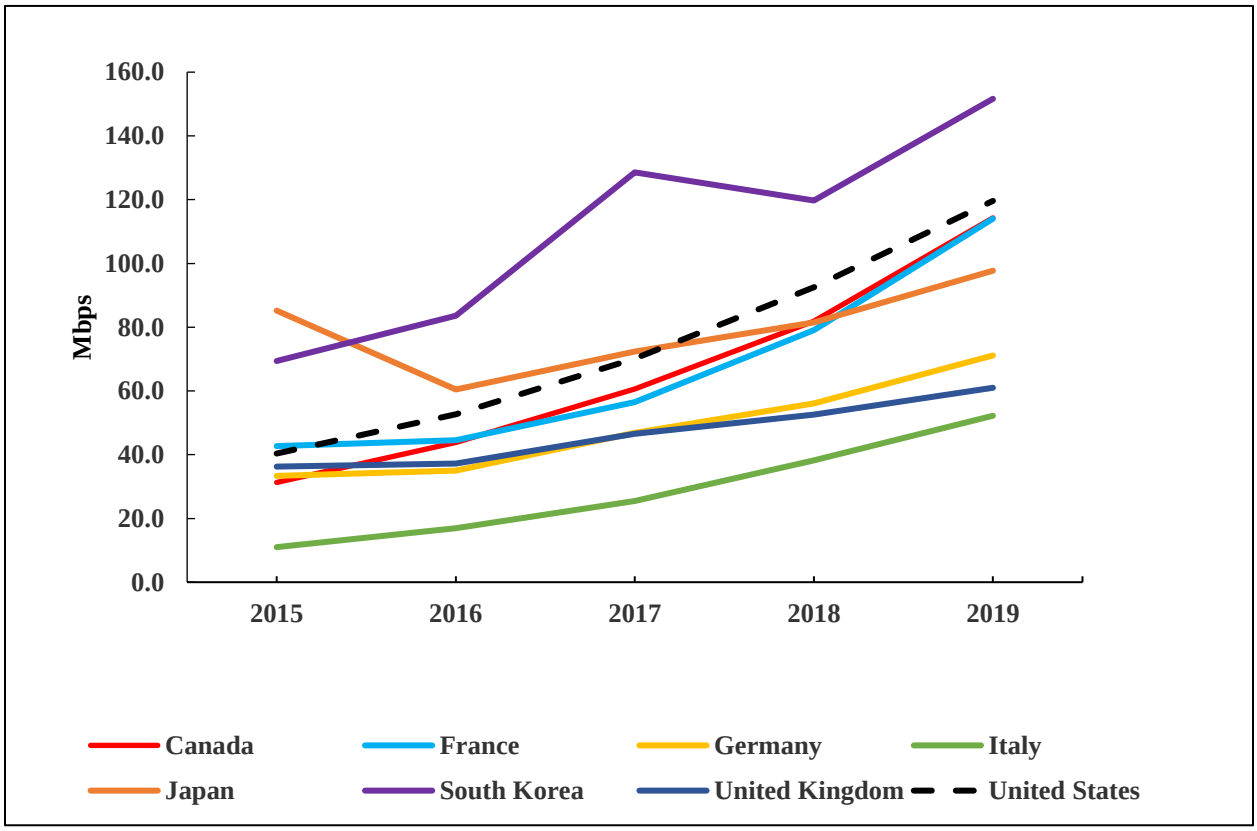


Fig. G-7: Fixed Broadband City Count and Test Count by Country (2015-2019)

Country	Test Count (1000s)					City Count				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Australia	15,161	19,271	31,912	28,426	27,127	4,350	8,021	9,648	10,939	13,246
Austria	2,571	3,539	6,234	6,267	4,732	5,535	1,403	1,413	1,417	1,422
Belgium	2,914	3,932	5,940	4,996	4,814	3,701	607	606	608	612
Canada	17,720	21,948	31,334	30,081	29,883	4,501	2,637	2,830	2,895	3,225
Chile	5,852	6,089	9,458	9,558	7,902	664	230	231	260	267
Czech Republic	3,119	3,340	5,140	5,267	4,870	4,231	5,736	5,941	5,984	5,955
Denmark	2,326	3,452	5,080	5,160	5,012	3,278	588	586	587	634
Estonia	899	597	996	1,359	1,163	671	1,581	1,893	3,514	3,629
Finland	2,516	2,220	3,967	4,170	3,989	3,549	81	83	83	330
France	13,024	17,328	25,845	23,568	21,586	31,852	34,258	35,131	35,104	35,309
Germany	13,369	24,012	37,897	37,737	37,640	28,765	11,610	11,632	11,617	11,642
Greece	4,003	3,791	6,924	7,761	7,984	1,753	5,466	6,233	6,878	7,775
Hungary	4,541	4,729	7,398	7,954	7,306	3,314	3,011	3,070	3,095	3,113
Iceland	171	157	274	276	235	105	82	99	95	106
Ireland	2,140	1,234	2,394	2,517	2,657	2,815	160	163	160	159
Israel	2,288	2,521	4,320	5,437	5,056	1,095	992	1,007	1,003	1,045
Italy	27,924	32,991	57,872	54,093	43,095	14,173	36,909	40,379	40,802	40,126
Japan	2,458	8,431	16,314	15,445	14,063	3,156	2,014	1,965	2,010	1,905
Latvia	1,036	708	1,260	1,121	1,093	595	1,025	1,257	1,229	1,305
Lithuania	854	893	1,586	1,418	1,303	689	2,200	2,722	2,854	2,760
Luxembourg	360	327	505	547	447	365	421	427	434	431
Mexico	23,903	25,851	39,054	42,458	44,245	6,740	8,212	9,083	10,138	11,034
Netherlands	6,342	11,448	17,843	15,760	15,106	4,048	2,446	2,458	2,457	2,458
New Zealand	2,247	3,191	4,460	3,994	3,551	1,321	2,150	2,223	2,252	2,268
Norway	2,674	2,130	3,486	3,447	3,212	3,251	726	741	755	1,941
Poland	11,160	8,881	13,248	12,608	12,537	16,089	3,953	3,995	4,015	9,734
Portugal	3,909	4,279	7,116	7,946	7,804	4,431	1,176	1,180	1,180	1,353
Slovakia	1,302	1,906	2,941	3,244	3,464	2,519	2,703	2,780	2,797	2,806

Country	Test Count (1000s)					City Count				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Slovenia	1,018	1,261	1,682	1,720	1,813	1,565	5,210	5,526	5,489	5,553
South Korea	704	1,229	2,686	2,971	3,062	638	162	161	162	162
Spain	9,689	12,335	15,392	14,399	12,943	9,054	12,915	13,739	14,201	14,169
Sweden	1,164	1,132	1,834	1,725	1,921	3,023	397	414	444	507
Switzerland	2,200	3,546	4,884	5,395	5,228	3,866	2,587	2,584	2,579	2,593
Turkey	5,885	8,696	12,025	14,058	13,806	2,984	4,074	4,500	4,652	4,767
United Kingdom	20,135	40,534	47,236	53,479	51,881	11,492	6,467	6,417	6,511	6,624
United States	**125,634**	**125,425**	**174,228**	**179,304**	**171,306**	**27,595**	**26,482**	**27,000**	**27,433**	**27,952**

Fig. G-8: Fixed Broadband Mean Download Speed by Country (2019)

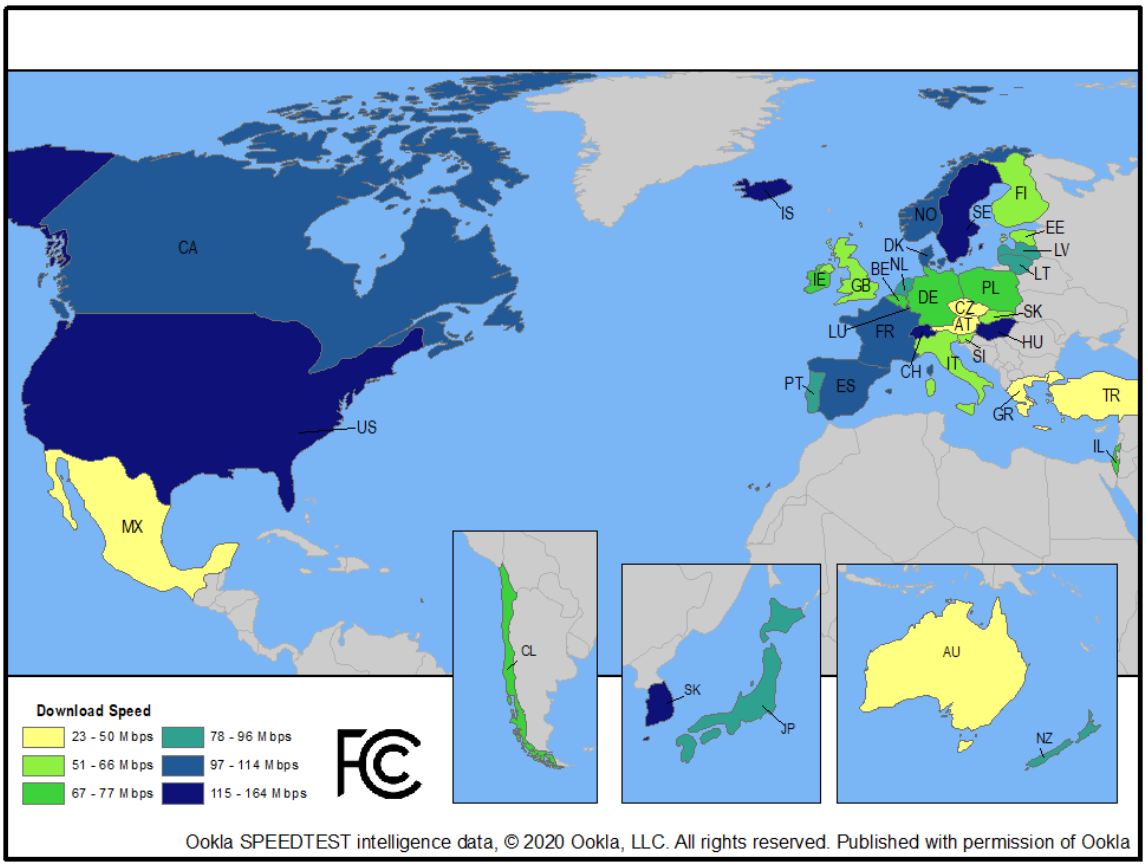


Fig. G-9: Fixed Broadband Mean Upload Speed by Country (2019)

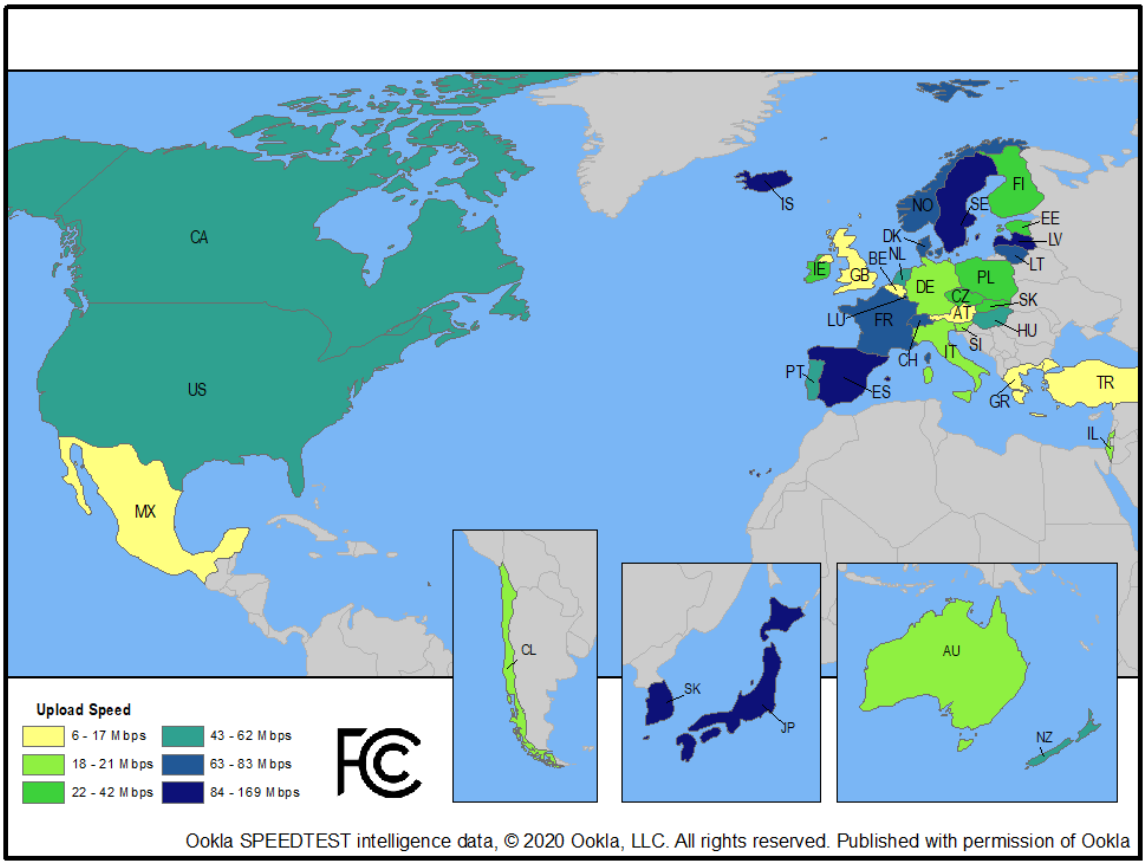


Fig. G-10: Fixed Broadband Mean Latency by Country (2019)

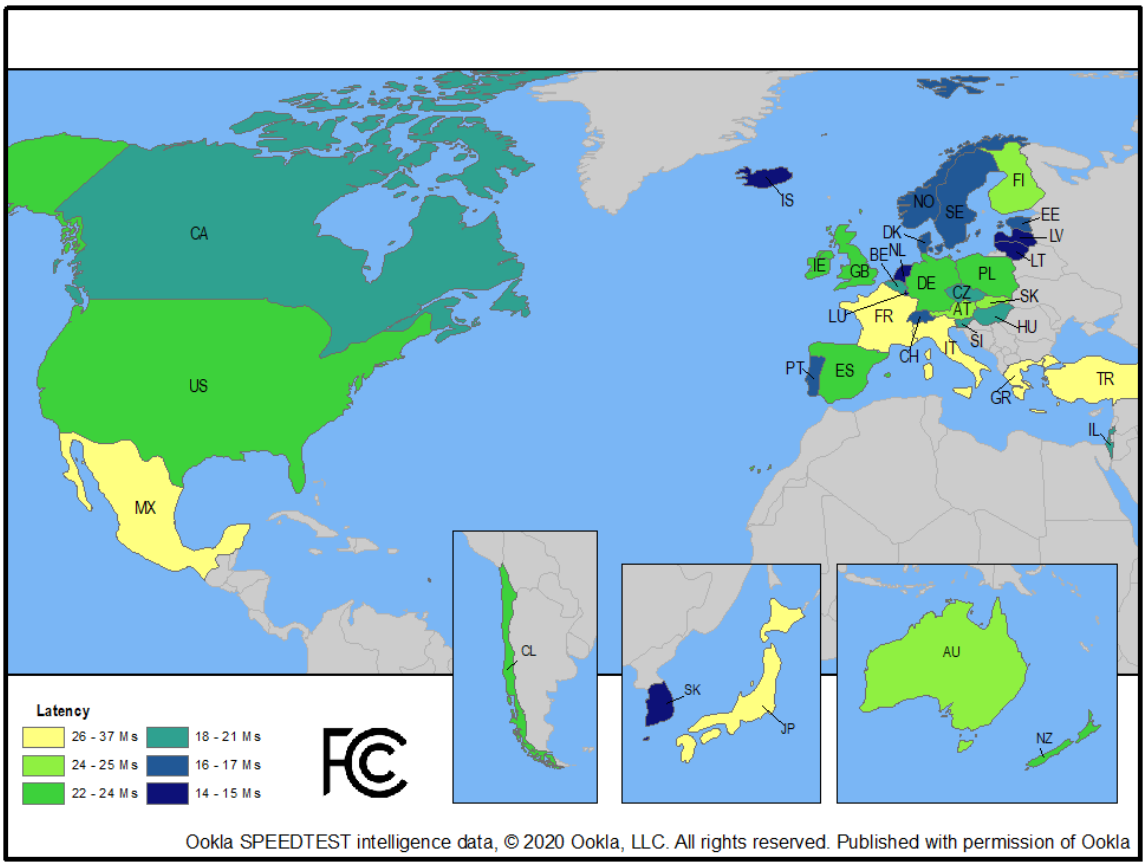


Fig. G-11: Mobile Broadband – 4G LTE Mean Download Speed by Country (2016-2019)

Country	2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	5	42.8	5	48.5	4	56.3	5	62.7
Austria	7	41.0	18	36.5	19	39.0	17	45.6
Belgium	19	32.8	11	40.7	7	50.4	10	50.3
Canada	14	36.2	6	44.8	3	59.2	3	71.3
Chile	32	24.7	36	20.9	36	20.0	36	21.2
Czech Republic	30	27.2	21	32.8	15	42.8	16	46.4
Denmark	10	39.2	9	42.2	11	46.9	11	49.4
Estonia	27	29.3	24	31.6	22	35.8	19	44.2
Finland	16	34.3	19	36.3	17	41.8	14	47.5
France	18	33.0	22	32.0	20	38.5	15	46.8
Germany	22	31.7	28	30.0	26	33.3	27	35.7
Greece	8	40.5	14	39.8	14	43.1	18	44.2
Hungary	1	46.1	3	50.5	8	50.2	20	43.2
Iceland	9	40.1	4	49.7	2	69.3	1	78.6
Ireland	28	28.7	25	31.0	29	30.5	32	31.7
Israel	29	27.7	31	26.3	33	26.9	34	27.8
Italy	20	32.3	17	37.6	23	35.3	26	36.6
Japan	36	18.8	35	22.1	34	26.7	33	31.7
Latvia	21	32.0	26	30.9	28	31.8	29	34.3
Lithuania	13	36.3	15	38.6	16	42.7	13	48.3
Luxembourg	11	38.2	10	41.5	9	47.6	12	48.4
Mexico	34	23.5	33	25.0	35	25.2	35	27.4
Netherlands	2	44.7	2	51.7	5	55.7	6	61.2
New Zealand	6	42.0	7	44.6	6	51.6	9	52.0
Norway	4	43.6	1	63.1	1	71.8	2	74.5
Poland	33	24.4	32	25.4	32	28.9	28	35.4
Portugal	24	31.0	30	29.4	25	33.5	23	37.7
Slovakia	26	30.2	23	31.6	27	33.3	30	34.2
Slovenia	31	26.3	27	30.1	24	34.5	22	38.5
South Korea	3	43.7	8	43.4	13	44.5	4	63.2
Spain	15	34.8	16	37.7	21	38.2	24	37.4
Sweden	17	33.8	12	40.5	10	46.9	7	54.3
Switzerland	23	31.4	20	35.7	12	46.3	8	52.1
Turkey	12	38.1	13	40.0	18	39.7	21	38.6
United Kingdom	25	30.3	29	29.6	31	29.5	31	33.4
United States	**35**	**21.4**	**34**	**24.4**	**30**	**30.4**	**25**	**37.0**

Fig. G-12: Mobile Broadband – 4G LTE Mean Upload Speed by Country (2016-2019)

Country	2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	9	15.4	10	15.8	10	16.0	7	16.9
Austria	11	15.4	21	14.1	18	14.4	17	15.3
Belgium	16	14.5	11	15.8	6	16.8	8	16.6
Canada	28	12.2	24	13.1	21	14.0	15	15.9
Chile	27	12.4	31	11.4	32	11.5	25	13.8
Czech Republic	23	13.3	14	14.9	8	16.4	6	17.0
Denmark	2	18.1	3	18.6	2	20.0	3	19.9
Estonia	32	11.0	30	11.6	26	12.6	24	13.8
Finland	13	15.1	12	15.7	11	15.8	10	16.3
France	33	10.9	34	10.3	33	10.6	33	11.4
Germany	31	11.7	29	11.7	27	12.5	27	13.3
Greece	17	14.4	22	14.0	20	14.1	19	15.1
Hungary	3	17.9	4	18.1	4	17.9	14	16.1
Iceland	1	19.3	1	21.5	1	23.0	1	22.6
Ireland	14	15.1	18	14.4	24	13.1	28	13.3
Israel	6	16.3	7	16.3	5	16.9	9	16.3
Italy	24	13.2	20	14.2	22	13.9	22	14.4
Japan	36	8.0	36	8.5	36	9.1	36	9.8
Latvia	19	14.2	23	13.3	25	13.1	29	12.9
Lithuania	18	14.3	17	14.4	17	14.9	21	14.9
Luxembourg	8	15.5	13	15.2	14	15.3	12	16.1
Mexico	15	14.7	8	16.0	19	14.2	23	14.0
Netherlands	7	16.3	9	15.9	13	15.6	13	16.1
New Zealand	4	17.5	6	16.3	12	15.7	11	16.3
Norway	12	15.3	2	19.6	3	19.7	2	20.3
Poland	30	11.7	33	10.6	34	10.4	34	11.3
Portugal	22	13.4	27	12.6	28	12.4	26	13.5
Slovakia	29	11.9	28	12.0	30	12.1	31	12.5
Slovenia	34	9.2	32	11.0	29	12.2	30	12.8
South Korea	10	15.4	19	14.4	15	15.2	16	15.7
Spain	21	13.6	16	14.7	16	15.1	20	15.0
Sweden	26	12.5	26	12.6	23	13.2	18	15.1
Switzerland	20	13.7	15	14.9	7	16.8	4	19.5
Turkey	5	17.3	5	16.8	9	16.3	5	17.1
United Kingdom	25	13.0	25	13.0	31	12.0	32	12.2
United States	**35**	**8.8**	**35**	**9.0**	**35**	**9.7**	**35**	**11.1**

Fig. G-13: Mobile Broadband – 4G LTE Mean Latency by Country (2016-2019)

Country	2016		2017		2018		2019	
	Rank	ms	Rank	ms	Rank	ms	Rank	ms
Australia	16	32.6	11	29.3	13	28.2	17	29.6
Austria	8	28.4	10	28.8	11	27.3	12	27.4
Belgium	10	29.9	8	27.6	9	27.0	18	29.7
Canada	30	41.9	28	38.8	27	35.9	23	34.1
Chile	26	38.4	23	34.6	24	34.2	22	33.9
Czech Republic	17	32.8	13	29.5	8	26.7	8	26.4
Denmark	4	25.6	5	24.8	6	25.6	10	27.1
Estonia	6	27.1	6	25.3	5	24.2	4	24.9
Finland	5	27.0	7	26.7	7	25.7	5	25.3
France	28	40.5	31	40.9	30	41.3	30	41.5
Germany	32	44.7	32	41.7	28	38.1	28	38.2
Greece	13	31.6	21	32.0	12	27.3	11	27.4
Hungary	3	25.5	3	24.0	4	24.0	6	25.3
Iceland	7	27.5	4	24.4	1	21.0	1	21.1
Ireland	20	34.8	20	32.0	22	33.5	24	34.3
Israel	25	38.2	14	30.4	18	29.5	15	29.1
Italy	31	43.3	27	38.4	35	49.7	33	45.3
Japan	36	59.6	35	56.2	36	53.0	36	54.0
Latvia	1	21.7	1	21.3	2	22.5	2	23.4
Lithuania	9	29.3	9	28.3	10	27.2	7	26.3
Luxembourg	11	31.0	18	31.2	15	28.5	9	26.5
Mexico	35	58.2	36	60.1	34	49.2	35	50.0
Netherlands	15	32.6	12	29.4	17	29.1	20	31.0
New Zealand	21	35.5	26	38.1	29	39.3	29	39.4
Norway	23	36.6	24	34.7	26	35.4	27	37.6
Poland	24	36.6	25	35.6	23	33.9	25	34.5
Portugal	18	33.8	15	30.6	16	28.7	16	29.5
Slovakia	14	32.4	17	30.9	20	31.9	21	31.1
Slovenia	2	24.1	2	23.6	3	23.0	3	24.5
South Korea	27	40.3	29	39.3	25	34.5	26	35.4
Spain	33	50.5	33	47.5	32	45.3	32	43.6
Sweden	22	36.4	22	33.4	21	32.8	19	30.9
Switzerland	12	31.4	19	31.5	19	29.5	13	28.9
Turkey	19	34.6	16	30.6	14	28.4	14	29.0
United Kingdom	29	40.5	30	39.8	31	41.4	31	42.0
United States	**34**	**52.5**	**34**	**50.4**	**33**	**46.4**	**34**	**46.7**

Fig. G-14: Mobile Broadband – 4G LTE Mean Download Speed by Country Capital and U.S. State Capital Cities (2016-2019)

City, Country/State	2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Canberra, Australia	15	36.4	7	43.6	11	49.2	4	65.7
Vienna, Austria	3	44.8	21	37.1	28	38.2	29	44.0
Brussels, Belgium	24	31.2	14	39.7	8	49.7	14	49.7
Ottawa, Canada	28	30.6	16	39.4	3	56.0	3	65.9
Santiago, Chile	37	24.3	68	20.0	84	18.9	86	20.2
Prague, Czech Republic	23	32.3	6	43.9	4	55.0	9	55.6
Copenhagen, Denmark	17	35.5	13	41.0	12	47.2	11	51.3
Tallinn, Estonia	25	31.2	25	34.8	26	39.6	20	48.5
Helsinki, Finland	14	36.9	18	38.0	16	44.4	18	49.0
Paris, France	20	34.2	27	33.0	21	41.1	15	49.3
Berlin, Germany	22	32.6	32	30.6	29	37.3	26	44.9
Athens, Greece	8	38.1	15	39.7	19	41.4	30	42.6
Budapest, Hungary	2	45.6	2	53.9	5	54.3	23	46.5
Reykjavik, Iceland	9	38.1	4	48.6	2	71.1	1	82.2
Dublin, Ireland	29	29.7	31	31.0	49	30.2	65	31.8
Jerusalem, Israel	52	20.5	48	25.3	48	30.2	81	24.2
Rome, Italy	21	32.8	19	37.3	36	34.8	52	36.7
Tokyo, Japan	51	20.8	55	23.2	60	27.0	73	29.1
Riga, Latvia	19	34.5	28	33.0	41	33.0	60	35.0
Vilnius, Lithuania	6	39.9	8	43.3	15	44.8	17	49.2
Luxembourg City, Luxembourg	11	37.9	11	42.6	10	49.3	22	47.1
Mexico City, Mexico	39	23.7	58	23.0	72	24.5	78	27.3
Amsterdam, Netherlands	1	46.7	3	50.7	7	53.5	6	58.0
Wellington, New Zealand	16	36.2	5	44.9	6	53.9	13	50.2
Oslo, Norway	4	43.0	1	64.6	1	72.2	2	74.2
Warsaw, Poland	34	25.9	39	27.9	47	30.4	54	36.5
Lisbon, Portugal	10	38.0	23	35.6	25	39.7	31	42.1
Bratislava, Slovakia	18	35.0	20	37.1	22	40.3	34	42.1
Ljubljana, Slovenia	27	31.1	22	36.3	23	40.2	43	38.2
Seoul, South Korea	5	42.9	12	42.3	17	43.7	5	63.3
Madrid, Spain	7	39.3	9	43.1	18	42.7	32	42.1
Stockholm, Sweden	13	37.2	10	42.9	9	49.5	7	57.7
Bern, Switzerland	26	31.1	24	35.6	13	45.4	10	52.8
Ankara, Turkey	12	37.7	17	39.4	24	39.7	50	37.1
London, United Kingdom	30	28.3	40	27.8	55	28.5	51	37.1
Albany, New York	63	19.5	64	21.0	64	26.6	61	34.6
Annapolis, Maryland	48	22.6	29	32.0	14	44.9	8	55.6
Atlanta, Georgia	43	23.0	38	28.3	32	35.9	21	48.4
Augusta, Maine	82	14.8	78	17.8	78	22.1	79	26.1
Austin, Texas	56	20.3	47	25.3	46	31.0	56	36.0
Baton Rouge, Louisiana	67	18.1	59	22.5	58	28.2	57	35.8

City, Country/State	2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Bismarck, North Dakota	33	26.0	30	31.1	68	25.4	55	36.1
Boise, Idaho	77	16.7	69	20.0	44	31.4	41	38.7
Boston, Massachusetts	62	19.7	51	24.5	45	31.2	35	41.7
Carson City, Nevada	70	17.8	83	16.6	86	17.8	84	21.5
Charleston, West Virginia	83	12.9	81	16.8	66	25.9	62	34.6
Cheyenne, Wyoming	85	12.2	85	15.0	83	19.3	71	29.5
Columbia, South Carolina	76	16.7	63	21.1	57	28.4	63	33.6
Columbus, Ohio	47	22.7	42	25.8	35	34.9	27	44.7
Concord, New Hampshire	84	12.5	82	16.8	82	19.8	83	23.3
Denver, Colorado	80	14.8	65	20.9	51	29.3	48	37.2
Des Moines, Iowa	49	21.8	53	23.7	71	24.7	74	29.1
Dover, Delaware	44	22.8	36	28.7	27	38.8	16	49.2
Frankfort, Kentucky	45	22.8	66	20.4	65	26.5	38	40.2
Harrisburg, Pennsylvania	53	20.4	54	23.6	33	35.7	28	44.6
Hartford, Connecticut	61	20.0	57	23.1	43	31.7	53	36.6
Helena, Montana	66	18.5	72	19.4	73	24.4	46	37.7
Honolulu, Hawaii	69	18.0	71	19.8	67	25.5	67	31.4
Indianapolis, Indiana	40	23.5	35	29.1	37	34.6	36	40.9
Jackson, Mississippi	73	17.2	80	17.0	76	23.1	80	24.6
Jefferson City, Missouri	74	17.2	75	18.4	77	22.3	68	30.9
Juneau, Alaska	57	20.3	77	18.3	85	17.9	85	21.2
Lansing, Michigan	32	26.6	34	30.2	31	36.7	39	39.0
Lincoln, Nebraska	60	20.1	56	23.1	70	24.8	72	29.2
Little Rock, Arkansas	46	22.8	41	26.9	34	35.4	33	42.1
Madison, Wisconsin	71	17.5	76	18.3	80	20.2	82	24.0
Montgomery, Alabama	35	25.8	37	28.3	52	29.1	64	31.9
Montpelier, Vermont	75	16.9	79	17.4	69	25.2	76	28.9
Nashville, Tennessee	65	18.9	61	22.1	54	29.0	45	38.1
Oklahoma City, Oklahoma	79	16.4	73	19.3	75	23.3	77	27.4
Olympia, Washington	64	19.1	74	19.2	74	24.2	69	30.4
Phoenix, Arizona	72	17.4	62	21.2	63	26.8	42	38.7
Pierre, South Dakota	41	23.1	43	25.7	62	26.8	58	35.8
Providence, Rhode Island	55	20.4	46	25.5	40	33.3	12	51.1
Raleigh, North Carolina	59	20.1	50	24.6	50	29.5	47	37.4
Richmond, Virginia	58	20.1	52	24.4	42	32.2	40	38.9
Sacramento, California	54	20.4	60	22.4	59	28.0	59	35.5
Saint Paul, Minnesota	36	25.6	26	34.5	20	41.1	19	48.7
Salem, Oregon	31	27.5	33	30.4	30	37.0	37	40.9
Salt Lake City, Utah	68	18.1	70	19.9	61	26.9	44	38.2
Santa Fe, New Mexico	86	12.1	86	14.6	81	20.0	66	31.6
Springfield, Illinois	38	23.8	44	25.6	53	29.1	49	37.1
Tallahassee, Florida	42	23.1	45	25.6	39	33.5	24	45.5
Topeka, Kansas	78	16.4	67	20.4	56	28.5	70	30.1

City, Country/State	2016		2017		2018		2019	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Trenton, New Jersey	81	14.8	84	16.4	79	21.8	75	29.0
Washington, District of Columbia	50	21.6	49	24.8	38	34.0	25	44.9

Fig. G-15: Mobile Broadband – 4G LTE Download Speed Percentiles (2019)

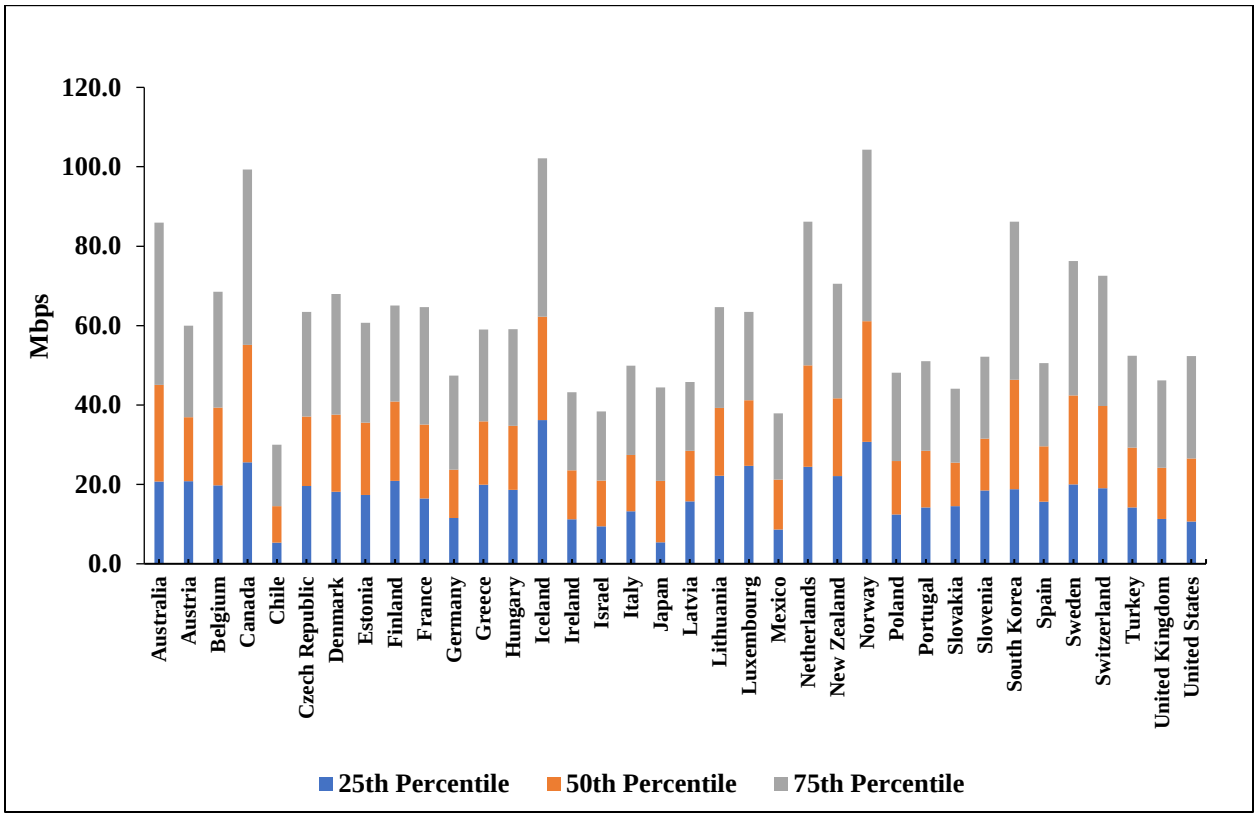


Fig. G-16: Mobile Broadband – 4G LTE Mean Download Speeds (2016-2019)

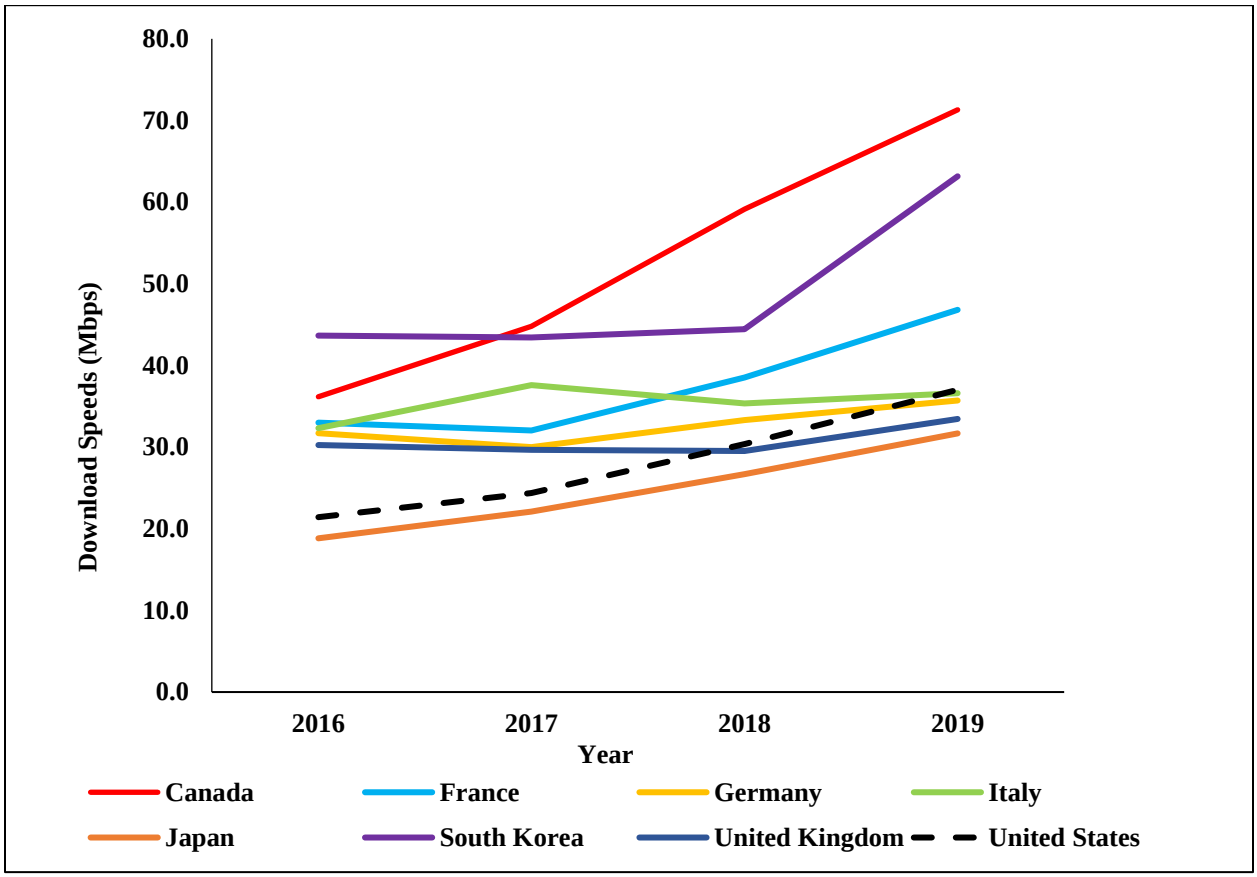


Fig. G-17: Mobile Broadband – 4G LTE City Count and Test Count by Country (2016-2019)

Country	Test Count (1000s)				City Count			
	2016	2017	2018	2019	2016	2017	2018	2019
Australia	1,551	2,567	3,310	3,711	9,247	10,240	11,139	12,240
Austria	551	872	912	872	1,380	1,396	1,402	1,398
Belgium	101	165	182	214	600	602	607	610
Canada	773	1,180	1,130	1,255	1,985	2,359	2,395	2,628
Chile	424	768	1,430	1,245	215	227	241	245
Czech Republic	119	187	211	313	4,431	4,838	4,974	5,333
Denmark	364	502	558	559	586	586	586	615
Estonia	118	184	239	200	1,563	1,965	3,388	3,510
Finland	944	1,733	1,823	1,838	84	85	83	396
France	1,436	3,649	4,209	3,187	19,151	27,016	28,838	29,598
Germany	1,206	1,971	2,634	2,907	10,127	10,470	10,679	10,865
Greece	203	408	477	510	2,940	4,649	5,283	5,960
Hungary	211	427	577	618	2,455	2,843	2,922	2,923
Iceland	11	22	30	20	63	80	82	100
Ireland	109	205	291	339	127	140	148	143
Israel	291	477	606	651	743	925	969	1,023
Italy	2,834	5,268	11,786	9,563	23,279	28,550	33,594	34,517
Japan	1,984	2,585	2,186	1,802	1,991	1,930	1,996	1,826
Latvia	126	216	219	247	881	1,084	1,171	1,242
Lithuania	98	156	171	202	1,721	2,207	2,340	2,390
Luxembourg	25	36	35	28	310	349	365	361
Mexico	810	1,498	2,230	2,244	2,864	3,855	4,958	6,018
Netherlands	419	802	850	880	2,324	2,404	2,429	2,428
New Zealand	87	140	138	159	1,058	1,326	1,465	1,574
Norway	226	245	235	209	624	682	685	1,619
Poland	1,324	2,235	2,213	2,013	3,547	3,791	3,856	7,913
Portugal	125	249	316	305	1,072	1,128	1,142	1,264
Slovakia	84	168	198	231	1,756	2,190	2,305	2,399
Slovenia	51	118	130	171	3,201	4,161	4,247	4,261
South Korea	119	159	272	387	161	162	162	162
Spain	498	663	698	727	5,643	7,833	8,677	9,639
Sweden	64	89	105	120	400	405	414	434
Switzerland	350	657	873	970	2,445	2,525	2,542	2,569
Turkey	2,158	1,097	1,513	1,702	2,029	2,208	2,784	3,428
United Kingdom	2,488	3,464	3,772	4,199	6,019	6,331	6,407	6,494
United States	**14,332**	**20,657**	**18,576**	**17,941**	**24,471**	**25,922**	**25,975**	**26,346**

Fig. G-18: Mobile Broadband – 4G LTE Mean Download Speed by Country (2019)

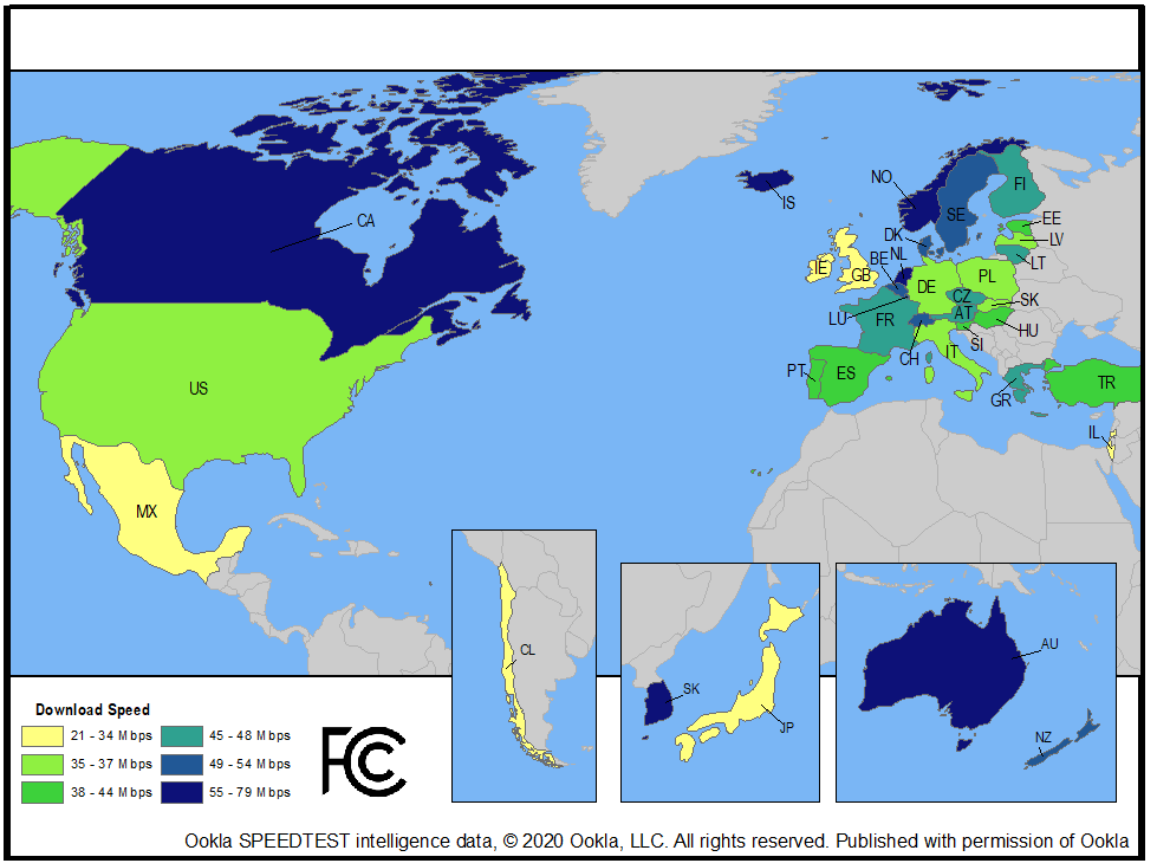


Fig. G-19: Mobile Broadband – 4G LTE Mean Upload Speed by Country (2019)

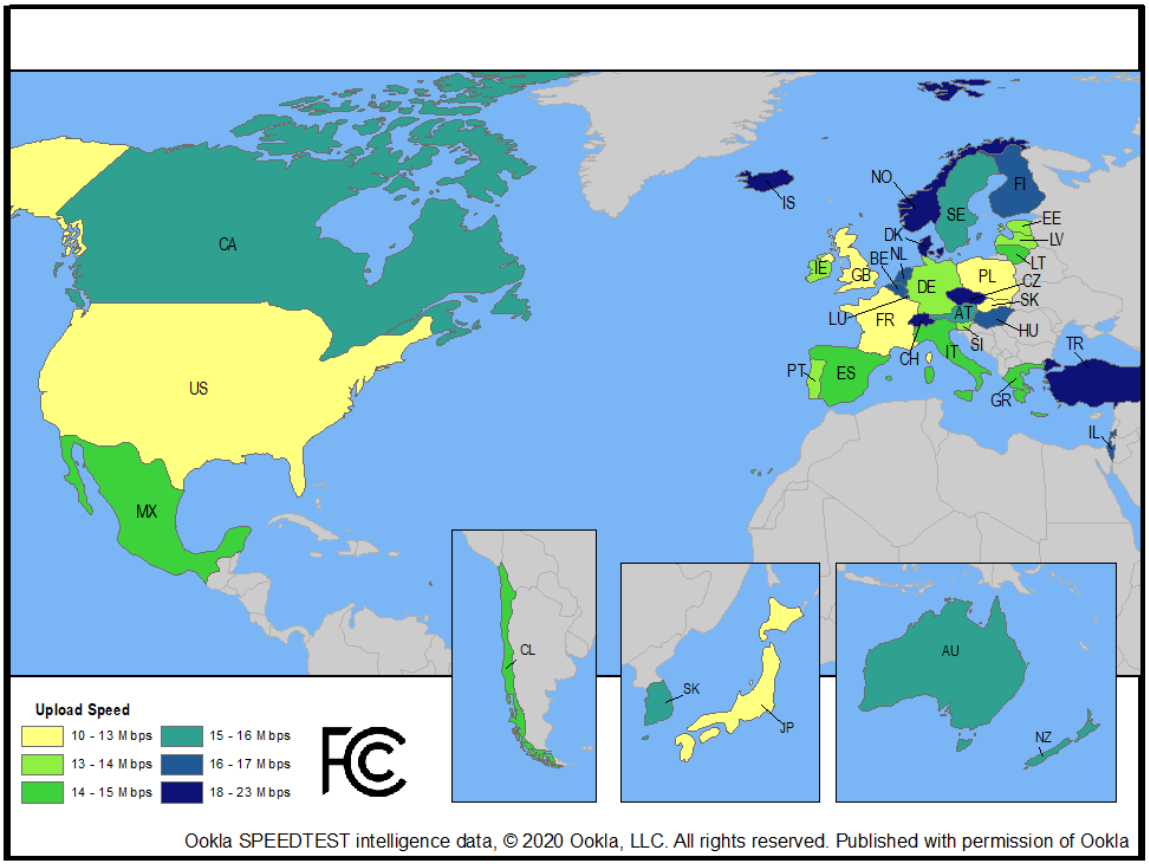
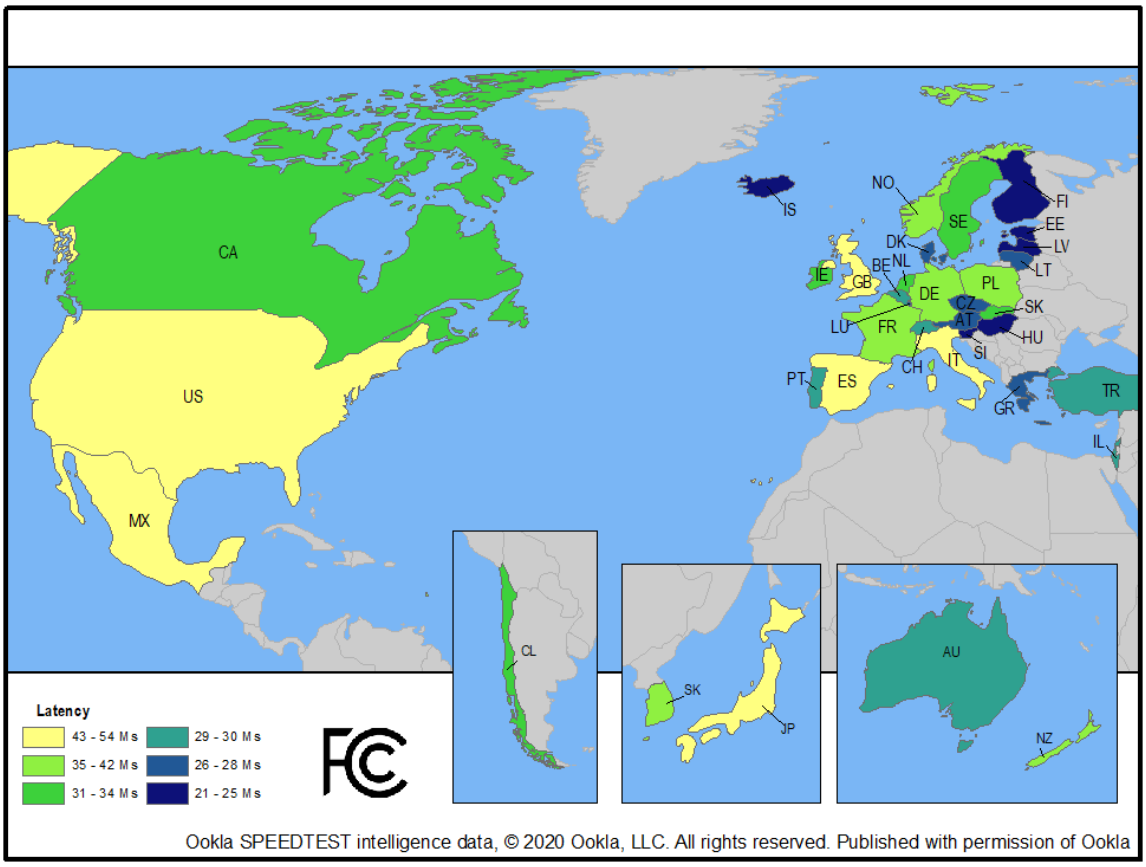


Fig. G-20: Mobile Broadband – 4G LTE Mean Latency by Country (2019)



IV. OPENSIGNAL ANALYSIS

25. This section presents mobile download speed data for 3G/4G and 5G as well as 5G availability data, as measured and calculated by OpenSignal.[22] Average combined 3G/4G download speeds for the first half of 2019 and the first half of 2020 are presented in Figure G-21 below.[23] Figure G-

[22] OpenSignal gathers crowdsourced mobile speed data through the use of its mobile app as well as through partner apps. The partners they work with are strategically selected to cover a wide range of users, demographics, and devices. OpenSignal, *Methodology Overview: How OpenSignal Measures Mobile Network Experience*, https://www.opensignal.com/sites/opensignal-com/files/opensignal_methodology_overview_june_2020.pdf (last visited Oct. 27, 2020).

[23] Fig. G-21 presents Download Speed Experience by country and shows the average download speed (Mbps) experienced by OpenSignal users across an operator's 3G and 4G networks. This metric factors in 3G and 4G download speeds along with the availability of each technology. 4G availability measures the proportion of time OpenSignal users with a 4G device have a 4G connection, while 3G availability measures the proportion of time OpenSignal users with a 3G device have a 3G connection. Data for the first half of 2019 were collected from January 1–March 31, 2019, and data for the first half of 2020 were collected from January 1–March 30, 2020. Peter Boyland, *The State of Mobile Network Experience: Benchmarking Mobile on the Eve of the 5G Revolution*, OpenSignal (May 2019), https://www.opensignal.com/sites/opensignal-com/files/data/reports/global/data-2019-05/the_state_of_mobile_experience_may_2019_0.pdf; Sam Fenwick and Hardik Khatri, *The State of Mobile Network Experience 2020: One Year into the 5G Era*, OpenSignal (May 2020),

(continued….)

22 presents average 5G download speeds as well as 5G availability, which is defined as the proportion of time that OpenSignal users with a 5G device and subscription have a 5G connection, for the first and second half of 2020.[24]

Fig. G-21: OpenSignal – Mobile Broadband Download Speed by Country (2019-2020)

Country	1H2019	1H2020
	Mbps	Mbps
Afghanistan		2.9
Albania	21.4	25.8
Algeria	3.1	4.0
Argentina	12.8	17.4
Australia	37.4	43.0
Austria	27.5	34.6
Azerbaijan	13.4	17.8
Bahrain	13.9	16.4
Bangladesh	5.7	6.8
Belarus	7.7	10.8
Belgium	34.2	37.6
Bolivia	12.5	13.6
Brazil	13.0	15.3
Brunei		16.4
Bulgaria	22.5	
Cambodia	5.6	8.0
Cameroon		7.5
Canada	42.5	59.6
Chile	12.0	13.7
Colombia	10.0	13.4
Costa Rica	10.1	14.0
Cote d'Ivoire		7.4
Croatia	26.7	36.6
Czech Republic	31.5	32.7
Denmark	34.6	33.5
Dominican Republic	8.5	11.5

https://www.opensignal.com/sites/opensignal-com/files/data/reports/pdf-only/data-2020-05/state_of_mobile_experience_may_2020_opensignal_3_0.pdf.

[24] Fig. G-22 presents 5G download speed by country, which is the average download speed for each operator on an active 5G connection as experienced by OpenSignal users. This Figure also presents 5G availability, which is the proportion of time OpenSignal users with a 5G device and subscription have a 5G connection. Data for the first half of 2020 were collected from January 22–April 21, 2020, and data for the second half of 2020 were collected from May 16–August 14, 2020. Ian Fogg, *5G Download Speed is Now Faster than Wifi in Seven Leading 5G Countries*, OpenSignal (May 6, 2020), https://www.opensignal.com/2020/05/06/5g-download-speed-is-now-faster-than-wifi-in-seven-leading-5g-countries; Ian Fogg, *Benchmarking the Global 5G User Experience*, OpenSignal (Aug. 26, 2020), https://www.opensignal.com/2020/10/13/benchmarking-the-global-5g-user-experience-october-update.

Country	1H2019	1H2020
	Mbps	Mbps
Ecuador	10.5	13.3
Egypt	8.6	10.7
El Salvador	5.4	5.8
Finland	27.0	29.8
France	25.2	28.6
Germany	22.6	28.7
Ghana	5.1	6.8
Greece	23.8	23.7
Guatemala	10.8	15.0
Honduras		13.4
Hong Kong	16.7	21.8
Hungary	32.7	31.7
India	6.8	8.1
Indonesia	6.9	9.9
Iraq	1.6	1.6
Ireland	16.2	19.2
Israel	13.6	15.2
Italy	19.9	24.3
Ivory Coast	6.7	
Japan	33.0	49.3
Jordan	10.4	12.5
Kazakhstan	11.4	11.9
Kenya	10.1	10.9
Kyrgyzstan		10.5
Kuwait	16.2	16.6
Laos		17.1
Lebanon	16.9	23.8
Lithuania		33.3
Malaysia	11.5	11.0
Maldives		19.4
Mexico	14.9	19.6
Morocco	11.2	17.4
Myanmar	16.0	16.4
Nepal	4.4	7.5
Netherlands	42.4	54.8
New Zealand	27.3	35.2
Nigeria	5.4	7.3
North Macedonia		30.0
Norway	48.2	47.5
Oman	20.3	25.2

Country	1H2019	1H2020
	Mbps	Mbps
Pakistan	6.2	8.4
Panama	7.2	8.4
Paraguay	10.6	10.8
Peru	11.7	12.1
Philippines	7.0	8.5
Poland	17.3	20.7
Portugal	21.6	26.3
Puerto Rico		18.0
Qatar	24.6	31.3
Romania	20.6	21.4
Russian Federation	12.0	14.5
Saudi Arabia	13.6	21.4
Senegal	5.1	9.1
Serbia	21.5	25.2
Singapore	39.3	47.5
Slovakia	23.3	25.3
Slovenia		26.0
Somalia		6.4
South Africa	15.0	19.1
South Korea	52.4	59.0
Spain	24.8	26.2
Sri Lanka	10.7	10.2
Sweden	30.8	29.7
Switzerland	35.2	42.8
Tanzania		5.4
Taiwan	26.6	28.9
Thailand	5.7	9.2
Tunisia	13.4	15.5
Turkey	17.1	20.0
Ukraine	11.2	14.0
United Arab Emirates	19.9	32.2
United Kingdom	21.7	22.9
United States	21.3	26.7
Uruguay		20.3
Uzbekistan	5.0	6.2
Vietnam	14.1	20.6

Fig. G-22: OpenSignal – 5G Download Speed and Availability by Country (1H2020, 2H2020)

Country	1H2020		2H2020	
	Mbps	Availability	Mbps	Availability
Australia	163.9	6.1%	215.7	8.6%
Canada			178.1	8.8%
Germany			102.0	10.3%
Hong Kong			142.8	26.1%
Kuwait	185.1	34.9%	171.5	29.1%
Netherlands			79.2	13.2%
Saudi Arabia	291.2	30.8%	414.2	34.4%
South Korea	224.0	14.2%	312.7	20.7%
Spain	146.8	6.9%		
Switzerland	201.9	8.7%	150.7	7.5%
Taiwan			210.2	18.6%
United Kingdom	138.1	5.2%	133.5	4.5%
United States	52.3	12.7%	50.9	19.3%

APPX. G-3
Broadband Pricing Comparisons

1. Congress directs the Commission to compare broadband pricing in "communities of a population size, population density, topography, and demographic profile that are comparable to the population size, population density, topography, and demographic profile of various communities within the United States."[25] To meet this directive, we first collected a comprehensive sample of advertised prices and terms for over 1,000 fixed and mobile broadband plans from the largest broadband providers' in the United States and 25 other countries.[26] We then rank the countries by fixed and mobile broadband prices from the least expensive (1st) to most expensive (26th) according to two different methodologies. The first method calculates weighted average prices for a set of fixed broadband products based on download speeds and for a set of mobile broadband products based on data usage allowances.[27] These two weighted average prices are then used to calculate an overall average price, and countries are ranked by this measure.[28] To more closely match the characteristics of the comparison communities and their broadband offerings, the second method constructs hedonic fixed and mobile broadband price indexes from a regression of broadband prices on broadband product characteristics and country-level variables to control for differences in broadband market conditions.[29] The hedonic method seeks to better assess how U.S. broadband prices compare to prices in other countries after accounting for country-level cost and demographic differences that likely affect broadband pricing, including population density, topography, income, and education levels. The hedonic price index also adjusts for observable differences in broadband plan characteristics across countries (e.g., speed and usage limits) and generates prices for a set of standardized broadband plans to facilitate price comparisons across countries. The results of our fixed and mobile broadband pricing analyses demonstrate that accounting for these country-level differences in cost, demand, and quality factors gives a substantially different assessment of the competitiveness of the U.S. broadband market.

I. OVERVIEW AND DATA HIGHLIGHTS

2. Comparing broadband prices across countries presents several challenges. One difficulty is that broadband product offerings are complex and vary widely across countries. Among other aspects, the plans may differ with respect to: (1) download and upload speeds; (2) types of technology used to deliver broadband services; (3) limitations on use, including limits on upload and download volumes; (4) contractual conditions; (5) additional services included; and (6) consequences of exceeding usage limits, with some plans reducing speeds, imposing surcharges, or shutting off service. In addition, broadband

[25] 47 U.S.C. § 1303(b)(2); *see also* RAY BAUM'S Act.

[26] The *2018 International Broadband Data Report* included three additional comparison countries: Chile, Japan, and South Korea. These countries were excluded from this *Report* due to resource limitations and the difficulty of collecting information from Japan and South Korea's providers' websites. *2018 International Broadband Data Report*, 33 FCC Rcd at 981, para. 6.

[27] The data was collected between February and September 2020. The data we use for these comparisons contain the terms and advertised prices for select fixed and mobile broadband plan offerings available on the websites of the largest broadband providers in each country. *See infra* paras. 39-60.

[28] Our broadband price index measures the dollar amount that U.S. broadband subscribers would need to have added or subtracted from their incomes to purchase the same basket of broadband services under the pricing structures in other countries. Quantity weights for the price index are the share of broadband subscribers in the United States that, for fixed broadband, take each of the three broadband speed tiers and, for mobile broadband, take each of the three data usage tiers in the analyses. *See infra* paras. 61-62.

[29] A hedonic regression provides an empirical summary of how prices vary with the characteristics of a good (e.g., download speed). In this *Report*, the hedonic regression builds on the price index method by allowing adjustment of prices for quality, cost, and demographic differences across countries and then predicting broadband prices for each country at the average U.S. values of these variables. *See infra* paras. 28-32.

service is also frequently purchased as part of a discounted bundle of services, making it difficult to identify the price of the broadband service. Lastly, differences across countries in the quality of networks deployed, cost factors (e.g., population density and topography), and demand factors (e.g., demographics and content quality), would be expected to affect pricing, all else equal. Building on the work in the *6th International Broadband Data Report*, which was released by the International Bureau,[30] our hedonic price index analysis accounts for these differences, with the intention of producing comparisons that are more meaningful for the purposes of assessing which countries have broadband policies that foster competition and provide the greatest consumer benefits.[31]

A. Fixed Broadband Pricing Results

3. *Broadband Price Index Results*. This analysis compares broadband prices across countries by calculating weighted average prices within each fixed broadband download speed tier and then aggregating these prices into an overall average fixed broadband price measure.

- For broadband service purchased on a standalone basis, we find that the United States ranks 21st out of the 26 countries in our broadband price index, not adjusting for cost and demand factor differences across countries.[32]
- For broadband service purchased in a bundle with video service, we find that the United States ranks 19th out of the 26 countries.
- Overall, we find that the United States ranks 21st out of the 26 countries that does not account for cost and demand differences across countries.

4. *Hedonic Price Index Results*. The hedonic price index adjusts broadband prices for differences in demographic and cost profiles across countries using a hedonic regression framework. The hedonic regression also adjusts for observable differences in broadband plan characteristics across countries (e.g., the speed and usage limits of each plan) and generates prices for a set of standardized broadband plans in every country to facilitate price comparisons. Based on the predicted prices for these standardized plans, we then calculate a hedonic price index to serve as our price comparison measure across countries. This index estimates what the average U.S. consumer would expect to pay for service in each country if that country had the same demographics, cost structure, and broadband plan characteristics as the United States.[33]

- After adjusting for differences in cost and demographic factors across countries, as well as differences in broadband plan characteristics, our hedonic price index estimates that the United States ranks 12th out of the 26 countries.[34]

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[30] *2018 International Broadband Data Report*, 33 FCC Rcd 978.

[31] Using standard discrete choice consumer demand models, it is simple to construct examples where consumers in a country with higher broadband prices receive greater consumer surplus (i.e., are better off) from their broadband services, compared to consumers in a country with lower prices. Similarly, higher prices may not indicate that one market is less competitive than another in terms of the economic profits earned by broadband firms. As such, simple broadband price comparisons may not be appropriate for comparing the effectiveness of competition and regulatory policies across countries.

[32] *See infra* Fig. G-24.

[33] The country rankings would not change if, instead of using the United States as our baseline country, we predicted prices at the values of the country-level variables for any other country or at the average of these variables across all countries. The only difference in our results would be in the levels of the predicted prices. Due to the provider-level random coefficients in the hedonic model, changing the values of the plan characteristics used to predict prices would change the country rankings.

[34] *See infra* Fig. G-26.

- The U.S. ranking remains unchanged at 12th after adjusting for our measure of fixed broadband network quality.
- After further adjusting prices for measures of broadband content quality, the United States ranks 2nd among the 26 countries.

B. Mobile Broadband Pricing Results

5. Our mobile broadband price comparison methodology is the same as our fixed broadband price methodology with two exceptions. First, because nearly all mobile broadband plans are sold by data usage allowance rather than speed, we classify mobile broadband products by data usage allowances rather than by download speeds. Second, we account for bundling in this sector by analyzing multi-line data plans (i.e., family plans) rather than the video and broadband bundling that is more common in the fixed broadband market.

6. *Broadband Price Index*. This analysis compares countries by calculating weighted average prices for mobile plans that fall within specified data usage tiers and then aggregates these prices into an overall average mobile broadband price.

- The United States ranks 22nd in single-line plan pricing and 21st in multi-line pricing out of the 26 countries.[35]
- Overall, we find that the United States ranks 21st out of the 26 countries in our mobile broadband price index, not adjusting for cost and demand factor differences across countries.

7. *Hedonic Price Index Results.* As in our fixed broadband analysis, we calculate a hedonic index that estimates what the average U.S. consumer would expect to pay for her level of mobile broadband service in each country if that country had the same demographics, cost structure, and broadband plan characteristics as the United States.

- After adjusting for differences across countries in the cost and demographic factors, as well as differences in broadband plan characteristics, our hedonic price index estimates that the United States ranks 22nd out of the 26 countries.[36]
- Adjusting for mobile network quality measures, the United States ranks 17th out of 26 countries.
- After we further adjust the mobile hedonic price index for our measures of content quality, the United States is ranked 7th.

8. *Combining Fixed and Mobile Hedonic Price Index Rankings.* Typical consumers in the United States subscribe to both fixed and mobile broadband services, so we also measure overall broadband affordability by calculating the average monthly cost that U.S. consumers would pay to subscribe to both services in each country. After accounting for differences in content quality, costs, demographics and broadband plan characteristics, we find that the United States ranks 2nd overall by this measure, at $121.49 per month for a mobile and fixed broadband connection.[37]

[35] *See infra* Fig. G-28.

[36] *See infra* Fig. G-30.

[37] *See infra* Fig. G-32.

II. FIXED BROADBAND PRICING ANALYSIS

9. Many studies compare advertised prices for "similar" telecommunications services.[38] While such price comparisons are appropriate for descriptive assessments of price levels, they are less useful for identifying which countries have industry structures and policies that produce the greatest broadband consumer benefits.[39] Rankings that account for these factors are necessary to inform government competition and regulatory policy because the determinants of price that are outside the scope of competition policy may differ across countries and distort comparisons. The challenge in comparing prices across markets is that the supply and demand factors which generate different broadband prices and offerings vary widely from one market to the next. An analysis that seeks to make normative comparisons of broadband prices across countries would, at a minimum, need to account for: (1) the different costs of deploying and operating broadband networks; (2) demographic differences that affect demand for broadband service; (3) multi-product bundling in broadband pricing; (4) different product offerings in each country; and (5) the availability and quality of complementary content and applications. The *2018 International Broadband Data Report* described in detail how each of these factors would be expected to affect international price comparisons and why these should be accounted for when comparing prices across countries.[40]

10. As in the *2018 International Broadband Data Report*, we attempt to adjust for these cost and demand factor differences by estimating a hedonic regression.[41] Our approach extends a standard hedonic framework by controlling for cost and demand factors instead of only adjusting prices for differences in product characteristics.[42] The first step of constructing the index is to use our model to predict broadband prices for a set of standardized plans for each provider in our study, setting the country and demographic characteristic variables at the U.S. values but using the estimated provider-specific product characteristic random coefficients and random intercepts.[43] From these predicted prices, we then construct a hedonic price index that facilitates comparisons by adjusting for observable differences in

[38] For example, *see* Carol Corrado and Olga Ukhaneva, *Hedonic Prices for Fixed Broadband Services: Estimation Across OECD Countries* (Oct. 20, 2016), https://www.oecd-ilibrary.org/docserver/5jlpl4sgc9hj-en.pdf?expires=1603997556&id=id&accname=guest&checksum=1D0A776B692D8F368F8A696A24A0E702.

[39] In the language of economics, price indexes are positive analyses that describe what the price differences are across countries or what the typical consumer would be expected to pay for broadband in each country. However, cross-country price differences are frequently used to normatively rank countries and interpreted as meaningful differences in industry performance or regulatory policies. In order to provide a more normative assessment, our analysis also accounts for potentially exogenous supply and demand differences across countries that would result in price differences regardless of broadband policy differences. However, given the limited number of country-level variables that we can include in the analysis, even our results should still be interpreted with caution when comparing country rankings.

[40] *2018 International Broadband Data Report*, 33 FCC Rcd at 980-81, paras. 5-6, Appx. C, paras. 7-13.

[41] A hedonic regression provides an empirical summary of how prices vary with the characteristics of a good and is a standard technique used to adjust prices for differences in quality in price indexes. U.S. Department of Labor, Bureau of Labor Statistics, *Consumer Price Index, Quality Adjustment in the CPI* (Nov. 20, 2017), https://www.bls.gov/cpi/quality-adjustment/home.htm.

[42] In a standard hedonic broadband pricing analysis, a country fixed effect would be included to account for country-level differences in cost and demand factors. However, since the country fixed effect is used to predict prices from the model, these cost and demand differences remain in the predicted price levels. Our approach differs by decomposing the fixed effect into observable cost components and an unobserved random effect to remove the effect of exogenous country-level observable cost and demand differences from predicted prices. *See infra* paras. 28-32.

[43] All plan characteristics of the standardized plans we generate to predict prices have the exact same characteristics (other than download speed) in order to make prices comparable across countries. These features of the standardized plans are as follows: no contract, no phone service, and an unlimited data usage allowance.

broadband plan characteristics across countries (e.g., speed and data usage limits), as well as differences in market cost and demand conditions (e.g., population density and income).

A. Fixed Broadband Price Index

11. To compare broadband pricing across countries, we need an estimate of "the price" of broadband in each country. Our approach is to follow well-established practices in the price index literature. Price indexes calculate measures of price changes for goods and services by comparing the prices in a base period to those in a comparison period. One such index is the U.S. CPI, calculated by the Bureau of Labor Statistics of the U.S. Department of Labor.[44] While the CPI involves measuring price changes across time periods, our application to price changes across countries is analogous, with the two periods now corresponding to two different countries.

12. Our goal is to calculate the following Laspeyres broadband price index,[45] where $p_{j,t}$ represents the price of product j in comparison country t, $p_{j,0}$ is the price of product j in the base country and $q_{j,0}$ is the market share of product j in the base country. The index is therefore the ratio of the weighted average price of all of the j broadband products sold in the comparison country to the weighted average price of these same products in the base country, where the weights are the percentage of broadband consumers who choose each product in the base country.[46]

$$L(p) = \frac{\sum_{j=1}^{N} p_{j,t} q_{j,0}}{\sum_{j=1}^{N} p_{j,0} q_{j,0}}$$

13. Ideally, the price index would be calculated over every broadband plan offered in every country. However, there are at least two difficulties in doing so. First, we would need to know the number of households that subscribe to each base country plan, and we do not have these data. Second, the broadband products available in each country are not the same. Even if we had such quantity weights for the base country, they would not be applicable in the comparison countries. To deal with these issues, we classify all available broadband plans into $j = 6$ products based on download speed categories for which we have information on the U.S. broadband product shares.[47] We define three standalone products

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[44] U.S. Department of Labor, Bureau of Labor Statistics, *Consumer Price Index Frequently Asked Questions (FAQs)* (Jan. 15, 2019), https://www.bls.gov/cpi/questions-and-answers.htm.

[45] The Laspeyres price index yields an upper bound for the average compensating variation from a price change. Compensating variation measures the dollar amount by which a given consumer would need to have their income adjusted to obtain the same level of utility, or well-being, under the comparison prices and product choice set. *See* Ariel Pakes, *A Reconsideration of Hedonic Price Indexes with an Application to PCs*, 93 American Economic Review 1578-96 (2003).

[46] The United States is used as the base country for several reasons. First, the focus of this *Report* is to evaluate how the prices of broadband products purchased in the United States compare to those of other countries. Second, we have better estimates of the subscriber quantity weights for the United States than for any other country. Finally, this index ensures that U.S. broadband consumers would be at least as well-off as in higher ranked countries by measuring the dollar amount that U.S. broadband subscribers would need to have added or subtracted from their incomes to purchase the same basket of broadband services under the pricing structures in the other countries.

[47] Aggregating products in this manner is common in the differentiated products demand model literature. *See* Steven Berry, James Levinsohn, and Ariel Pakes, *Automobile Prices in Market Equilibrium*, 63 Econometrica 841 (1995), http://people.stern.nyu.edu/wgreene/Econometrics/BLP.pdf; Aviv Nevo, *Measuring Market Power in the Ready-to-Eat Cereal Industry*, 69 Econometrica 307 (2001), https://economia.uniandes.edu.co/files/profesores/jorge_tovar/docs/Seminario%20de%20Tesis%20PEG/apuntes%20de%20clase/Nevo_2001_Measuring_Mkt_Pwr_Econometrica.pdf; Austan Goolsbee and Amil Petrin, *The Consumer* (continued….)

classified by the following download speed tiers: less than 25 Mbps; at least 25 Mbps but less than 100 Mbps; and at least 100 Mbps but no more than 1000 Mbps.[48] We also define three additional products when these speed tiers are purchased in a bundle with video service.

14. *Fixed Product Shares.* To calculate the U.S. quantity weights for each of the six products in our price indexes, we use the FCC Form 477 data[49] to estimate the share of U.S. households that subscribe to each of the three broadband speed tiers and an estimate from *S&P Global* that about 65% of all U.S. broadband households purchase their service in a bundle.[50] The resulting broadband products and their estimated U.S. market shares are shown in Figure G-23 below.

Fig. G-23: Fixed Broadband Product Shares

Product	Download Speed Tier	Bundle Share	Speed Tier Share	Product Share	Plans
1	**Standalone: 0 < Mbps < 25**	34.69%	28.95%	10.04%	67
2	**Standalone: 25 ≤ Mbps < 100**	34.69%	31.58%	10.96%	105
3	**Standalone: 100 ≤ Mbps ≤ 1000**	34.69%	39.47%	13.69%	253
4	**Bundle: 0 < Mbps < 25**	65.31%	28.95%	18.90%	77
5	**Bundle: 25 ≤ Mbps < 100**	65.31%	31.58%	20.62%	133
6	**Bundle: 100 ≤ Mbps ≤ 1000**	65.31%	39.47%	25.78%	319

Sources: *S&P Global*; Preliminary December 2019 FCC Form 477 data.

15. Calculating comparable prices for each of our six broadband products for each country is more difficult. We again follow the price-index literature in implementing two common approaches: a standard price index and hedonic analysis. The standard price index approach, discussed in section IV.B, calculates a price for each of the six products in a country by calculating the weighted average price of all plans that fall within that product category, and then constructs a Laspeyres price index using the U.S. product shares as weights.[51] To calculate the broadband price index, we first calculate simple unweighted average prices for each provider's offerings that fall into each of the six product categories. We then use the market share of each provider to calculate a country-level weighted average for each of the six broadband products from these provider-level prices.[52] Finally, we calculate an average broadband price

Gains from Direct Broadcast Satellites and the Competition with Cable TV, 72 Econometrica 351 (2004), https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1468-0262.2004.00494.x.

[48] The speed tier cutoffs were chosen to correspond to quantity data available in the FCC Form 477 broadband subscription data collection.

[49] FCC, *Form 477 Resources*, https://www.fcc.gov/economics-analytics/industry-analysis-division/form-477-resources (last visited Oct. 27, 2020). All FCC Form 477 data used in this *Report* have been certified as accurate by the filers. We note that the *Report*'s analysis may understate or overstate consumers' options for services to the extent that broadband providers fail to report data or misreport data. *See* FCC, *Explanation of Broadband Deployment Data*, https://www.fcc.gov/general/explanation-broadband-deployment-data (last visited Oct. 27, 2020) (describing quality and consistency checks performed on providers' submitted data and explaining any adjustments made to the FCC Form 477 data as filed).

[50] S&P Global, *Estimated broadband-only homes as a percentage of wireline broadband households, Q1'18 vs. Q1'19 vs. Q1'20* (last accessed July 21, 2020). We used preliminary December 2019 FCC Form 477 subscription data for these calculations. We again note that the year-end FCC Form 477 data are preliminary only and are subject to corrections as appropriate by the service provider, and the final data will be published in due course by the agency.

[51] *See infra* paras. 33-38, 45-47.

[52] If a provider does not offer any plans in the product category, that provider's market share is distributed proportionally to the providers that do offer plans in the product category (i.e., the logit assumption). If no providers (continued….)

for each country by weighting these six product level prices by the estimated percentage of consumers in the United States that subscribe to each product category. The hedonic analysis, discussed in section IV.A, extends this analysis by constructing a price index that accounts for missing product prices, quality differences within product categories, and differences in the broadband cost and demand structures in each country.

16. *Fixed Broadband Price Index Results*. In Figure G-24 below, we present country rankings based on the fixed broadband price index, as well as this index divided by the average monthly data usage per subscriber to calculate a unit price measured in dollar per gigabyte of data consumption ($/GB).[53] The United States ranks 21st out of 26 countries in standalone pricing but the ranking improves to 19th for broadband bundled with video service, due to more extensive bundle discounting.[54] Combining standalone and bundled pricing, the overall ranking of the United States is 21st out of 26. On a price per GB of data consumed basis, the United States ranks 3rd out of the 18 countries for which we have usage data. However, it may not be appropriate to divide the monthly price by average monthly data consumption. The problem with doing so is that data consumption affects broadband pricing, and broadband pricing also likely affects data consumption—in other words, data consumption is endogenous to price. For broadband services without usage allowances, the monthly subscription price should arguably not affect usage because the cost of additional data is zero once the access price is paid. The flaw in this reasoning is that consumers likely choose whether or not to adopt broadband based on their expected monthly data usage and how much they value that usage.[55] If prices were higher in a country, then we would expect that consumers with lower expected data usage would be less likely to subscribe to broadband. Conversely, in countries with lower prices, we would expect more low-usage consumers to subscribe. As a result, dividing price by usage may unfairly advantage countries with higher prices and disadvantage those with lower prices. To account for higher data usage that may result from better applications and content, in our hedonic analysis we control for content quality using a proxy measure that is less susceptible to this reverse causality issue.[56] This approach isolates the effect of content quality on prices and allows us to predict prices from the hedonic regression holding content quality fixed.

in the country offer the highest product, we assign the next highest available product price to the highest missing product price(s). If no providers in a country offer any plans in a product category, we assign the next closest available product price to the missing category prices. *See infra* para. 36.

[53] All reported prices for the broadband index are adjusted using a measure of PPP to make the results comparable to the income-adjusted hedonic index results. The figure presents the weighted average prices in each country for the indicated products. The Laspeyres index for each country would be calculated by dividing the given country's weighted price by the U.S. weighted price.

[54] To calculate the price of broadband for each bundle offering, we first calculate the bundle discount as the difference between the total price of the standalone offerings for each service and the bundle. We then assume that this bundle discount is allocated to each component of the bundle in proportion to the standalone costs of each component. In this manner, we remove the video component price from the broadband bundle price. We also note that the bundle and standalone pricing measures are not strictly comparable in Fig. G-24 because the plans that are included in each calculation may be different. For this reason, the bundle price in a country may be higher than the standalone price. *See infra* Fig. G-33.

[55] This is known as "selection bias" in the econometrics literature. *See* James J. Heckman, *Sample Selection Bias as a Specification Error*, 47 Econometrica 153 (1979).

[56] Access to a broad range of valuable applications and content over both fixed and mobile connections increases the value that each user derives from broadband service (i.e., content is a complement). To construct our measure of content quality, we perform a principal components factor analysis on the following four measures of content quality and availability: number of web pages in the country's primary domain(s), number of web sites in the top-level domain(s) (TLDs), the percentage of all web sites in the country's primary language, and English proficiency of the country. We then predict the first factor component based on the estimated factor loadings and use this as our measure of content quality. *See infra* paras. 64-65.

Fig. G-24: Fixed Broadband Price Indexes (PPP Adjusted)

Country	Standalone		Bundled		Overall		$/GB	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Australia	61.73	16	61.19	16	61.37	16	0.34	9
Austria	59.91	13	49.29	8	52.97	12	0.42	13
Belgium	50.90	9	50.18	11	50.43	10	0.34	11
Canada	69.93	23	67.39	22	68.27	22	0.35	12
Czech Republic	48.74	6	45.84	5	46.85	5	0.32	7
Denmark	48.53	5	48.53	6	48.53	6	0.22	4
Estonia	68.01	20	64.23	20	65.54	20		
Finland	38.68	2	37.53	2	37.93	2		
France	38.76	3	38.76	3	38.76	3		
Germany	49.21	7	48.82	7	48.95	7	0.42	14
Greece	67.31	19	62.01	17	63.85	18	0.71	17
Iceland	72.82	24	72.82	24	72.82	24	0.27	5
Ireland	51.11	10	50.78	12	50.89	11	0.98	18
Italy	44.02	4	44.02	4	44.02	4	0.34	10
Latvia	35.34	1	33.10	1	33.88	1	0.15	1
Luxembourg	72.92	25	72.92	25	72.92	25		
Mexico	69.87	22	69.87	23	69.87	23		
Netherlands	63.57	17	63.57	18	63.57	17		
New Zealand	59.95	14	59.95	14	59.95	14	0.34	8
Norway	84.50	26	74.51	26	77.98	26		
Portugal	56.03	12	53.80	13	54.57	13	0.43	15
Spain	64.66	18	64.66	21	64.66	19	0.46	16
Sweden	51.28	11	49.90	10	50.38	9		
Switzerland	60.05	15	60.05	15	60.05	15	0.32	6
United Kingdom	49.74	8	49.74	9	49.74	8	0.16	2
United States	**68.74**	**21**	**64.23**	**19**	**65.80**	**21**	**0.19**	**3**

Sources: International Telecommunications Union (ITU), *World Telecommunications/ICT Indicators Database 2020* (24th Edition/July 2020) (last accessed Aug. 19, 2020); TeleGeography, *GlobalComms Database* (last visited Oct. 27, 2020); OpenVault, *Broadband Industry Report—4Q 2019*, Quarterly Advisories (Feb. 11, 2020), https://openvault.com/ovbi-median-broadband-usage-on-pace-to-surpass-250-gb-per-month-in-2020/.

Note: To make the results comparable to the income-adjusted hedonic analysis, prices are reported in purchasing power parity (PPP) adjusted U.S. dollars.

B. Fixed Broadband Hedonic Price Index

17. We estimate four hedonic regression models and then construct hedonic price indexes from each model. Our hedonic regression is a multilevel random coefficients model that allows the coefficients on some of the broadband plan characteristics (e.g., download speeds) to vary by broadband provider.[57] From the regression model, the hedonic index is constructed by predicting provider-specific

[57] *See infra* paras. 59-64.

prices for each of our six standardized broadband products based on each provider's estimated coefficients. While the details of the hedonic modeling are contained in section IV.A, we summarize the basic approach here. The first model regresses the logarithm of broadband plan price on the plan characteristics to account for how plan characteristics explain differences in plan prices across countries. The second model builds upon the first by adding income per capita, a measure of terrain ruggedness, population density, and educational attainment into the model to capture how country-level differences in these broadband demand and cost factors influence observed pricing.[58] The third model adds the percentage of households in the country that have access to speeds of at least 100 Mbps as a measure of network quality and investment.[59] The final model adds our proxy measure for content availability and quality.

18. To calculate the hedonic price index, we predict provider-specific prices from the estimated hedonic regression for six standardized broadband plans. For these price predictions, we set the income per capita, terrain ruggedness, population density, education, and content quality variables at the U.S. values, and use the estimated provider-specific coefficients on product characteristics to predict prices. This procedure effectively estimates what each provider's price would be for each of the six standardized broadband products in each country if income per capita, terrain, population density, education, and content quality were at U.S. levels.[60] We then aggregate these provider-specific price predictions for each of the six products using U.S. product share weights and the previously described Laspeyres price index formula, to arrive at the price that U.S. consumers would have to pay in each country for their broadband services if those countries had U.S. broadband cost and demand conditions.

19. *Fixed Hedonic Price Index Results*. The estimated coefficients for the four fixed broadband hedonic models are shown in Figure G-25 below.[61] Before reviewing the estimates, we first note that the estimated coefficients in our models are reduced form estimates of how prices are correlated with product characteristics and country-level factors, so they should not be given a causal interpretation for how we would expect price to change if, for example, the income level of a country increased. Despite this issue, the coefficients generally align with expectations and are often statistically significant. The model estimates that higher speed plans cost more and the rate of increase in price (i.e., slope) is higher for plans at a higher speed tier.[62] Bundling broadband with other services is estimated to lower the price of the broadband service by approximately 4.7% on average across all countries.[63] A 1% higher

[58] Our measure of terrain in each country is the population weighted terrain ruggedness index calculated in Nathan Nunn and Diego Puga, *Ruggedness: The Blessing of Bad Geography in Africa*, 94 Review of Economics and Statistics 20-36 (2012). *See infra* Section IV.

[59] We do not control for observed broadband performance characteristics in each country (e.g., actual download and upload speeds, latency, etc.) because the general practice of pricing fixed broadband access by speed tier would influence these observed network performance measures. Lower prices for higher speed tiers would tend to increase measured download speed and vice-versa. This would create an endogeneity problem in the regression and bias the estimated coefficients. Network deployment measures are less susceptible to this issue because such measures are not directly affected by broadband pricing.

[60] We predict prices from the hedonic regression for broadband plans at the following download speeds for both standalone and bundled plans: 25 Mbps, 100 Mbps, and 1000 Mbps. All other plan characteristics are the same in order to make prices comparable across countries. The other features of the plans used to predict prices are as follows: no contract, no phone service, and an unlimited data usage allowance.

[61] The estimated random coefficient variances are provided in Fig. G-36.

[62] The effect of download speeds on broadband prices is estimated as a piecewise linear spline with three download speed cutoffs. A linear spline allows the estimated coefficients to be different between for the range of download speeds between each cutoff. For example, our estimated coefficients imply that price of fixed broadband increases more steeply for plans with download speeds above 100 Mbps compared to those below 25 Mbps.

[63] When a dependent variable is measured in log form, the percentage change in the dependent variable for a change (continued….)

data usage allowance is estimated to increase price by about 0.1% in all models. For the country-level control variables, we find that the per capita income in a country has a large and statistically significant effect on prices. Both the population density and educational attainment variables are statistically insignificant. However, our other broadband cost proxy variable, terrain ruggedness, has a large and statistically significant effect on fixed broadband prices. In Model 4, we estimate that a 1% increase in terrain ruggedness increases broadband prices by nearly 0.2%, and this is statistically significant at the 1% level. Finally, as observed in Model 4, the proxy variable for content availability and quality also has a strong positive effect on broadband prices, and this is also significant at the 1% level.

in a dummy variable from 0 to 1, or a logged continuous independent variable, is calculated as $100[\exp(\beta) - 1]$. A dummy, or indicator, variable refers to a binary variable that can take only the values 0 and 1. *See, e.g.*, James H. Stock & Mark W. Watson, Introduction to Econometrics 145 (4th ed. 2019).

Fig. G-25: Fixed Broadband Hedonic Regressions

Log Average Monthly Price (USD)	Model 1			Model 2			Model 3			Model 4		
	Coef.	SE	p	Coef.	SE	p	Coef.	SE	p	Coef.	SE	p
Spline: 0 < Mbps < 50	0.068	0.018	0.000	0.072	0.018	0.000	0.071	0.018	0.000	0.071	0.018	0.000
Spline: 50 ≤ Mbps < 100	0.122	0.038	0.002	0.118	0.038	0.002	0.118	0.038	0.002	0.123	0.038	0.001
Spline: 100 ≤ Mbps ≤ 1000	0.196	0.022	0.000	0.192	0.022	0.000	0.192	0.022	0.000	0.193	0.022	0.000
Bundle Dummy	-0.047	0.013	0.000	-0.047	0.013	0.000	-0.047	0.013	0.000	-0.047	0.013	0.000
Fixed Voice Dummy	-0.012	0.040	0.762	-0.006	0.040	0.880	-0.003	0.040	0.933	0.000	0.040	0.999
Log Contract Length	-0.033	0.017	0.055	-0.034	0.017	0.041	-0.032	0.017	0.058	-0.033	0.017	0.051
Unlimited Data Dummy	-0.096	0.070	0.172	-0.087	0.070	0.215	-0.087	0.070	0.212	-0.081	0.070	0.248
Log Data Cap Allowance	0.110	0.023	0.000	0.104	0.023	0.000	0.105	0.023	0.000	0.103	0.023	0.000
Log GNI Per Capita				0.426	0.109	0.000	0.410	0.113	0.000	0.318	0.101	0.002
Log Non-Rural Population Density				-0.033	0.049	0.501	-0.029	0.049	0.560	-0.001	0.043	0.974
Educational Attainment				1.173	0.884	0.184	1.066	0.896	0.234	0.568	0.777	0.465
Log Terrain Ruggedness Weighted by Population				0.113	0.062	0.067	0.121	0.063	0.054	0.174	0.056	0.002
Coverage (% Households with > 100 Mbps)							0.135	0.226	0.550	0.218	0.192	0.257
Content Quality (1st Principal Component) (Standardized)										0.134	0.044	0.002
Constant	2.678	0.145	0.000	-1.902	1.030	0.065	-1.822	1.043	0.081	-0.859	0.944	0.363
Number of Observations	954			954			954			954		
Log Likelihood	82.4			94.1			94.3			98.1		
Likelihood Ratio Test vs. Linear Model												
P-Value	0.000			0.000			0.000			0.000		

Note: The estimated random coefficient variances and measures of goodness of fit are provided in Fig. G-36 of this appendix.

20. The resulting country rankings under each model are shown in Figure G-26 below. This figure reports the overall rankings that aggregate over the three standalone and three bundled products in each country. In Model 1, after adjusting for only broadband plan characteristics, we find that the United States ranks 19th out of the 26 countries in our sample, with an average broadband price of $65.54. Countries with lower average incomes like Latvia, the Czech Republic, and Estonia rank near the top before we correct the price levels for per capita income. In Model 2, after we correct price levels for differences in income, terrain, education, and population density, we find that the United States ranks 12th. The change in ranking from the first model is due to the United States having relatively high income and educational levels and more rugged terrain compared to the other countries in our sample.[64] Model 3 includes the percentage of households with access to broadband connection speeds of at least 100 Mbps, and the U.S. ranking remains at 12th. Model 4 adds our content quality proxy variable into the hedonic regression and results in the United States ranking 2nd least expensive out of the 26 countries.

Fig. G-26: Fixed Broadband Hedonic Price Indexes

Country	Model 1		Model 2		Model 3		Model 4	
	Price	Rank	Price	Rank	Price	Rank	Price	Rank
Australia	87.41	25	101.53	25	105.94	25	125.38	23
Austria	59.28	16	73.73	18	74.23	18	90.85	18
Belgium	57.69	13	68.48	14	68.13	14	96.74	20
Canada	65.76	20	78.88	22	79.03	20	86.59	13
Czech Republic	31.87	2	55.78	5	56.50	5	71.81	6
Denmark	50.11	11	58.58	7	58.49	6	81.38	8
Estonia	48.02	8	78.44	21	80.57	21	119.62	22
Finland	47.25	7	56.12	6	58.94	7	88.99	14
France	35.29	4	48.75	2	50.22	3	69.51	4
Germany	49.65	10	62.78	11	63.48	11	84.39	10
Greece	58.51	15	90.20	23	98.14	24	129.93	24
Iceland	68.67	22	61.78	9	63.35	10	89.74	16
Ireland	64.37	18	69.70	15	72.63	16	81.93	9
Italy	33.06	3	49.80	3	52.34	4	69.76	5
Latvia	17.88	1	36.74	1	36.24	1	51.58	1
Luxembourg	76.36	24	67.97	13	67.47	13	96.11	19
Mexico	46.12	6	122.31	26	120.94	26	142.07	26
Netherlands	61.48	17	91.12	24	91.41	23	132.63	25
New Zealand	67.46	21	74.98	19	76.51	19	86.24	12
Norway	89.96	26	72.66	17	73.32	17	101.99	21
Portugal	38.13	5	62.61	10	61.71	9	75.41	7
Spain	49.30	9	70.76	16	68.96	15	89.36	15
Sweden	53.47	12	59.71	8	60.40	8	85.32	11
Switzerland	69.44	23	50.33	4	49.79	2	68.02	3
United Kingdom	58.48	14	77.67	20	81.63	22	90.16	17
United States	**65.54**	**19**	**65.48**	**12**	**65.63**	**12**	**65.61**	**2**

[64] *See infra* Fig. G-43.

III. MOBILE BROADBAND PRICING ANALYSIS

21. The issues confronted when comparing mobile broadband pricing across countries are similar to those encountered in our fixed broadband pricing analysis with two exceptions. First, mobile plans are generally sold by data usage allowances instead of download speed, so we classify mobile products by data allowance rather than download speed. Second, the most prevalent form of bundling in mobile broadband involves the number of lines on a given plan rather than bundling mobile broadband with other telecommunications services. Cisco estimates that 79% of U.S. subscribers obtain their mobile service through multi-line data plans (i.e., "family plans").[65] These bundled plans are offered at greatly discounted rates and need to be properly accounted for to reflect the prices that U.S. consumers actually pay for their mobile services. As in our fixed analysis, for mobile broadband we also define three single-line products, which are classified by the following data usage limits: less than or equal to 5GB per line; greater than 5GB but less than or equal to 20GB per line; greater than 20GB per line. We also define three additional multi-line products when these products are bundled with additional lines.

A. Mobile Broadband Price Index

22. In this section, we compare mobile broadband prices by calculating a mobile broadband price index using the same Laspeyres formula and price index construction methodology we used for fixed broadband.[66]

23. *Mobile Product Shares.* To construct our mobile price indexes, we need to estimate the percentage of U.S. consumers who subscribe to each of our six mobile products defined by data usage allowance and number of lines. To estimate these product shares, we assume that consumers choose the optimal amount of data given their expected usage. We use Cisco data coupled with an assumption on the shape of the usage distribution to estimate the percentage of U.S. consumers who would find each usage allowance optimal.[67] Based on the estimated log-normal distribution,[68] in Figure G-27 below, we calculate the product shares for each of our six standardized mobile products. The column "Data Usage (Per Line) Share" provides the estimated percentage of all subscribers from the estimated log-normal distribution that consume an amount of data within the corresponding ranges of data usage and number of lines on the plan. For example, 38% of all single-line plans in the United States are estimated to consume between 0 and 5 GB of data per line (product 1), while 50% of multi-line plans would be expected to consume this amount of data per line (product 4).[69] We then multiply these estimated single-line and

[65] *See* Cisco, *Annual Internet Report (2018-2023) White Paper*, Fig. 17 (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html. We are treating the share of "shared data" plans as equivalent to the share of "multi-line" plans in the United States.

[66] We again calculate a Laspeyres price index that estimates how much consumers in the United States would pay for their mobile broadband plans in each of the comparison countries. The formula is identical to that used for fixed broadband. *See supra* paras. 12-15.

[67] *See infra* Section IV and Cisco, *Annual Internet Report (2018-2023) White Paper*, Fig. 17 (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html.

[68] *See infra* Fig. G-31 for the estimated log-normal parameters and distribution.

[69] We use the terms "shared plan," "multi-line plan," and "family plan" interchangeably in this report. However, some multi-line plans may have shared data among the lines, but some other multi-line plans have separate data allowances for each line. We do not distinguish between shared data and separate data allowances for multi-line plans.

multi-line data usage shares by the percentage of all U.S. plans that are single versus multi-line to arrive at our final mobile product shares.[70]

Fig. G-27: Mobile Broadband Product Shares

Product	Lines	Data Allowance (Per Line) Tier	Bundling Shares	Data Usage (Per Line) Share	Product Share	Plans
1	**1**	**0 < GB ≤ 5**	21.0%	38.0%	8.0%	101
2	**1**	**5 < GB ≤ 20**	21.0%	44.0%	9.2%	122
3	**1**	**GB > 20**	21.0%	18.0%	3.8%	182
4	**2**	**0 < GB ≤ 5**	79.0%	50.0%	39.5%	113
5	**2**	**5 < GB ≤ 20**	79.0%	39.0%	30.8%	124
6	**3**	**GB > 20**	79.0%	11.0%	8.7%	169

Sources: Cisco, *Annual Internet Report (2018-2023) White Paper*, Fig. 17 (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html.

24. *Mobile Broadband Price Index Results*. In Figure G-28 below, we present the country rankings based on the Laspeyres broadband price index formula. We present an index for single-line plans, another for multi-line plans, and an overall index that is a weighted average of the single- and multi-line plan indexes.[71] The United States ranks 22nd out of the 26 countries in single-line plan pricing at $70.22, and is in the 21st place for multi-line pricing at $47.70 per line. Iceland ranks 1st in single-line plan pricing and multi-line pricing, at $26.52 per line per month and $23.63 per line per month, respectively. Combining single-line and multi-line data plan pricing, the overall ranking of the United States is 21st. Finally, due to the relatively high data usage of U.S. subscribers, on a dollar per GB basis, the U.S. ranking improves substantially to 15th place.[72]

[70] For multi-line plans, we assume that the number of lines increases with the data usage allowance. We assume plans with over 20 GB of data have three lines on average while those below 20 GB have two lines.

[71] The product prices by country that were used in the mobile broadband price index calculations are presented in Fig. G-40 of section IV.F and adjusted using a measure of PPP.

[72] The same caveat given in the fixed analysis regarding the potential problems with dividing price by data usage also applies to mobile, although now the plans are sold by usage allowances so the endogeneity problem may be even more severe.

Fig. G-28: Mobile Broadband Price Indexes (PPP Adjusted)

Country	Single-Line		Multi-Line		Overall		$/GB	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Australia	33.11	8	31.67	9	31.97	10	9.43	14
Austria	30.43	5	27.73	6	28.30	6	1.73	2
Belgium	37.04	12	34.07	11	34.70	11	17.26	21
Canada	87.96	26	81.64	25	82.97	26	33.73	25
Czech Republic	69.70	21	64.25	23	65.39	23	19.29	22
Denmark	28.31	2	24.26	2	25.11	2	3.29	6
Estonia	33.51	9	25.37	3	27.08	3	2.76	3
Finland	31.97	7	31.97	10	31.97	9	1.65	1
France	29.76	3	27.58	5	28.04	5	4.97	8
Germany	49.25	20	37.73	16	40.15	17	15.74	20
Greece	76.12	24	66.08	24	68.19	24	44.57	26
Iceland	26.52	1	23.63	1	24.24	1	3.11	5
Ireland	36.57	11	36.57	14	36.57	14	5.40	9
Italy	44.52	18	44.52	20	44.52	20	10.43	16
Latvia	37.24	13	35.37	13	35.76	12	2.80	4
Luxembourg	30.77	6	26.31	4	27.25	4	6.83	10
Mexico	71.99	23	61.46	22	63.67	22	30.18	23
Netherlands	39.12	14	37.15	15	37.57	15	14.56	17
New Zealand	40.10	15	35.33	12	36.33	13	15.01	19
Norway	42.97	16	38.82	17	39.69	16	8.20	12
Portugal	83.92	25	82.69	26	82.95	25	31.42	24
Spain	47.23	19	39.87	18	41.42	18	14.64	18
Sweden	35.46	10	28.60	8	30.04	8	4.10	7
Switzerland	44.21	17	41.70	19	42.23	19	6.93	11
United Kingdom	29.79	4	27.97	7	28.36	7	8.44	13
United States	**70.22**	**22**	**47.70**	**21**	**52.43**	**21**	**9.73**	**15**

Note: To make the results comparable to the income-adjusted hedonic analysis, prices are reported in PPP adjusted U.S. dollars.

B. Mobile Hedonic Price Index

25. The mobile broadband price index in Figure G-28 does not account for several factors that likely affect the observed price levels in each country, so we again extend the analysis by estimating four hedonic regression models to adjust prices for country-level differences in cost and demographic factors, differences in mobile broadband product characteristics, and content quality. We then predict prices out of these hedonic models for a standardized set of mobile broadband products at the U.S. averages of the country-level control variables. This approach again seeks to estimate the mobile broadband prices that would be observed in each country if that country had the mobile broadband cost and demand characteristics of the United States.[73] To calculate our mobile hedonic price index, these

[73] We predict prices from the hedonic regression for mobile broadband plans at the following data allowances for both single-line and multi-line plans: 5 GB, 20 GB, and 50 GB per line. For the multi-line products, the 5 GB and 20 GB plans have two lines each and the 50 GB plan has three lines. Both the single-line and three-line 50 GB plan (continued….)

predicted prices are then weighted in the same manner that we used to calculate the fixed hedonic price index.

26. The estimated coefficients for the four mobile broadband hedonic models are shown in Figure G-29 below.[74] The four models presented in this section mirror the models in our fixed pricing analysis with the exception that the network quality variables now include measures of both network coverage and average download speeds.[75] As expected, the regression coefficients imply that higher data usage allowances increase the expected price per line of a mobile broadband plan, while adding more lines to the plan is expected to lower the average price per line. Increasing the number of minutes on a plan by 1% is expected to raise the expected price per line by approximately 0.17%, while increasing the contract duration by a month would be expected to lower the price per line by about 0.14% across all four models. For mobile broadband, the estimated effects of the country-level variables on broadband prices differ from the patterns we observed in our fixed hedonic analysis. Surprisingly, the estimated effect of income on mobile broadband prices is negative, but this result is not statistically significant in any specification. However, educational attainment, a measure closely related to income, is found to increase expected mobile broadband prices, and this result is significant at the 5% level in Models 3 and 4. The estimated impact of our two cost proxy variables (terrain variability and population density) are similar to our findings for fixed broadband. Population density is again found to have weak and statistically insignificant effects on mobile broadband prices, while greater terrain variation in a country has a statistically significant positive effect on mobile broadband prices. As we would expect, higher network quality is associated with higher prices; however, only the 4G availability measure is statistically significant. Finally, in Model 4 we again find that our measure of content quality has a positive and statistically significant effect on mobile broadband prices, implying that consumers are willing to pay higher mobile broadband prices when they have access to higher quality and more diverse broadband content.

are set to unlimited data without throttling. The other plan features for the price predictions are as follows: no contract, unlimited minutes, and unlimited texts.

[74] The estimated random coefficient variances and measures of goodness of fit are provided in Fig. G-41 of section IV.F.

[75] Mobile plans are not generally sold by speed, so the endogeneity issues regarding the inclusion of observed network performance measures are less of a concern in mobile than fixed broadband pricing analysis.

Fig. G-29: Mobile Broadband Hedonic Regressions

Log Average Monthly Price Per Line (USD)	Model 1			Model 2			Model 3			Model 4		
	Coef.	SE	P	Coef.	SE	p	Coef.	SE	p	Coef.	SE	p
Spline: 0 < GB ≤ 5	0.185	0.025	0.000	0.185	0.025	0.000	0.184	0.025	0.000	0.182	0.025	0.000
Spline: 5 < GB ≤ 20	0.251	0.022	0.000	0.251	0.022	0.000	0.252	0.022	0.000	0.252	0.022	0.000
Spline: 20 < GB	0.218	0.036	0.000	0.218	0.036	0.000	0.219	0.036	0.000	0.218	0.036	0.000
Number of Lines	-0.032	0.006	0.000	-0.032	0.006	0.000	-0.032	0.006	0.000	-0.032	0.006	0.000
Unlimited Data Dummy	0.122	0.016	0.000	0.122	0.016	0.000	0.122	0.016	0.000	0.122	0.016	0.000
Log Contract Length	-0.140	0.034	0.000	-0.145	0.035	0.000	-0.141	0.035	0.000	-0.138	0.034	0.000
Unlimited Minutes Dummy	-0.453	0.091	0.000	-0.453	0.091	0.000	-0.450	0.091	0.000	-0.449	0.091	0.000
Log Minutes	0.170	0.022	0.000	0.170	0.022	0.000	0.169	0.022	0.000	0.169	0.022	0.000
Unlimited Text Messages Dummy	0.022	0.087	0.798	0.028	0.087	0.748	0.021	0.087	0.810	0.018	0.087	0.835
Log Text Messages	-0.070	0.016	0.000	-0.069	0.016	0.000	-0.069	0.016	0.000	-0.069	0.016	0.000
Throttle Dummy	-0.235	0.028	0.000	-0.235	0.028	0.000	-0.236	0.028	0.000	-0.235	0.028	0.000
Log GNI Per Capita				-0.090	0.226	0.689	-0.219	0.236	0.354	-0.345	0.230	0.133
Log Country Population Density				0.012	0.067	0.858	-0.012	0.064	0.852	0.031	0.063	0.623
Educational Attainment				3.318	1.792	0.064	4.452	1.765	0.012	3.721	1.672	0.026
Log Terrain Ruggedness Weighted by Population				0.230	0.126	0.067	0.277	0.119	0.020	0.319	0.113	0.005
4G Availability							2.557	1.212	0.035	2.231	1.133	0.049
Download Speed							0.001	0.003	0.748	0.002	0.003	0.430
Content Quality (1st Principal Component) (Standardized)										0.194	0.101	0.054
Constant	2.355	0.163	0.000	2.405	2.156	0.265	1.244	2.150	0.563	2.802	2.161	0.195
Number of Observations	1639			1639			1639			1639		
Log Likelihood	708.4			711.0			713.0			714.7		
Likelihood Ratio Test vs. Linear Model												
P-Value	0.000			0.000			0.000			0.000		

Note: The estimated random coefficient variances and measures of goodness of fit are provided in Fig. G-41 of this appendix.

27. *Mobile Hedonic Price Index Results.* Our hedonic price indexes based on the four estimated hedonic regressions are provided in Figure G-30. For mobile broadband service, adjusting for cost and demographic factors does not have as large of an impact on the U.S. ranking as we observed for fixed broadband service. In Model 1, before adjusting for income, terrain, educational attainment, and population density factors, the United States ranks 24th among the 26 countries in mobile broadband pricing. Correcting for these factors in Model 2 changes the U.S. ranking to 22nd. Adding the network performance measures in Model 3 improves the U.S. ranking to 17th. And finally, the United States ranks 7th in mobile broadband pricing after adding the content quality proxy measure in Model 4.

Fig. G-30: Mobile Broadband Hedonic Price Indexes

Country	Model 1		Model 2		Model 3		Model 4	
	Price	Rank	Price	Rank	Price	Rank	Price	Rank
Australia	29.96	10	38.17	15	43.02	11	62.78	12
Austria	26.50	8	36.15	13	51.42	15	75.21	15
Belgium	34.79	13	31.09	9	35.30	5	59.61	8
Canada	69.23	25	78.95	25	81.06	24	100.36	22
Czech Republic	38.59	15	45.97	18	55.78	18	81.21	17
Denmark	24.05	6	30.30	8	39.13	7	61.42	10
Estonia	18.07	1	19.82	1	26.19	1	45.54	2
Finland	22.70	5	25.75	4	29.61	2	54.83	6
France	26.58	9	36.53	14	52.83	16	77.66	16
Germany	46.18	18	54.38	21	78.64	23	115.21	24
Greece	138.24	26	114.81	26	138.31	26	204.90	26
Iceland	31.23	12	24.61	3	51.41	14	83.35	19
Ireland	22.29	4	21.21	2	39.68	9	49.59	3
Italy	21.52	2	29.09	6	41.28	10	62.31	11
Latvia	22.18	3	29.94	7	39.52	8	63.95	14
Luxembourg	49.64	20	42.61	16	62.80	20	96.90	21
Mexico	46.36	19	59.11	23	78.13	22	110.74	23
Netherlands	44.96	17	69.46	24	82.01	25	126.39	25
New Zealand	36.34	14	34.22	12	47.43	12	53.57	4
Norway	52.22	22	46.78	19	48.06	13	82.77	18
Portugal	50.70	21	52.52	20	65.61	21	90.79	20
Spain	24.44	7	26.31	5	30.52	3	44.77	1
Sweden	30.55	11	33.45	11	36.00	6	59.75	9
Switzerland	54.29	23	32.87	10	33.85	4	53.61	5
United Kingdom	40.99	16	43.72	17	56.24	19	63.04	13
United States	**55.65**	**24**	**55.65**	**22**	**55.70**	**17**	**55.88**	**7**

IV. DATA AND METHODOLOGY

A. Hedonic Model

28. While the classic hedonic framework involves adjusting for changing product quality over time, accounting for product quality differences across firms and countries is analogous. In the

equation below, we present a standard linear hedonic regression of prices on product characteristics.[76] The dependent variable, $\ln(P_{ik})$, is the logarithm of the price of plan *i* in country *k*, X_i is a vector of plan characteristics, and ε_{ik} is a scalar idiosyncratic error term. Under this approach, the country specific intercepts, α_k, estimate the differences in the average quality-adjusted price levels across countries. This framework has been widely used in making temporal and spatial price comparisons; however, it is not ideal for cross-country broadband pricing comparisons because it assumes that coefficients on product characteristics (the slope parameters β) are the same for each country.[77] While it is plausible that the supply and demand conditions that generate the β coefficients could be similar in adjacent time periods, or even cities, within the same country, it is highly unlikely that these conditions are similar across countries. If broadband cost structures, determinants of demand (e.g. demographics), product offerings, ownership structures, regulatory conditions, subsidies, or other conditions that impact prices vary across countries, then we would expect the slope parameters to reflect these differences.

$$\ln(P_{ik}) = \alpha_k + X_i\beta + \varepsilon_{ik}$$

29. We estimate a more flexible model that allows the slope coefficients for certain characteristics to differ across providers. However, due to sample size limitations in our pricing data, we do not estimate all of the *j* possible slope parameters for each product characteristic at the provider level but rather use multilevel modeling techniques similar to those recently proposed in broadband price hedonic work at the OECD.[78] The multilevel model recognizes that plans are nested within providers which are nested within countries and that prices are likely correlated within these nests. Rather than estimating separate parameters for each provider and product characteristic, the model assumes normally distributed zero-mean random coefficients on some product characteristics at the provider level and then estimates the variance of each random coefficient. The model is therefore more parsimonious because it estimates a single unknown variance parameter for each product characteristic rather than a separate slope parameter for each provider by product characteristic combination. Our base multilevel hedonic pricing equation (Model 1 in Figures G-25 and G-29 above) is as follows.

30. To explain why prices may differ across countries, we also include some exogenous supply and demand shifters into the model that we expect to explain why broadband quality-adjusted price levels may differ by country. In the standard model, these factors are absorbed in the country fixed effect, so instead of including this fixed effect we parametrize the more traditional country effect as a random effect plus country-level supply and demand factors that we expect to be correlated with average price levels. This allows us to remove the effect of these country-level supply and demand conditions when predicting prices rather than having them remain in the price predictions as they would in a fixed effect specification.

$$\ln(P_{ijk}) = X_i\beta + Z_k\gamma + \tilde{X}_i\tilde{\beta}_j + \mu_j + \nu_k + \varepsilon_{ijk}, \text{ where}$$

- P_{ijk} is the price for plan *i*, offered by provider *j*, in country *k*;

[76] *See* Zvi Griliches, *Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change*, National Bureau of Economic Research (NBER) (1961), https://www.nber.org/system/files/chapters/c6492/c6492.pdf.

[77] *See* W. Erwin Diewert et al., *Hedonic Imputation versus Time Dummy Hedonic Indexes in Price Index Concepts and Measurement*, NBER (Dec. 2009), https://www.nber.org/system/files/chapters/c5073/c5073.pdf.

[78] *See* Carol Corrado and Olga Ukhaneva, *Hedonic Prices for Fixed Broadband Services: Estimation Across OECD Countries* (Oct. 20, 2016), https://www.oecd-ilibrary.org/science-and-technology/hedonic-prices-for-fixed-broadband-services_5jlpl4sgc9hj-en;jsessionid=yPSoFOaGChbj-Yk8Cf8ZedL3.ip-10-240-5-72. These models are also called "random effects models," "hierarchical linear models," and "mixed models."

- X_i is a vector of plan characteristic variables;[79]
- β is a vector of unknown fixed coefficients;
- Z_k is a vector of country characteristics (e.g., measures of income and population density) for the country in which the given plan is offered;
- γ is a vector of unknown, fixed coefficients for the country characteristics;
- $\tilde{X}_i$ is a subset of the variables in X_i for which the coefficients will be treated as random realizations for each provider in each country;
- $\tilde{\beta}_j$ is a vector of random coefficients for the variables included in $\tilde{X}_i$. These random coefficients apply to all plans of provider *j*. We assume that $E[\tilde{\beta}] = 0, Cov[\tilde{\beta}, \varepsilon] = 0, and\ Var[\tilde{\beta}] = G$;[80]
- μ_j is a random coefficient applying to all plans offered by provider *j*;
- ν_k is a random coefficient applying to all plans offered in country *k*; and
- ε_{ijk} is an idiosyncratic error term.

31. The multilevel model is estimated by maximum likelihood estimation (MLE) as follows. In matrix form, the model can be written as:[81]

$$\ln(p) = X\beta + \tilde{X}\tilde{\beta} + Z\gamma + \varepsilon$$

32. The n × 1 vector of errors ε is assumed to be distributed mean zero multivariate normal with variance-covariance matrix $\sigma^2 I_n$. We also assume that $\tilde{\beta}$ is mean zero, orthogonal to ε, and has variance-covariance matrix G. This implies the following:

$$\text{Var}\begin{bmatrix}\beta \\ \varepsilon\end{bmatrix} = \begin{bmatrix}G & 0 \\ 0 & \sigma_\varepsilon^2 I_n\end{bmatrix}$$

33. Letting $u = \tilde{X}\tilde{\beta} + \varepsilon$ be the combined error term, we see that ln(p) is distributed multivariate normal with mean $X\beta + Z\gamma$ and the following variance-covariance matrix.

$$V = ZGZ' + \sigma_\varepsilon^2 I_n$$

[79] The plan characteristics included in X_i for fixed broadband are three splines of download speed, a dummy variable for whether the plan is bundled with video service, a dummy for whether fixed voice is included, the log of contract length (in months), a dummy variable for whether more than 2000 GB of data is included (i.e., unlimited data), and the log of the data usage allowance. For mobile broadband, they are three splines of data usage allowances, the number of lines, an unlimited data dummy, the log of contract length, an unlimited minutes dummy, the log of the number of minutes, an unlimited text messages dummy, the log of the number of text messages, and a dummy for whether the plan throttles speed. Since the inclusion of too many variables can result in the statistical problem of "overfitting" the data, we did not include all observed product characteristics in the model and limited the random coefficients to only those we determined were key product characteristics that likely had the greatest impact on consumer choices.

[80] The model does not estimate the random coefficients $\tilde{\beta}$, μ_j, or ν_k, but instead estimates the diagonal variance elements of the variance-covariance matrix G, known as the variance components. The off-diagonal covariances are assumed to be zero. When predicting prices for each provider, we use the best linear unbiased predictors (BLUPs) of the random coefficients based on the estimated variance components.

[81] In the matrix representation, the provider and country random effects are now included in the vector of random coefficients $\tilde{\beta}$.

34. Letting θ be a vector of the unknown variance components of G, we have the following likelihood function that is used to find the unique vectors β, θ and σ_ε^2 that maximize this likelihood of observing our data sample.[82]

$$L(\beta, \theta, \sigma_\varepsilon^2) = \left\{-\frac{1}{2}\mathrm{n}\ln(2\pi) + \ln|V| + (\ln(p) - X\beta - Z\gamma)'V^{-1}(\ln(p) - X\beta - Z\gamma)\right\}$$

35. Following estimation of the model, we predict broadband prices for each provider for a set of standardized plans. Since the random effects $\tilde{\beta}$ are not directly estimated, we calculate them post-estimation by using the following best linear unbiased estimator of the random effects, where variables with ^ denote estimated objects from the MLE.

$$\hat{b} = \hat{G}'\tilde{X}'\hat{V}^{-1}(\ln(p) - X\hat{\beta} - Z\hat{\gamma})$$

36. The predicted price for any one of the six standardized plans used to compare prices across countries is then given by the following formula.

$$\ln(P_{ijk}) = X_i\hat{\beta} + Z_k\hat{\gamma} + \tilde{X}_i\hat{b}_j + \mu_j + \nu_k$$

37. The random coefficients on product characteristics measure how each provider's pricing of the characteristic differs from the pricing of the average provider in the sample as measured by the coefficient β.[83] In our fixed broadband hedonic models, the product characteristics with random coefficients are three download speed splines, the bundling dummy variable, and the logarithm of the plan's contract length.[84] In our mobile broadband hedonic models, there are random coefficients on three data usage allowance splines, the number of lines, and the logarithm of contract length.[85]

38. In an imperfectly competitive market such as broadband, there is no meaningful interpretation of the hedonic regression coefficients. Under perfect competition, the coefficient vector β estimates both the marginal consumer value and marginal production costs for each product characteristic.[86] However, in markets like broadband with substantial fixed costs, the coefficient also includes the markup over cost for that characteristic, and these markups are complex functions of the characteristics of competing products, firm costs, consumer preferences, and market structure.[87] As such, in imperfectly competitive markets, hedonic coefficients should only be considered a reduced-form

[82] We use the Stata mixed command to estimate the model. For further details on the maximum likelihood estimation routine, *see* StataCorp LP, *STATA Multilevel Mixed-Effects Reference Manual Release 13*, https://www.stata.com/manuals13/me.pdf (last visited Oct. 27, 2020).

[83] *See infra* Fig. G-36 and Fig. G-41 for the fixed and mobile broadband, respectively, estimated variances of the random coefficients.

[84] We control for download speed using a linear spline in the logarithm of download speed with knot points at the top-end of our speed categories used to define the six broadband products (i.e., knots at 50 and 100 Mbps).

[85] We control for data allowance using a linear spline in the logarithm of the data allowance with knot points at the top-end of our data allowance categories used to define mobile broadband products with the three highest data allowances (i.e., knots at 5 and 10 GB).

[86] *See* Sherwin Rosen, *Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition*, 82 Journal of Political Economy 34-55 (1974), https://www.jstor.org/stable/1830899?seq=1#metadata_info_tab_contents.

[87] *See* Ariel Pakes, *A Reconsideration of Hedonic Price Indexes with an Application to PCs*, 93 American Economic Review 1578-96 (2003); Robert C. Feenstra and Gordon H. Hanson, *Foreign Investment, Outsourcing and Relative Wages*, 5121-NBER (May 1995), https://www.nber.org/system/files/working_papers/w5121/w5121.pdf; Diane Bruce Anstine, *How Much Will Consumers Pay? A Hedonic Analysis of the Cable Television Industry*, 19 Review of Industrial Organization 129-147 (2001), https://www.jstor.org/stable/41799034?seq=1. Even if the broadband market is competitive in a country, pricing will still need to be above marginal cost for firms to recover their fixed deployment costs.

description of how prices (costs plus markups) vary with changes in product characteristics. The focus should not be on the particular value, sign, or precision of any one coefficient but rather on how predictive the hedonic pricing function is of provider prices in each country.[88] We therefore follow a standard hedonic approach, except we correct price levels for exogenous country-level factors that we expect to be correlated with costs and markups.

39. The last issue that we need to account for in the hedonic regression is product bundling. As noted above, most U.S. consumers purchase broadband and video service in a bundle at steeply discounted rates.[89] Further, it is very difficult to compare multichannel video products across countries. The product offerings in terms of channels included are completely different across countries and the same content may be highly watched in some countries (e.g., American football in the United States) but uninteresting to most viewers in another country (e.g., American football in Europe). Therefore, unlike broadband, where a download speed of 25 Mbps is a product characteristic where more of the characteristic is always better (i.e. vertical characteristics), there is no standardized video product that would be comparable across countries that would hold consumer utility fixed. While many studies attempt to control for video quality differences based on observable product characteristics and because we do not believe the observable measures adequately capture quality differences across countries, we calculate a bundle discount and allocate this across the standalone component pricing as described below to isolate the price of broadband when purchased in a bundle.

B. Fixed and Mobile Broadband Price Index Calculations

40. We use the same general methodology to calculate the fixed broadband and mobile broadband price indexes in Figure G-24 and Figure G-28, respectively. The supplementary figures of broadband prices by product referenced here are available in section IV.F Supplementary Figures.

41. *Step 1.* We calculate the unweighted average price of all plans for each provider within each product type.[90] Therefore, each provider has up to six product prices.

42. *Step 2.* Next, we calculate a weighted average price of each product category across providers, using provider market shares as the weight. If a provider does not offer any plans in a particular product category, the weight is proportional to only those providers that do offer a product in the given product category.[91] Figure G-35 and Figure G-40 display the country-level product prices for fixed broadband and mobile broadband, respectively.

43. *Step 3.* There are cases in which no provider in a country offers plans in a product category, so we make assumptions about missing country-level product prices. First, if a bundled product price is missing, we replace it with the corresponding standalone product price (i.e., setting the bundle discount to zero). Next, if the highest tiered product(s) are not offered, we set the missing product prices to the next available product price. For example, if no providers in the country offer products 2 and 3, then we set product 2's and product 3's prices to product 1's price. Finally, for any remaining missing product prices, we set these to the next highest available product price.[92] For example, if a country's providers only offer products 1 and 3, then product 2's price is set to product 3's price.

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[88] *See* Ariel Pakes, *A Reconsideration of Hedonic Price Indexes with an Application to PCs*, 93 American Economic Review 1578-96 (2003).

[89] *See supra* para. 14.

[90] This calculation includes "synthetic plans." *See infra* paras. 46, 59 for a discussion of synthetic plans.

[91] If only one provider in a country offers plans in a product category, that provider's unweighted average price would represent 100% of the country level product price.

[92] This assures that U.S. consumers are at least as well off with the product provided as they would have been with the product available in the United States.

44. *Step 4.* Finally, we calculate the price indexes using the full set of country-level product prices from Step 3, and the product shares in Figure G-23 for fixed broadband and Figure G-27 for mobile broadband.[93] For fixed broadband, we calculate the overall standalone price and overall bundled price using the download speed shares in Figure G-23. For mobile broadband, we calculate the overall single-line price and overall multi-line price using the data usage shares in Figure G-27. To calculate the overall broadband price, we use the bundle shares to weight the overall standalone price and overall bundle price.

45. *Step 5.* To produce per GB rankings, we divide the overall broadband price calculated in the prior step by the average monthly data usage in each country.[94]

C. Fixed Broadband Pricing Data Collection

46. *Collection of Broadband Prices and Timeframe.* We collected fixed residential broadband plan prices and terms from 82 providers in 26 countries, including the United States, between April and July 2020. To determine which providers to sample in each comparison country, we used the *TeleGeography GlobalComms Database* to select providers with broadband market shares of at least 10% nationally as of December 2019.[95] This threshold was chosen to balance data collection costs against the desire to obtain a representative sample of broadband pricing.[96] For each provider, we collected plans from 10 randomly selected addresses from the country's capital city.[97] These addresses were then entered into providers' websites to determine the product offerings at each address. While many providers' websites displayed general "promotional splash page" plan offerings, entering an address allowed us to capture the variation in product availability within a city, as well as more detailed pricing information.[98] Where we could not collect address-level plan data, we collected "promotional splash page" plans.[99]

47. For each provider, we recorded each combination of download speed, upload speed, data usage allowance, and technology (D/U/A/T). For example, a provider offering a fiber-based plan with 100 Mbps download, 100 Mbps upload, and no data cap; a fiber-based plan with 100 Mbps download, 50

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[93] *See supra* para. 12 for the price index formula. TeleGeography *GlobalComms Database*, (last visited Oct. 27, 2020). International Telecommunications Union, *World Telecommunications/ICT Indicators Database 2020* (24th Edition/July 2020) (last accessed Aug. 19, 2020). OpenVault, *Broadband Industry Report—4Q 2019*, Quarterly Advisories (Feb. 11, 2020), https://openvault.com/ovbi-median-broadband-usage-on-pace-to-surpass-250-gb-per-month-in-2020/.

[94] For fixed broadband, we only have monthly average usage per subscriber data for 18 of the 26 countries. For mobile broadband, we rely on OECD monthly average usage per subscriber. OECD, *Broadband Portal*, https://www.oecd.org/sti/broadband/broadband-statistics/ (last visited Oct. 27, 2020).

[95] TeleGeography, *GlobalComms Database* (last visited Oct. 27, 2020). We obtained these data as of February 2020. There is one exception to the 10% rule: Verizon is estimated to have a national broadband market share below 10% in the United States, but it was sampled as it is the largest Fiber to the Premises (FTTP) provider as well as the second largest Incumbent Local Exchange Carrier.

[96] On average, our sample covers about 90% of all broadband subscribers over all 26 comparison countries. The lowest total market share is just under 70% while most countries have over 90% total market share covered in our sample.

[97] In some cases, a provider did not offer service in the capital city (e.g., AT&T in Washington, D.C.), this required collecting some providers' plans from another city. Additionally, when capital cities were not major cities in the given country (e.g., Canberra, Australia), we collected plans from another major city, in addition to the capital city. *See 2018 International Broadband Data Report*, 33 FCC Rcd at 1027-28, para. 14.

[98] If we were able to collect address level plans, we only collected plans that were available for at least one address. Therefore, plans that were advertised on "promotional splash pages" may not have been collected if these plans were not available at any of the 10 addresses.

[99] Some providers do not provide an option to enter an address to check available plans but instead require customers to call or e-mail to receive more information about availability of plans.

Mbps upload, and no data cap; and a cable-based plan with 100 Mbps download, 100 Mbps upload, and no data cap has three separate plans recorded.[100] Both standalone broadband plans as well as double play packages of broadband bundled with multichannel video services were collected.[101] With some exceptions, we did not collect information on "triple play" bundles of fixed voice phone, Internet, and video because the extent of the bundle discount received did not tend to increase with the addition of phone service and doing so would have greatly increased the data collection burden.[102] In cases where a provider only offered Internet service to customers who also subscribed to fixed voice phone services, we collected Internet bundled with fixed voice phone service plans and any relevant bundled plans of Internet, fixed voice phone service, and television.[103] In such cases, we collected triple play bundles from the provider that included that particular phone plan to isolate the bundled broadband price using the methodology described below. Finally, if the provider did not offer video service, bundle discounts, or standalone TV plans, we did not collect bundled plans for the particular D/U/A/T combinations for the provider.[104]

48. Given the large number of countries, providers, and product offerings, we limited the scope of the collection along several additional dimensions. First, we assumed customers were new to the provider and did not receive any special discounts that were not available to all new customers (e.g., student discounts). Second, we only recorded information for the combination of features that resulted in the lowest price for a given plan.[105] For example, we did not include optional add-on features (e.g., HBO, security software, etc.), always chose the lowest priced equipment required for the plan, and assumed consumers were willing to sign up for a two-year contract if this offered the lowest price.[106] Also, we did not include any plans with spectrum-based technologies (e.g., fixed wireless, satellite, 4G) and any plans with an advertised download speed of more than 1000 Mbps.

49. We collected three types of data for each plan: (1) general information; (2) pricing data; and (3) non-pricing data. General information captures information such as the name of the plan, date of collection, and currency of prices. For pricing data, we collected all pricing information available on the provider's website including promotions, equipment fees, installation fees, and rebates, in order to calculate the total cost of the broadband service plan over a two-year time horizon. Non-pricing data includes information such as download and upload speeds, data usage allowances, number of channels (if

[100] We excluded plans with download speeds above 1000 Mbps as these are generally non-residential offerings.

[101] By multichannel video services, we mean linear television packages usually offered using cable, satellite, or Internet with regularly scheduled programs. Over the Top services, which stream programs to specific users, that are bundled with a broadband plan are not considered in our analysis and are thus unobserved product characteristics if they are included in any plans. *See supra* Section II.D.1.

[102] Additionally, we did not collect fixed broadband plans bundled with mobile voice and data services.

[103] In cases where fixed voice phone plans are bundled in the plan, we always chose the lowest priced fixed voice phone package and indicated that fixed voice phone service is included in the bundled plan.

[104] In the *2018 International Broadband Data Report*, we collected bundled plans even when providers did not offer bundle discounts (i.e., add-on pricing), resulting in bundle discounts of 0%, and when providers did not offer standalone TV plans that were needed in our bundle discount calculation, requiring making assumptions about standalone TV price. In this report, we only collected information of bundled plans when the provider offered a clear discount for bundling Internet and TV service (e.g., a plan with a bundle discount due to duplicative installation or activation fees was not eligible for collection).

[105] Essentially, if a provider offered multiple plans that would have appeared identical within our data framework, we recorded the lowest priced plan. This approach would exclude any optional add-on products.

[106] More generally, if a provider offered the same plan with different contract length options with discounts for longer contracts, we chose the longest contract length available (up to 24 months).

applicable), and contract length. A unique plan is defined by country, city, provider, broadband plan, TV plan, phone service, technology, download speed, upload speed, and data allowance.

50. *Data Review and Cleaning Process.* Upon completion of the data collection, we reviewed the data for accuracy and completeness. When the variables essential for the analysis were unavailable, we made the following assumptions to impute the missing data:

- If a provider did not explicitly state the length of the contract, we assumed the plan was month-to-month (i.e., one month).
- When generally advertised download speeds were not reported, but providers displayed address-specific download speeds, we used the average download speed across addresses for which the plan was available.
- If the provider's website did not list a data allowance, we assumed the plan offered an unlimited data allowance.
- If a plan advertised a promotional price without specifying duration, we assumed the promotion lasted 12 months.
- If the regular monthly price was not found, we assumed that the last available promotional price stayed in effect for the remaining period.
- If equipment prices were not available, we assumed the relevant equipment was included.
- If activation fees, installation fees, and other recurring and non-recurring fees and rebates were not listed clearly on a provider's website, we assumed that these fees were included or did not apply to the plan.
- For Canada and the United States, if taxes were not explicitly stated as included in the list prices and not reported separately, we added a percentage to the total pre-tax prices.[107] For all other countries, we assumed taxes were included.[108]

51. We also made two other assumptions that apply to only two specific providers:

- For one of Iceland's providers that did not display download speeds, we assumed the same download speed as all the plans offered by Iceland's other two providers (1000 Mbps). In Iceland, plan prices varied by data usage allowance, not download speed.
- For one of New Zealand's providers that did not display a download speed for its two ADSL plans, we assumed the same download speed as another of New Zealand's provider's ADSL plan (20 Mbps).

52. *Broadband Price Calculation.* After cleaning the data, we calculated the total cost of each plan over the first 24 months. A 24-month price was selected to produce a comparable pricing measure across plans that accounted for all promotional and regular pricing and to amortize one-time fees over a sufficiently long-term horizon. This total 24-month price was calculated using the formula below:

[107] International Telecommunications Union, *World Telecommunications/ICT Indicators Database 2020* (24th Edition/July 2020) (last accessed Aug. 19, 2020).

[108] Outside of the United States and Canada, most providers note that listed prices included taxes (VAT). In the United States and Canada, providers generally stated prices that did not include taxes. In some cases, taxes were not included in prices but were reported separately, in which case we were able to add the reported tax (i.e., we didn't apply a percentage of the pre-tax total price to estimate the tax).

$$Price_{24Month} = (PromoPrice_1 * PromoDuration_1) + (PromoPrice_2 * PromoDuration_2) + (24 - PromoDuration_1 - PromoDuration_2) * NonPromoPrice + 24 * (ModemPrice + STBPrice - RebateMonthly + OtherMonthly + Tax) + InstallationFee + ActivationFee - RebateOneTime + OtherFees$$

53. We then divided this price by 24 months to calculate the average monthly price. We converted all currencies to U.S. dollars using Purchasing Power Parity (PPP) for the broadband price index and Currency Exchange Rate conversion factors for the hedonic price index.[109] Next, we matched all bundled plans with their corresponding standalone Internet and standalone video component plans to calculate a bundle discount percentage. The formula below calculates the bundle discount percentage D_B based on the standalone Internet price P_I, the standalone video price P_V, and the bundle price P_B. For most bundled plans, we were able to collect the exact corresponding standalone Internet and video component plans.[110] However, for bundled plans without corresponding standalone Internet plans and for standalone Internet plans without corresponding bundled plans, we created "synthetic plans" with the same product characteristics but with a price to set the bundle discount equal to zero. Synthetic plans that correspond with collected bundled plans may represent bundled plans that could be available without a bundle discount (i.e., add-on pricing).

$$D_B = \frac{(P_I + P_V) - P_B}{(P_I + P_V)} = \left(1 - \frac{P_B}{P_I + P_V}\right)$$

54. After calculating the discount percentage from the standalone Internet and standalone video prices for each bundled plan, we applied the percentage equally to the standalone broadband and video component plan prices to arrive at the implied price of broadband when purchased in a bundle.[111] To illustrate, suppose the standalone prices for a particular video and Internet broadband plan are $100 and $50, respectively, but the two can be purchased in a bundle for $120. Then the bundle discount percentage is 20% and the implied price of the video plan when purchased in a bundle is $80, while the implied price of broadband when bundled is $40. This implied broadband price when bundled and the associated broadband characteristics would then be included as a plan in the dataset. In this manner, our analysis does not compare video and broadband bundles across countries, but rather isolates an implied price of broadband when bundled to avoid video product comparability issues across countries.

55. In Figure G-33, we calculate country level average bundle discounts over all bundled plans (including synthetic plans). First, we take a simple unweighted average of the bundle discount and bundle discount rates over all plans for each provider's product categories.[112] Then, we aggregate over providers, weighting by their market shares. Finally, we aggregate over country level products using the download speed tier shares to arrive at our bundle discount estimate for each country. The results of this analysis confirm that bundling discounts vary widely across countries and therefore accounting for

[109] OECD, *PPP*, https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm (last visited Oct. 27, 2020); OECD, *Exchange rates*, https://data.oecd.org/conversion/exchange-rates.htm#indicator-chartt (last visited Oct. 27, 2020).

[110] In one case, a provider offered standalone broadband without fixed voice but bundled plans with fixed voice. We collected broadband plans with fixed voice to match with these bundled plans, but we excluded the broadband plans with fixed voice from the analysis.

[111] Allocating the bundle discount percentage equally to each of the standalone components is equivalent to allocating the bundle discount amount in proportion to the standalone component prices.

[112] In some cases, a plan may change data usage tiers as the number of lines increases. For example, if a provider offers an 8 GB single-line plan that allows a customer to add lines to the plan and share the data allowance, the single-line plan with 8 GB is in the 5 to 20 GB data usage (per line) tier and the 2-line plan with 4 GB per line is in the 0 to 5 GB data usage (per line) tier.

product bundling is important in order to accurately reflect the prices actually paid by consumers for broadband services in each country.

D. Mobile Broadband Pricing Data Collection

56. *Collection of Broadband Prices and Timeframe*. We collected mobile broadband plan prices and terms from 83 providers from 26 countries including the United States between February and September of 2020. To determine which providers to sample in each comparison country, we used the *TeleGeography GlobalComms Database* to select providers with national broadband market shares of at least 10% as of March 2019.[113] Given the wide scope of offerings by mobile providers, we limited the collection to 4G postpaid smartphone plans that allowed unlimited voice calling and texting for up to four lines (when adding lines provided a discount).[114] However, where providers did not offer plans with unlimited minutes or unlimited text messages, we collected plans with the highest number of minutes and text messages for a particular data allowance.

57. We collected mobile plan information in three broad categories: (1) general information including country, provider, plan name, and date of collection; (2) pricing information including all types of recurring and non-recurring costs such as promotional prices, activation fees, and rebates; and (3) non-price information such as data usage allowance, number of minutes and text messages (when not unlimited), and consequence of exceeding data allowance.[115] We only collected plans available online and to new customers without any special discounts (e.g., student discounts). A unique plan is defined by the country, provider, data allowance, number of lines, contract duration, data allowance consequence, number of minutes, and number of text messages.[116]

58. We sought to collect pricing information excluding the cost of handsets due to both the complexity that handsets introduce in measuring price and because most providers allow customers to bring their own devices. Generally, providers either sold handsets separately from the service plan and/or allowed customers to bring their own devices (i.e., customers received a SIM card from the provider). Although handsets are a significant portion of the cost of mobile broadband services, we chose not to consider these costs in our pricing analysis due to the additional complexity and in order to keep prices comparable across countries.

59. One of the most important price factors for mobile broadband service is the data usage allowance.[117] We recorded the monthly data allowance for each plan.[118] In general, providers set a "soft" data allowance per month before the provider imposes a consequence for exceeding these usage

[113] We obtained these data as of February 2020. TeleGeography GlobalComms, *Company Broadband Statistics*, (last visited Oct. 27, 2020).

[114] By postpaid plans, we refer to plans that are paid after usage (i.e., not prepaid or "pay-as-you-go" plans). By smartphone plans, we refer to plans that have a data component. We did not collect plans marketed as 5G-only plans, since most countries' providers did not market any plans as 5G, or marketed 4G plans with access to 5G where available.

[115] All price variables are recorded as the total for all lines for the plans (i.e., not on a per-line basis).

[116] We did not collect all possible mix-and-match combinations of plans. For example, a provider may offer a 5 GB plan that can be combined with a 2 GB plan for a discount, but we only collected multi-line plans of identical data allowances.

[117] We only consider data that can be consumed within the customer's country. In some cases, particularly European providers' plans, customers can use the main data allowance in several countries and/or have a separate international data allowance. International data allowances are not considered in our analysis as each provider has different policies regarding international data usage.

[118] We do not consider promotional (i.e., limited time) data allowances unless the data allowances are included for the entire length of the contract.

allowances.[119] If a customer exceeds the allowance, the provider *may* decrease mobile broadband speeds for the remainder of the month, charge overage fees (i.e., a consumer pays for additional data use), or stop service entirely (i.e., a "hard" data limit). The structure of the data allowance policies varies by provider and can be quite complex, so we record the default consequence for exceeding the first data allowance.[120]

60. We encountered a few issues unique to a small number of providers that required making assumptions about customer preferences. For providers that offered a plan with a set number of units to allocate between talk and text messages, we split these equally across the services and recorded the exchange rate among the services (e.g., 1 unit = 1 minute = 1 text).[121] If a provider offered multiple plans that would appear identical within our data framework, we recorded the cheapest of these plans.[122] If a provider did not offer any plans with included text messages, we set the number of text messages equal to one.[123]

61. Since the *2018 International Broadband Data Report's* Mobile Broadband Pricing Data Collection in 2017, the prominence of unlimited plans has expanded greatly, especially for the U.S. providers. Two U.S. providers offer unique unlimited plans in that customers do not have a specified data allowance but can be throttled at any time due to network congestion.[124] These providers also offer more expensive plans with "premium data" that will not experience throttling until the customer has used beyond the allotted premium data and the network is experiencing congestion.[125] Two other U.S. providers offer variations of unlimited plans where the "soft" data cap is the same for each plan, but because these more expensive plans have other characteristics outside our data framework (e.g. 1080p video), we only recorded the cheapest of each of the provider's unlimited plans.[126]

62. Some other countries' providers have similar issues. Finland's providers offer only unlimited data plans with prices varying by speeds. In this case, we set each provider's highest speed plan (150 Mbps) as unthrottled and each provider's slowest speed plan (with unlimited data) as throttled.[127] One German provider offered an unlimited data plan with a maximum download speed of 2 Mbps so we set these plans as throttled. Each of Portugal's providers' unlimited plans have a maximum download speed of 10 Mbps so we treated these plans as throttled. One of the United Kingdom's providers has an unlimited plan with a maximum download speed of 2 Mbps which we also define as throttled.

[119] In our regressions, "unlimited" is reserved for plans that have at least 50 GB per line per month before there is a consequence imposed.

[120] For example, some providers have several data allowance thresholds with different consequences for exceeding each one, while other providers limit the amount of extra data a customer can buy. Some providers allow customers to choose from various data allowance consequences, so there is no clear default data cap consequence.

[121] Luxembourg's providers typically have this structure for units of minutes and text messages.

[122] For example, a provider may offer an Unlimited Talk/Text plan with 50 GB of data with varying levels of international data or with or without a streaming service included. As we do not have variables for international data or other services, we recorded the cheapest of these plans.

[123] Two of Spain's providers only offer plans with Pay-As-You-Go Text Messages.

[124] For the regression models, we account for these "Anytime Throttling" plans with a dummy that equals one for throttled plans.

[125] We have treated these "premium data" plans as plans with "soft" data caps.

[126] For example, these more expensive unlimited plans have more hotspot data or higher hotspot speeds, inclusion of streaming services such as Hulu and Tidal, and/or HD video streaming.

[127] Finland's providers offered several higher speed plans marketed as 5G plans so we did not collect these plans.

63. *Data Review and Cleaning Process.* After completing the data collection, we reviewed the data for any issues. When certain essential variables were missing, we made the following assumptions to complete the analysis:

- If a provider did not explicitly state the length of the contract, we assumed the plan was month-to-month (i.e., one month).
- If a plan advertised a promotional price without specifying duration, we assumed the promotion lasted 12 months.
- If the regular monthly price was not found, we assumed that the last available promotional price stayed in effect for the remaining period.
- If activation fees, access fees, other recurring and non-recurring fees, and rebates were not listed clearly on a provider's website, we assumed that these fees were included or did not apply to the plan.
- For Canada and the United States, if taxes were not explicitly stated as included in the list prices and not reported separately, we added a percentage to the total pre-tax prices.[128] For all other countries, we assumed taxes were included.

64. *Broadband Price Calculation*. After cleaning the data, we then calculated the total cost of each plan over the first 24 months. A 24-month price was selected to produce a comparable pricing measure across plans that accounted for all promotional and non-promotional pricing and to amortize one-time fees over a sufficiently long-term horizon. This total 24-month price was calculated using the formula below:

$$\begin{aligned} Price_{24Month} = {} & (PromoPrice_1 * PromoDuration_1) + (PromoPrice_2 * PromoDuration_2) \\ & + (24 - PromoDuration_1 - PromoDuration_2) * NonPromoPrice + 24 \\ & * (AccessFee - RebateMonthly + OtherMonthly + Tax) + ActivationFee \\ & - RebateOneTime + OtherFees \end{aligned}$$

65. Next, we divided the price by the number of lines in the plan to get the total 24-month price per line. Then, we divided the price per line by 24 months to calculate the average monthly price per line. We converted all currencies to U.S. dollars using PPP for the broadband price index calculations and Currency Exchange Rate conversion factors for the hedonic price index.[129]

66. Similar to our fixed broadband analysis, we also created mobile broadband synthetic plans when a provider did not offer a particular plan at a discounted price for bundling additional lines, up to four lines. The simplest example is when a provider offers only a single-line plan without any discounts for bundling more lines; in this example, we would create a 2-line synthetic plan, a 3-line synthetic plan, and a 4-line synthetic plan with the same product characteristics and price per line (i.e., no bundle discount relative to the single-line plan). As a slightly more complex example, suppose a provider offers a plan as a single-line plan and a 2-line plan but offers no discount for three or four lines. In this example, we create a synthetic 3-line plan with the per line price set to a weighted average of the single-line and 2-line plan prices (i.e., the total price of purchasing a 2-line plan and a single-line plan divided by three) and a synthetic 4-line plan with the per line price set to the per line price of the 2-line plan (i.e., the total price of purchasing two 2-line plans divided by four). We made other similar synthetic plan

[128] International Telecommunications Union, *World Telecommunications/ICT Indicators Database 2020* (24th Edition/July 2020) (last accessed Aug. 19, 2020).

[129] OECD, *PPP*, https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm (last visited Oct. 27, 2020); OECD, *Exchange rates*, https://data.oecd.org/conversion/exchange-rates.htm#indicator-chart (last visited Oct. 27, 2020).

calculations for plans that are not available with bundle discounts with up to four lines, but in all cases synthetic plans are plan combinations that consumers are able to purchase from the provider.[130]

67. In Figure G-38, we present country-level average mobile broadband bundle discounts (relative to single-line plans). The calculations include all plans (including synthetic plans), except for plans that do not have a single-line option. We calculated the bundle discount relative to the corresponding single-line plan, and then we took a simple unweighted average of the bundle discount and bundle discount rate over all plans for each provider's product categories. We then aggregated over providers, weighting by their market shares. Finally, we aggregated over country level products using the data usage product shares. We again find that bundle discounts vary widely across countries and must be accounted for to properly measure the prices consumers are paying for their mobile services in each country. Many countries, such as the United States, offer large bundle discounts when multiple lines are purchased, but some other countries offer no discounts.

E. Data Sources and Variable Construction

68. *Fixed Product Shares.* To calculate the U.S. quantity weights for each of the six products in our price indexes, we use the FCC Form 477 data to estimate the share of U.S. broadband subscribers that subscribe to each of the three broadband download speed tiers and an estimate from *S&P Global* that about 65% of all U.S. broadband subscribers purchase their service in a bundle.[131] The resulting broadband products and their estimated U.S. market shares are shown in Figure G-23 above.

69. *Mobile Product Shares.* Based on Cisco data, we know that 18% of all U.S. mobile subscribers use less than two GB of data per month, 23% of mobile subscribers use between two GB and five GB, 41% of mobile subscribers use between five GB and 20 GB, and 18% use more than 20 GB. Cisco also finds that 79% of users subscribe to shared plans with an average usage of approximately 10 GB per line, while 21% of users subscribe to non-shared plans with an average usage of approximately 14 GB of data per month.[132] We assume that the percentage of shared data plans is equal to the percentage of multi-line plans (and the percentage of non-shared plans is equal to the percentage of single-line plans).[133] However, we do not have an estimate of the percentage of single-line and multi-line plan customers who fall into each of our data usage allowance categories— we only know the overall average usage for single and multi-line customers.

70. The log-normal distribution has been shown to approximate consumer usage over nearly every communications network, including broadband.[134] This makes estimating the distribution of data usage simple because a log-normal distribution is entirely determined by only two parameters: a location

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[130] In some cases where a provider does not offer a single-line plan, we cannot calculate some combinations of number of lines. For example, if a plan was only offered as a 2-line plan, then we would calculate a 4-line plan price with the same per line price as the 2-line plan, but we would not have corresponding single-line and 3-line plans.

[131] S&P Global, *Estimated broadband-only homes as a percentage of wireline broadband households, Q1'18 vs. Q1'19 vs. Q1'20* (last accessed July 21, 2020). We use preliminary December 2019 FCC Form 477 subscriber data collection for these calculations. We again note that the year-end FCC Form 477 data are preliminary only and are subject to corrections as appropriate by the service provider, and the final data will be published in due course by the agency.

[132] *See* Cisco, *Annual Internet Report (2018-2023) White Paper*, Fig. 18 (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html.

[133] Some providers may have multi-line plans with separate data allowances. However, for the limited data plans collected, the two U.S. providers offered a set amount of data shared among lines on the plan.

[134] Ioannis Antoniou et al., *On the Log-Normal Distribution of Network Traffic*, 167 Physica D: Nonlinear Phenomena 72 (2002), https://www.sciencedirect.com/science/article/abs/pii/S0167278902004311.

parameter that pins down the mean and a scale parameter that determines the shape of the usage distribution.[135] Another important property of the distribution is that percentiles are preserved if the mean of the distribution is shifted up or down.[136] Combining the Cisco data with a log-normal distribution assumption, we are able to estimate the percentage of subscribers in the United States that have usage between the data usage allowances of our standardized mobile broadband products. The results of this approach are summarized in Figure G-31 below. The column with the heading "Cisco" presents Cisco's estimates of the percentage of all U.S. mobile broadband consumers who have usage between the specified ranges of data usage. The next column provides our estimates using a log-normal distribution calibrated to the Cisco percentiles data based on the reported distribution parameters at the bottom of the figure.[137] We find that our estimates are a close match and that the log-normal assumption fits these data well, although the Cisco distribution appears to have more mass in the tails. The next two columns provide our estimates for the percentage of single-line and multi-line plan subscribers that fall into each usage category.[138] These values multiplied by the percentage of consumers who take single and multi-line products serve as the product shares in our price indexes.

Fig. G-31: Mobile Broadband Data Usage Shares

Usage Tier	Cisco	Log-Normal Estimates		
	Overall Usage	Overall Usage	Single-Line Plan Usage	Multi-Line Plan Usage
0 < Usage (GB) ≤ 2	18.0%	16.0%	14.0%	21.0%
2 < Usage (GB) ≤ 5	23.0%	26.0%	24.0%	29.0%
5 < Usage (GB) ≤ 10	23.0%	24.0%	24.0%	22.0%
10 < Usage (GB) ≤ 20	18.0%	19.0%	20.0%	17.0%
20 < Usage (GB) ≤ 50	14.0%	13.7%	16.2%	10.2%
50 < Usage (GB)	4.0%	1.3%	1.8%	0.8%
Distribution Parameters				
Plan Type	**Mean**		**Standard Deviation**	
Overall	1.844		1.15	
Individual	1.978		1.15	
Shared	1.641		1.15	

71. *Content Quality Variable.* In Figure G-44, we report various proxy measures for content quality as well as each country's primary language. The number of websites in top-level domains (TLDs) shows the count of all domains in each country's main TLD (e.g., Germany uses .de) according to DomainTools.com. For the United States, we aggregate over several major domains: .com, .net, .org, and .us. Similarly, we used the same TLDs to report the number of web pages in the TLDs by searching Google's search engine ("site:.de") and recording the number of search results. We divide the number of domains and the number of webpages by the country's population to get per capita measures. Also, we

[135] *See* George S. Ford, *Approximating the Distribution of Broadband Usage from Publicly-Available Data*, 7, n.5 (2012), https://www.phoenix-center.org/perspectives/Perspective12-03Final.pdf. A random variable is log-normally distributed if the logarithm of the variable is normally distributed.

[136] *Id*.

[137] The calibration chooses the standard deviation that results in the closest approximation to the data usage percentiles observed in the *Cisco White Paper* data: Cisco, *Annual Internet Report (2018-2023) White Paper*, (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html.

[138] These calculations assume that the standard deviation is the same as the overall usage distribution, but the mean is shifted to match the mean per line usage of multi-line and single-line plan subscribers.

report each country's English Proficiency Index (EPI) score as a measure of access to English language content. Another proxy measure is the percent of the top 10 million websites in each country's primary language.[139] From this data, we find that English-based websites represent over 50% of the top 10 million websites. Although these statistics are not perfect measurements of content quality, they demonstrate that English language content is the dominant form of content available to broadband subscribers.[140]

72. To construct the content quality measure used in our hedonic regressions, we perform a principal components analysis of the four content quality proxy variables (webpages by TLD per capita, domains by TLD per capita, EPI, and content language percentage), using the 26 country-level observations.[141] We keep only the first principal component from this analysis, which explains about 53% of the variation in the 4 content quality measures. We then standardized the first principal component so that the mean value is zero and the standard deviation is one across the 26 country level values. This standardized first principal component is then used as a proxy measure of content quality in both the fixed broadband and mobile broadband hedonic analyses.

73. *Purchasing Power Parity.* To convert pricing data collected in local currency (LCU) to U.S. dollars, we use the OECD's 2019 PPPs which are defined as "the rates of currency conversion that try to equalise the purchasing power of different currencies, by eliminating the differences in price levels between countries. The basket of goods and services priced is a sample of all those that are part of final expenditures: final consumption of households and government, fixed capital formation, and net exports."[142]

74. *Exchange Rates.* To convert pricing data collected in LCU to U.S. dollars, we also used the OECD's 2019 exchange rates which are defined as "the price of one country's' currency in relation to another country's currency."[143]

75. *Gross National Income Per Capita.* The Gross National Income (GNI) data are used as a demographic control variable in the hedonic regression models and are from the OECD.[144] We use the most recently available value for each country and convert all values to 2019 U.S. dollars using the PPP conversion factors.

76. *Educational Attainment.* These data are used as a demographic control variable in the hedonic regression models and are from the OECD.[145] We used the 2018 percentage of 25 to 64-year-olds with Bachelor's (or equivalent education), Master's (or equivalent education), or Doctoral (or equivalent education) degrees.

77. *Non-Rural Population Density.* For the fixed broadband hedonic analysis, we constructed a measure of non-rural population density using four OECD datasets: (1) National

[139] W^{3}Techs, *Usage Statistics of Content Languages for Websites*, https://w3techs.com/technologies/overview/content_language (last visited Oct. 27, 2020).

[140] We have found our results to be robust to using different measures of content quality as well as dropping the United States from the sample and then running the estimation.

[141] Principal components analysis is a standard method used in statistics for reducing a large set of variables into a smaller set of variables that retain most of the information contained in the larger variable set.

[142] OECD, *PPP*, https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm (last visited Oct. 27, 2020).

[143] OECD, *Exchange rates*, https://data.oecd.org/conversion/exchange-rates.htm#indicator-chartt (last visited Oct. 27, 2020).

[144] OECD, *Gross national income*, https://data.oecd.org/natincome/gross-national-income.htm (last visited Oct. 27, 2020).

[145] OECD, *OECD.Stat*, https://stats.oecd.org/ (last visited Oct. 27, 2020).

Population Distribution (NPD),[146] (2) National Area Distribution (NAD),[147] (3) land area, and (4) population. The NPD is the percent of the population living in three categories: urban, intermediate, and rural areas. The NAD is the percent of the area in three categories: urban, intermediate, and rural. The NPD and NAD are from 2014, therefore we multiplied the percentages by the 2014 population and 2014 land area, respectively, to get the total population and total land area in each category. Then, we divided the total population by category by the total land area in the corresponding category. Non-rural population density is the sum of urban and intermediate population divided by the sum of urban and intermediate land area.

78. *Population Density.* For the mobile broadband hedonic analysis, we calculated the overall national population density using the OECD's population and land area datasets.[148] We divided the most recently available national population (2018) by the most recently available land area (2016) to get 2018 population density.[149]

79. *Coverage (Fixed).* For the fixed broadband hedonic analysis, we included a variable measuring the percentage of households with access to download speeds of greater than 100 Mbps in each country. For the 21 European comparison countries, we used data reported in the EC's *2019 Broadband Coverage in Europe Report* on the percentage of households living in areas where the download speed of greater than 100 Mbps was deployed as of June 2018.[150] For the United States, we relied on FCC Form 477 data for the same measure, as of December 2018.[151] For Canada, we used the percentage of households with fixed broadband service of at least 100 Mbps available as of 2018.[152]

80. For the remaining three countries, we relied on proxy measures of coverage. For Australia, the National Broadband Network Company reports the number of premises ready for service by technology as of June 2018.[153] We assumed that Fiber to the Premises (FTTP), Fiber to the Node/Basement/Curb (FTTN/B/C), and Hybrid Fiber Coaxial technologies are capable of achieving at least 100 Mbps, while Fixed Wireless and Satellite are not.[154] We divided the number of premises designated as ready for service[155] by the total number of premises as our network coverage measure for

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[146] OECD, *National population distribution*, https://data.oecd.org/popregion/national-population-distribution.htm#indicator-chart (last visited Oct. 27, 2020).

[147] OECD, *National area distribution*, https://data.oecd.org/popregion/national-area-distribution.htm#indicator-chart (last visited Oct. 27, 2020).

[148] OECD, *OECD.Stat*, https://stats.oecd.org/ (last visited Oct. 27, 2020).

[149] Land area rarely changes from year to year in the dataset, and when it does, the changes are minimal, so we believe that 2016 land area is reasonable to use with 2018 population data.

[150] European Commission, *Broadband Coverage in Europe 2019* (Sept. 4, 2020), https://op.europa.eu/en/publication-detail/-/publication/077cc151-f0b3-11ea-991b-01aa75ed71a1, (*2019 Broadband Coverage in Europe Report*).

[151] FCC Form 477. *See infra* Fig. G-53.

[152] Canadian Radio-television and Telecommunications Commission, *Communications Monitoring Report 2019*, (2020), https://crtc.gc.ca/pubs/cmr2019-en.pdf.

[153] NBN Corporation, *Annual Report 2018*, (Oct. 31, 2018), https://www.nbnco.com.au/content/dam/nbnco2/2018/documents/media-centre/nbn-co-annual-report-2018.pdf *(NBN Annual Report 2018).*

[154] *NBN Annual Report 2018* reports that the wholesale products' maximum speeds as 1 Gbps / 400 Mbps for FTTP, 100/40 Mbps for FTTN/B/C and Hybrid Fiber Coaxial, 50/20 Mbps for Fixed Wireless, and 25/5 for Satellite.

[155] *NBN Annual Report 2018* defines "ready for service" as "A Rollout Region is ready for service when the majority of premises are passed by the nbn access network and RSPs are able to begin selling services over the nbn access network in that Rollout Region."

Australia.[156] For Mexico, we used data from Instituto Federal de Telecomunicaciones - Banco de Informacion de Telecomunicaciones which reports the percentage of accesses by technology as of June 2018.[157] We assumed that Fiber and Cable Coaxial are the only technologies that could achieve 100 Mbps; and that DSL, Satellite, Fixed Wireless, and Other Technologies are below this threshold. For New Zealand, we relied on data from the country's Ministry of Business, Innovation, and Employment on progress of their Ultra-Fast Broadband (UFB) initiative.[158] In particular, we used the percentage of New Zealanders with access to UFB as of March 2019.

81. *Mobile Download, Upload, and Latency.* For the mobile broadband hedonic analysis, we used 2019 country-level mean download speeds based on our analysis of Ookla Speed Test data.[159]

82. *Mobile 4G Availability.* For the mobile broadband hedonic analysis, we used OpenSignal's measure of 4G Availability which is defined as "the proportion of time users with a 4G device and subscription have a 4G LTE connection."[160] For most countries, we used the value from OpenSignal's most recent (May 2020) report, but when some countries were not reported, we used the most recently reported value.[161] Specifically, we relied on the February 2018 report for Estonia, Latvia, and Luxembourg,[162] and the November 2016 report for Iceland.[163]

83. *Fixed Data Usage.* For the fixed broadband analysis, we calculated the average monthly data usage from several data sources. Our primary source is the *International Telecommunications Union (ITU) Database*, which provides the total data usage by fixed broadband subscribers in each country.[164] We converted the total annual data in exabytes to monthly average data usage in gigabytes. Because the *ITU Database* does not have 2019 values for all 26 comparison countries, we supplement the data from two other sources. For Austria, New Zealand, and the United Kingdom, we relied on the *TeleGeography GlobalComms Database*'s Fixed Data Traffic Volume dataset which has a 2019 monthly average.[165] We

[156] *NBN Annual Report 2018* reports that "as of 30 June 2018, 7.0 million premises had been declared RTC, an increase of 29 per cent year-on-year. This means that about 60% of Australian premises were able to order a service over the nbn access network at the end of the financial year." This implies that the total number of premises in Australia is about 11.7 million.

[157] Instituto Federal de Telecomunicaciones, Banco de Informacion de Telecomunicaciones, *Indicadores Internacionales - Comparativo Entre Paises Miembros de Regulatel - Indicadores Por Pais*, https://bit.ift.org.mx/BitWebApp/indicadoresInternacioanles.xhtml (last visited Oct. 27, 2020).

[158] Crown Infrastructure Partners, *Quarterly Connectivity Update*, (Mar. 2019), https://www.mbie.govt.nz/assets/quarterly-connectivity-update-q1-31-march-2019.pdf.

[159] *See supra* Appx. G-2, Fig. G-11.

[160] Sam Fenwick and Hardik Khatri, *The State of Mobile Network Experience 2020: One Year into the 5G Era*, Open Signal (May 2020), https://www.opensignal.com/reports/2020/05/global-state-of-the-mobile-network.

[161] *Id.*

[162] OpenSignal, *State of LTE (February 2018)*, https://www.opensignal.com/reports/2018/02/state-of-lte (last visited Oct. 27, 2020).

[163] OpenSignal, *State of LTE (November 2016)*, https://www.opensignal.com/reports/2016/11/state-of-lte (last visited Oct. 27, 2020).

[164] International Telecommunications Union, *World Telecommunications/ICT Indicators Database 2020* (24th Edition/July 2020) (last accessed Aug. 19, 2020), "Fixed (wired)- broadband Internet traffic (exabytes) refers to traffic generated by fixed-broadband subscribers measured at the end-user access point. It should be measured adding up download and upload traffic. This should exclude wholesale traffic; walled garden; IPTV and cable TV traffic."

[165] TeleGeography GlobalComms, *Company Broadband Statistics*, (last visited Oct. 27, 2020). Fixed data traffic covers the number of bytes of data traffic originating on fixed broadband networks (xDSL, Cable, FTTx, WiMAX, etc.) within a given country. These volumes include download and upload wherever possible.

divided both the ITU and TeleGeography monthly averages by the total number of fixed broadband subscribers, according to the OECD, to get the monthly fixed broadband data usage per subscriber.[166]

84. *Mobile Data Usage.* For the mobile broadband analysis, we used average monthly data usage reported by the OECD as of December 2018.[167]

85. *Terrain Roughness (Weighted by Population).* Our measure of terrain roughness is a population weighted terrain ruggedness index.[168] The index is constructed by calculating the terrain ruggedness index for each 30 by 30 arc-second cell using elevation data across the surface of the Earth. Let $e_{r,c}$ denote the elevation at the point located in row r and column c of a grid of elevation points:

$$TRI_{r,c} = \sum_{i=r-1}^{r+1} \sum_{j=c-1}^{c+1} \left(e_{i,j} - e_{r,c}\right)^2$$

86. These values are then weighted by the share of the country population in each cell to calculate the weighted average terrain ruggedness index for the country. The values calculated are reported in 100s of meters.[169]

87. *Domains by Top-Level Domains Per Capita.* First, we determined the TLD(s) for each country, and then aggregated the counts of all domains in each TLD over the country's TLD(s).[170] Next, we divided the total domains by the country's population to get the domains per capita.[171] Figure G-44 reports the TLD(s) assigned to each country.

88. *Webpages by Top-Level Domains Per Capita.* Using the same TLDs for each country, we determined the number of webpages using Google's search engine for each TLD (for example, "site:.com").[172] Then, we aggregated over TLDs for each country and divided the total webpages for each country by the country's population to get the webpages per capita.

89. *English Proficiency Index*. We used a measure of a country's English proficiency from Education First, called the EPI.[173] In the most recent EPI report, Education First reports an EPI score for each country except Australia, Canada, Iceland, Ireland, New Zealand, the United Kingdom, and the United States. Besides Iceland, we assumed that these countries are all native English-speaking countries

[166] OECD, *Broadband Portal*, https://www.oecd.org/sti/broadband/broadband-statistics/ (last visited Oct. 27, 2020).

[167] *Id.* The OECD has released December 2019 data, but the data do not include a value for the United States. Therefore, we use December 2018 values.

[168] Nathan Nunn and Diego Puga, *Ruggedness: The Blessing of Bad Geography in Africa*, 94 Review of Economics and Statistics 20-36 (2012).

[169] Nathan Nunn and Diego Puga, *Data and Replication Files for "Ruggedness: The Blessing of Bad Geography in Africa,"* https://diegopuga.org/data/rugged/ (last visited Oct. 27, 2020).

[170] DomainTools, *Domain Count Statistics for TLDs*, https://research.domaintools.com/statistics/tld-counts/ (last visited Oct. 27, 2020).

[171] OECD, *OECD.Stat*, https://stats.oecd.org/ (last visited Oct. 27, 2020). The most recently available country population data is for 2018.

[172] Google, https://www.google.com/ (last visited Oct. 27, 2020).

[173] Education First, *EF English Proficiency Index*, (2019), https://www.ef.com/assetscdn/WIBIwq6RdJvcD9bc8RMd/legacy/__/~/media/centralefcom/epi/downloads/full-reports/v9/ef-epi-2019-english.pdf.

and set the EPI score to 100% for our analyses. For Iceland, we assumed a "Very High Proficiency" and set the EPI score to the average EPI score of other sampled countries in this category.[174]

90. *Content Language.* For both the fixed broadband and mobile broadband hedonic analyses, we used the percentage of websites with different content languages.[175] A content language is defined as the natural language of the text on a website. The primary language spoken in each country is shown in Figure G-44.

F. Supplementary Figures

91. This section provides the supplementary figures referenced in the text.

Fig. G-32: Fixed Broadband and Mobile Broadband Combined Hedonic Price Indexes

Country	Model 1		Model 2		Model 3		Model 4	
	Price	Rank	Price	Rank	Price	Rank	Price	Rank
Australia	117.37	20	139.69	22	148.96	22	188.16	21
Austria	85.78	10	109.88	15	125.66	17	166.06	16
Belgium	92.49	14	99.57	12	103.44	9	156.35	14
Canada	134.99	24	157.83	23	160.09	23	186.95	20
Czech Republic	70.46	6	101.74	13	112.28	11	153.02	12
Denmark	74.17	8	88.88	7	97.62	6	142.80	8
Estonia	66.09	4	98.26	11	106.76	10	165.17	15
Finland	69.95	5	81.87	3	88.55	3	143.82	9
France	61.87	3	85.28	5	103.05	8	147.17	11
Germany	95.83	15	117.16	18	142.12	21	199.60	23
Greece	196.75	26	205.01	26	236.45	26	334.83	26
Iceland	99.90	17	86.39	6	114.76	13	173.09	18
Ireland	86.66	11	90.91	8	112.31	12	131.52	4
Italy	54.58	2	78.89	2	93.62	4	132.07	5
Latvia	40.06	1	66.68	1	75.76	1	115.53	1
Luxembourg	126.00	23	110.57	16	130.27	19	193.01	22
Mexico	92.48	13	181.42	25	199.07	25	252.81	24
Netherlands	106.44	19	160.57	24	173.41	24	259.02	25
New Zealand	103.80	18	109.20	14	123.95	16	139.81	7
Norway	142.18	25	119.44	19	121.38	15	184.76	19
Portugal	88.83	12	115.13	17	127.32	18	166.21	17
Spain	73.73	7	97.08	10	99.48	7	134.13	6
Sweden	84.02	9	93.16	9	96.40	5	145.07	10
Switzerland	123.72	22	83.20	4	83.64	2	121.63	3
United Kingdom	99.47	16	121.38	21	137.87	20	153.20	13
United States	**121.19**	**21**	**121.12**	**20**	**121.33**	**14**	**121.49**	**2**

[174] In Iceland, English is the "first" foreign language in the Icelandic National Curriculum for compulsory schools. *See* Iceland, Ministry of Education, Science and Culture, *The Icelandic National Curriculum Guide for Compulsory Schools – with Subjects Areas*, 50 (2014), https://www.government.is/library/01-Ministries/Ministry-of-Education/Curriculum/adalnrsk_greinask_ens_2014.pdf.

[175] W3Techs, *Usage Statistics of Content Languages for Websites*, https://w3techs.com/technologies/overview/content_language (last visited Oct. 27, 2020).

Fig. G-33: Fixed Broadband Average Bundle Discounts and Discount Rates (PPP Adjusted)

Country	Discount	Discount Rate
Australia	2.55	3.4%
Austria	15.28	18.6%
Belgium	4.54	5.3%
Canada	18.26	13.3%
Czech Republic	19.02	20.1%
Denmark	0.00	0.0%
Estonia	37.13	30.9%
Finland	11.20	15.2%
France	0.00	0.0%
Germany	4.99	7.0%
Greece	10.47	9.5%
Iceland	0.00	0.0%
Ireland	19.13	15.3%
Italy	0.00	0.0%
Latvia	11.36	22.4%
Luxembourg	0.00	0.0%
Mexico	0.00	0.0%
Netherlands	0.00	0.0%
New Zealand	0.00	0.0%
Norway	33.25	19.9%
Portugal	44.66	41.9%
Spain	0.00	0.0%
Sweden	11.74	13.3%
Switzerland	0.00	0.0%
United Kingdom	0.00	0.0%
United States	**24.12**	**14.4%**

Note: Prices are reported in PPP adjusted U.S. dollars.

Fig. G-34: Fixed Broadband Unweighted Average Prices by Product (PPP Adjusted)

Country	Standalone						Bundled					
	0 < Mbps < 25		25 ≤ Mbps < 100		100 ≤ Mbps ≤ 1000		0 < Mbps < 25		25 ≤ Mbps < 100		100 ≤ Mbps ≤ 1000	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia	34.41	9	50.93	15	70.87	7	34.41	9	50.94	17	71.75	9
Austria	39.36	1	42.17	4	75.56	5	32.62	2	33.11	6	60.65	5
Belgium			35.79	1	56.94	3			35.79	1	55.27	3
Canada	42.67	5	62.15	12	76.97	18	42.67	5	58.70	14	72.77	19
Czech Republic	34.27	3	40.09	4	54.27	6	28.79	5	32.75	8	47.46	10
Denmark	38.48	4	39.90	6	54.16	7	38.48	4	39.90	6	54.16	7
Estonia	33.13	7	44.28	6	81.31	11	25.73	13	33.85	12	57.85	23
Finland			32.42	4	45.65	6			32.42	4	43.38	6
France	28.11	1	34.53	1	40.70	7	28.11	1	34.53	1	40.70	7
Germany	38.42	3	34.82	4	50.06	11	38.42	3	33.84	5	48.03	14
Greece	42.78	4	52.50	5	77.39	6	42.63	5	53.59	8	63.60	14
Iceland					72.73	8					72.73	8
Ireland	31.33	1	37.73	1	65.26	5	31.33	1	37.73	1	67.28	8
Italy	50.37	2			42.00	10	50.37	2			42.00	10
Latvia	39.30	1	21.79	1	36.52	7	39.30	1	17.44	2	30.45	9
Luxembourg	51.91	4			67.28	9	51.91	4			67.28	9
Mexico	53.33	2	48.22	5	92.18	8	53.33	2	48.22	5	92.18	8
Netherlands			56.55	2	66.63	5			56.55	2	66.63	5
New Zealand	57.25	3	54.62	6	61.55	11	57.25	3	54.62	6	61.55	11
Norway	68.23	2	65.69	7	80.67	17	68.23	2	62.83	7	73.11	17
Portugal	50.27	3	46.94	4	60.00	14	50.27	3	46.94	4	56.52	14
Spain	62.40	1			68.55	8	62.40	1			68.55	8
Sweden	36.67	6	46.65	4	61.25	33	36.67	6	40.50	6	55.49	45
Switzerland	46.84	1	53.35	2	57.32	7	46.84	1	53.35	2	57.32	7
United Kingdom	34.12	2	41.53	7	57.91	7	34.12	2	41.53	7	57.91	7
United States	**68.11**	**2**	**43.40**	**4**	**74.27**	**17**	**68.11**	**2**	**47.07**	**9**	**67.38**	**36**
Total		67		105		253		77		133		319

Note: Prices are reported in PPP adjusted U.S. dollars.

Fig. G-35: Fixed Broadband Weighted Average Prices by Product (PPP Adjusted)

Country	Standalone						Bundled					
	0 < Mbps < 25		25 ≤ Mbps < 100		100 ≤ Mbps ≤ 1000		0 < Mbps < 25		25 ≤ Mbps < 100		100 ≤ Mbps ≤ 1000	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia	37.23	9	53.24	15	71.28	7	37.23	9	52.66	17	70.59	9
Austria	39.36	1	44.67	4	70.23	5	32.62	2	33.70	6	58.59	5
Belgium			35.79	1	59.61	3			35.79	1	58.48	3
Canada	42.54	5	65.15	12	79.25	18	42.54	5	62.43	14	76.04	19
Czech Republic	34.84	3	41.75	4	54.78	6	32.43	5	39.09	8	51.67	10
Denmark	38.48	4	40.50	6	53.74	7	38.48	4	40.50	6	53.74	7
Estonia	34.76	7	45.95	6	83.99	11	31.90	13	42.58	12	79.83	23
Finland			33.40	4	41.73	6			33.40	4	39.90	6
France	28.11	1	34.53	1	43.07	7	28.11	1	34.53	1	43.07	7
Germany	42.01	3	40.82	4	53.69	11	42.01	3	41.22	5	52.97	14
Greece	46.76	4	55.07	5	76.78	6	46.59	5	53.57	8	68.91	14
Iceland					72.82	8					72.82	8
Ireland	31.33	1	37.73	1	60.69	5	31.33	1	37.73	1	60.16	8
Italy	50.37	2			42.58	10	50.37	2			42.58	10
Latvia	39.30	1	21.79	1	38.06	7	39.30	1	17.44	2	35.79	9
Luxembourg	48.98	4			78.33	9	48.98	4			78.33	9
Mexico	47.54	2	48.07	5	82.60	8	47.54	2	48.07	5	82.60	8
Netherlands			56.63	2	67.58	5			56.63	2	67.58	5
New Zealand	57.38	3	54.54	6	62.24	11	57.38	3	54.54	6	62.24	11
Norway	68.23	2	69.31	7	93.58	17	68.23	2	65.92	7	78.80	17
Portugal	50.45	3	46.43	4	60.39	14	50.45	3	46.43	4	56.89	14
Spain	62.40	1			65.17	8	62.40	1			65.17	8
Sweden	40.64	6	45.76	4	55.96	33	40.64	6	44.09	6	54.25	45
Switzerland	46.84	1	55.12	2	65.30	7	46.84	1	55.12	2	65.30	7
United Kingdom	34.24	2	42.71	7	56.26	7	34.24	2	42.71	7	56.26	7
United States	**66.93**	**2**	**48.36**	**4**	**75.10**	**17**	**66.93**	**2**	**46.39**	**9**	**68.55**	**36**
Total		67		105		253		77		133		319

Note: Prices are reported in PPP adjusted U.S. dollars.

Fig. G-36: Fixed Broadband Estimated Variances of Random Coefficients and Likelihood Ratio Tests

Random Coefficient Parameters	Model 1		Model 2		Model 3		Model 4	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Country: Variance(Constant)	0.104	0.037	0.025	0.015	0.025	0.015	0.010	0.012
Provider: Variance(0 < Mbps < 50)	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001
Provider: Variance(50 ≤ Mbps < 100)	0.032	0.014	0.033	0.014	0.033	0.014	0.031	0.013
Provider: Variance(100 ≤ Mbps ≤ 1000)	0.021	0.006	0.021	0.006	0.021	0.006	0.021	0.006
Provider: Variance(Bundle Dummy)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Provider: Variance(Log Contract Length)	0.003	0.001	0.003	0.001	0.003	0.001	0.003	0.001
Provider: Variance(Constant)	0.044	0.014	0.047	0.013	0.046	0.014	0.048	0.014
Variance(Residual)	0.030	0.002	0.030	0.002	0.030	0.002	0.030	0.002
Likelihood Ratio Tests			**1 vs. 2**		**2 vs. 3**		**2 vs. 4**	
P-Value			0.000		0.498		0.019	

Fig. G-37: Fixed Broadband Country Random Coefficients

Country	Model 1	Model 2	Model 3	Model 4
Australia	0.245	0.128	0.142	0.052
Austria	-0.154	-0.091	-0.093	-0.052
Belgium	0.029	-0.015	-0.024	0.009
Canada	0.306	0.190	0.178	0.046
Czech Republic	-0.518	-0.163	-0.165	-0.095
Denmark	0.029	-0.026	-0.034	0.002
Estonia	-0.533	-0.194	-0.193	-0.066
Finland	-0.135	-0.121	-0.102	-0.013
France	-0.255	-0.121	-0.112	-0.040
Germany	-0.069	-0.051	-0.051	-0.017
Greece	-0.107	0.045	0.082	0.056
Iceland	0.192	-0.019	-0.016	0.008
Ireland	0.088	-0.021	-0.009	-0.037
Italy	-0.125	0.001	0.019	0.021
Latvia	-0.675	-0.188	-0.196	-0.075
Luxembourg	0.259	-0.001	-0.010	0.014
Mexico	-0.352	0.132	0.117	0.039
Netherlands	0.222	0.176	0.167	0.101
New Zealand	0.395	0.174	0.173	0.058
Norway	0.392	0.003	0.000	0.025
Portugal	-0.078	0.078	0.063	0.020
Spain	0.233	0.190	0.172	0.097
Sweden	-0.025	-0.103	-0.103	-0.026
Switzerland	0.340	-0.072	-0.086	-0.030
United Kingdom	0.020	0.037	0.054	-0.016
United States	**0.277**	**0.033**	**0.028**	**-0.078**
Overall	0.000	0.000	0.000	0.000

Fig. G-38: Mobile Broadband Average Discount Rates by Number of Lines Relative to Single-Line Plan (PPP Adjusted)

Country	2-Lines		3-Lines		4-Lines	
	Discount	Discount Rate	Discount	Discount Rate	Discount	Discount Rate
Australia	-0.29	-1.0%	-0.59	-1.9%	-0.88	-2.9%
Austria	0.00	0.0%	0.00	0.0%	0.00	0.0%
Belgium	0.00	0.0%	0.00	0.0%	0.00	0.0%
Canada	-3.20	-3.7%	-4.27	-5.0%	-6.23	-7.0%
Czech Republic	0.00	0.0%	0.00	0.0%	0.00	0.0%
Denmark	-3.70	-10.3%	-5.32	-15.0%	-6.16	-17.5%
Estonia	-7.17	-13.8%	-9.51	-18.3%	-12.26	-22.0%
Finland	0.00	0.0%	0.00	0.0%	0.00	0.0%
France	0.00	0.0%	0.00	0.0%	0.00	0.0%
Germany	-7.35	-15.4%	-9.00	-18.5%	-11.29	-20.9%
Greece	-6.52	-7.5%	-7.88	-9.1%	-6.52	-7.5%
Iceland	-4.00	-10.6%	-6.74	-15.6%	-7.71	-17.9%
Ireland	0.00	0.0%	0.00	0.0%	0.00	0.0%
Italy	0.00	0.0%	0.00	0.0%	0.00	0.0%
Latvia	0.00	0.0%	-0.21	-0.4%	-0.31	-0.7%
Luxembourg	0.00	0.0%	0.00	0.0%	0.00	0.0%
Mexico	-10.09	-8.1%	-4.48	-5.6%	-5.83	-6.9%
Netherlands	0.00	0.0%	0.00	0.0%	0.00	0.0%
New Zealand	-6.56	-14.9%	-8.74	-19.9%	-9.83	-22.4%
Norway	-1.03	-1.7%	-1.38	-2.3%	-1.55	-2.6%
Portugal	-0.93	-1.4%	-1.24	-1.8%	-1.39	-2.0%
Spain	-3.76	-7.2%	-5.02	-9.6%	-5.64	-10.8%
Sweden	-7.74	-17.2%	-10.69	-23.5%	-12.39	-26.7%
Switzerland	0.00	0.0%	0.00	0.0%	0.00	0.0%
United Kingdom	0.00	0.0%	0.00	0.0%	0.00	0.0%
United States	**-10.65**	**-14.9%**	**-16.61**	**-23.3%**	**-19.72**	**-27.7%**

Note: Plans that are not available as Single-Line Plans are not included. Prices are reported in PPP adjusted U.S. dollars.

Fig. G-39: Mobile Broadband Unweighted Prices by Product (PPP Adjusted)

Country	Single-Line Plans						Multi-Line Plans					
	0.2 < GB ≤ 5		5 < GB ≤ 20		20 < GB		0.2 < GB ≤ 5		5 < GB ≤ 20		20 < GB	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia			29.22	3	44.35	11			28.77	3	43.18	11
Austria	19.24	2	29.18	6	50.72	3	19.24	2	29.18	6	50.72	3
Belgium	24.40	1	40.91	5	55.74	3	24.40	1	40.91	5	55.74	3
Canada			81.75	10	124.04	5			78.93	10	120.28	5
Czech Republic	49.59	7	72.51	5	107.05	8	49.59	7	72.51	5	107.05	8
Denmark			25.09	5	37.78	10			23.48	6	27.92	8
Estonia	18.23	5	33.11	6	61.17	5	17.31	6	29.17	6	47.54	4
Finland					32.18	6					32.18	6
France	21.56	3	29.91	2	44.04	12	21.56	3	29.91	2	44.04	12
Germany	32.94	3	50.53	8	64.91	10	29.35	3	41.93	8	61.32	10
Greece	57.42	17	79.15	8	105.23	15	55.01	20	69.90	9	95.71	14
Iceland	19.88	3	24.10	2	48.16	10	20.40	4	24.72	3	38.50	6
Ireland					36.24	3					36.24	3
Italy					44.28	7					44.28	7
Latvia	28.29	7	38.78	2	47.28	3	28.29	7	38.78	2	45.48	3
Luxembourg	15.11	5	29.36	2	61.86	4	15.11	5	29.36	2	61.86	4
Mexico	32.83	9	72.86	14	136.07	2	32.11	10	66.86	14		
Netherlands	31.02	10	40.42	12	51.51	9	31.02	10	40.42	12	51.51	9
New Zealand	32.09	3	40.11	3	55.52	5	28.19	5	38.25	4	50.50	4
Norway	31.26	5	46.56	6	60.34	1	31.26	5	46.56	6	47.84	1
Portugal					83.88	12					82.49	12
Spain	29.33	2	44.03	6	71.04	3	29.33	2	40.08	6	55.95	3
Sweden	23.78	4	35.26	6	53.90	9	24.09	6	30.26	6	37.06	7
Switzerland	30.31	3			48.58	3	30.31	3			48.58	3
United Kingdom	22.67	8	29.39	8	42.39	14	22.67	8	29.39	8	42.39	14
United States	**63.63**	**4**	**70.17**	**3**	**78.53**	**9**	**48.69**	**6**	**44.91**	**1**	**54.94**	**9**
Total		101		122		182		113		124		169

Note: The three multi-line products include 2, 2, and 3 lines, respectively; all other plans are excluded. Prices are reported in PPP adjusted U.S. dollars.

Fig. G-40: Mobile Broadband Weighted Prices by Product (PPP Adjusted)

Country	Single-Line Plans						Multi-Line Plans					
	0.2 < GB ≤ 5		5 < GB ≤ 20		20 < GB		0.2 < GB ≤ 5		5 < GB ≤ 20		20 < GB	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia			30.23	3	46.24	11			29.97	3	45.42	11
Austria	20.62	2	29.82	6	52.61	3	20.62	2	29.82	6	52.61	3
Belgium	24.40	1	40.47	5	55.35	3	24.40	1	40.47	5	55.35	3
Canada			80.26	10	123.06	5			77.05	10	118.79	5
Czech Republic	48.33	7	71.93	5	109.33	8	48.33	7	71.93	5	109.33	8
Denmark			25.28	5	42.08	10			23.67	6	28.99	8
Estonia	19.34	5	34.77	6	60.36	5	17.75	6	30.01	6	43.59	4
Finland					31.97	6					31.97	6
France	21.22	3	30.68	2	45.52	12	21.22	3	30.68	2	45.52	12
Germany	33.08	3	52.39	8	75.68	10	28.12	3	41.60	8	67.66	10
Greece	57.99	17	79.61	8	105.89	15	56.27	20	71.20	9	92.50	14
Iceland	19.19	3	24.07	2	47.99	10	20.02	4	24.67	3	36.38	6
Ireland					36.57	3					36.57	3
Italy					44.52	7					44.52	7
Latvia	30.22	7	39.04	2	47.63	3	30.22	7	39.04	2	45.74	3
Luxembourg	14.75	5	29.36	2	68.05	4	14.75	5	29.36	2	68.05	4
Mexico	33.64	9	78.89	14	136.07	2	33.55	10	76.21	14		
Netherlands	30.93	10	40.98	12	51.87	9	30.93	10	40.98	12	51.87	9
New Zealand	32.74	3	40.03	3	55.83	5	28.81	5	39.30	4	50.89	4
Norway	31.19	5	46.04	6	60.34	1	31.19	5	46.04	6	47.84	1
Portugal					83.92	12					82.69	12
Spain	34.99	2	47.88	6	71.48	3	34.99	2	41.30	6	57.01	3
Sweden	24.13	4	37.11	6	55.36	9	24.31	6	32.11	6	35.67	7
Switzerland	31.25	3			52.15	3	31.25	3			52.15	3
United Kingdom	22.50	8	30.90	8	42.49	14	22.50	8	30.90	8	42.49	14
United States	**61.41**	**4**	**76.23**	**3**	**74.15**	**9**	**49.02**	**6**	**44.91**	**1**	**51.62**	**9**
Total		101		122		182		113		124		169

Note: Prices are reported in PPP adjusted U.S. dollars.

Fig. G-41: Mobile Broadband Estimated Variances of Random Coefficients and Likelihood Ratio Tests

Random Coefficient Parameters	Model 1		Model 2		Model 3		Model 4	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Country: Variance(Constant)	0.209	0.079	0.164	0.066	0.130	0.056	0.102	0.050
Provider: Variance(0 < GB ≤ 5)	0.018	0.005	0.019	0.005	0.019	0.005	0.019	0.005
Provider: Variance(5 < GB ≤ 20)	0.022	0.005	0.021	0.005	0.021	0.005	0.021	0.005
Provider: Variance(20 < GB)	0.057	0.014	0.057	0.014	0.057	0.014	0.057	0.014
Provider: Variance(Number of Lines)	0.002	0.000	0.002	0.000	0.002	0.000	0.002	0.000
Provider: Variance(Log Contract Length)	0.022	0.008	0.022	0.009	0.022	0.008	0.021	0.008
Provider: Variance(Constant)	0.113	0.034	0.112	0.034	0.111	0.034	0.113	0.034
Variance(Residual)	0.013	0.001	0.013	0.001	0.013	0.001	0.013	0.001
Likelihood Ratio Tests			**1 vs. 2**		**2 vs. 3**		**2 vs. 4**	
P-Value			0.278		0.128		0.057	

Fig. G-42: Mobile Broadband Country Random Coefficients

Country	Model 1	Model 2	Model 3	Model 4
Australia	-0.123	0.008	-0.078	-0.073
Austria	-0.375	-0.175	-0.086	-0.079
Belgium	-0.127	-0.260	-0.325	-0.206
Canada	0.520	0.534	0.350	0.216
Czech Republic	0.060	0.137	0.093	0.083
Denmark	-0.210	-0.078	-0.064	-0.010
Estonia	-0.646	-0.603	-0.547	-0.389
Finland	-0.333	-0.276	-0.327	-0.154
France	-0.327	-0.119	-0.017	-0.012
Germany	0.172	0.233	0.314	0.293
Greece	1.226	0.968	0.876	0.821
Iceland	0.077	-0.175	0.207	0.266
Ireland	-0.363	-0.432	-0.144	-0.228
Italy	-0.405	-0.218	-0.132	-0.101
Latvia	-0.378	-0.181	-0.147	-0.066
Luxembourg	-0.122	-0.292	-0.173	-0.126
Mexico	-0.369	-0.221	-0.186	-0.193
Netherlands	0.281	0.554	0.469	0.474
New Zealand	0.121	0.010	0.071	-0.113
Norway	0.155	0.011	-0.139	-0.025
Portugal	0.277	0.232	0.203	0.152
Spain	-0.426	-0.406	-0.458	-0.428
Sweden	0.107	0.117	-0.023	0.074
Switzerland	0.444	-0.035	-0.194	-0.124
United Kingdom	0.118	0.105	0.111	-0.102
United States	**0.646**	**0.561**	**0.347**	**0.049**
Overall	0.000	0.000	0.000	0.000

Fig. G-43: Summary Statistics for Independent Variables

Country	PPP	Exchange Rate	Fixed Usage	Mobile Usage	GNI/ Capita	Non-Rural Pop. Density	Pop. Density	Educ. Attnmnt.	Fixed Coverage	4G Avail.	Terrain Ruggedness Index (Weighted by Pop.)	First Principal Component of Content Quality Variables
Australia	1.47	1.44	180.51	3.39	54,910	155	8	33.9%	60.9%	94.0%	0.18	1.56
Austria	0.77	0.89	126.34	16.40	51,300	686	277	17.7%	57.5%	91.4%	1.15	-0.36
Belgium	0.77	0.89	147.31	2.01	47,350	1,093	975	40.1%	95.5%	92.6%	0.26	-0.46
Canada	1.20	1.33	197.72	2.46	46,370	187	11	31.8%	84.9%	93.5%	0.37	1.46
Czech Republic	12.56	22.93	147.53	3.39	22,000	368	356	24.1%	58.2%	91.7%	0.58	-0.59
Denmark	6.75	6.67	216.83	7.64	63,240	715	357	33.0%	92.6%	90.5%	0.19	-0.13
Estonia	0.55	0.89		9.82	23,220	89	79	35.1%	68.5%	84.2%	0.19	-0.64
Finland	0.86	0.89		19.39	49,580	232	47	34.0%	51.8%	93.0%	0.27	-0.52
France	0.75	0.89		5.64	42,400	440	317	22.5%	47.5%	86.0%	0.50	-0.78
Germany	0.74	0.89	116.43	2.55	48,520	822	615	28.5%	66.3%	85.8%	0.41	-0.31
Greece	0.56	0.89	90.37	1.53	20,320	464	216	30.0%	0.4%	86.5%	1.29	-0.77
Iceland	140.66	122.61	268.12	7.79	72,850	540	9	41.5%	74.3%	60.7%	0.56	-0.25
Ireland	0.78	0.89	52.16	6.77	62,210	3,695	183	40.2%	55.4%	70.1%	0.28	1.42
Italy	0.67	0.89	129.17	4.27	34,460	664	532	19.3%	23.9%	89.6%	0.75	-0.87
Latvia	0.50	0.89	229.26	12.78	17,730	168	80	30.4%	87.8%	84.1%	0.14	-0.82
Luxembourg	0.85	0.89		3.99	73,910	593	648	39.5%	94.0%	80.0%	0.58	-0.36
Mexico	9.28	19.26		2.11	9,430	607	167	17.5%	57.5%	86.4%	0.82	-1.09
Netherlands	0.79	0.89		2.58	53,200	1,297	1,325	36.2%	93.0%	95.9%	0.04	0.12
New Zealand	1.45	1.52	178.52	2.42	42,670	44	48	35.5%	75.0%	81.7%	0.45	1.61
Norway	9.60	8.80		4.84	82,500	122	38	31.8%	82.0%	95.7%	1.25	-0.32
Portugal	0.57	0.89	128.20	2.64	23,080	775	291	25.0%	70.2%	87.6%	0.97	-0.67
Spain	0.63	0.89	139.90	2.83	30,390	382	242	25.9%	87.2%	90.7%	0.81	-0.83
Sweden	8.92	9.46		7.32	55,840	319	65	33.5%	78.4%	93.5%	0.34	-0.29
Switzerland	1.16	0.99	190.25	6.09	85,500	800	558	43.7%	98.5%	93.1%	1.45	-0.26
United Kingdom	0.69	0.78	306.39	3.36	42,370	893	711	36.1%	48.0%	89.2%	0.21	1.63

Country	PPP	Exchange Rate	Fixed Usage	Mobile Usage	GNI/ Capita	Non-Rural Pop. Density	Pop. Density	Educ. Attnmnt.	Fixed Coverage	4G Avail.	Terrain Ruggedness Index (Weighted by Pop.)	First Principal Component of Content Quality Variables
United States	1.00	1.00	344.00	5.39	65,760	252	93	36.7%	91.0%	96.1%	0.33	2.51
Analysis	Both	Both	Fixed	Mobile	Both	Fixed	Mobile	Both	Fixed	Mobile	Both	Both
Source	OECD	OECD	Various	OECD	OECD	OECD	OECD	OECD	Various	OpenSignal	Nunn & Puga	Various
Year	2019	2019	2019	2018	Most Recent	2014	2018	2018	2018	Most Recent	2000/2001	Various
Unit	LCU/ USD	LCU/ USD	GB/ Month/ Sub	GB/ Month/ Sub	USD 2019 (PPP)	People/ Mile2	People/ Mile2	%	%	%	100s Meters	Standardized

Note: *See supra* section IV: Data and Methodology for discussion of data sources, variable construction, and details of data issues.

Fig. G-44: Content Quality Variables

Country	Webpages by TLD Per Capita	Domains by TLD Per Capita	TLDs	EPI	Content Language	Language Assumed
Australia	53.22	0.12	.au	100.0%	59.8%	English
Austria	64.04	0.15	.at	64.1%	2.6%	German
Belgium	60.51	0.14	.be	63.1%	0.6%	Dutch
Canada	42.37	0.08	.ca	100.0%	59.8%	English
Czech Republic	89.12	0.12	.cz	59.3%	0.4%	Czech
Denmark	72.02	0.22	.dk	67.9%	0.2%	Danish
Estonia	195.92	0.09	.ee	58.3%	0.1%	Estonia
Finland	70.89	0.09	.fi	65.3%	0.1%	Finnish
France	38.24	0.05	.fr	57.3%	2.6%	French
Germany	42.94	0.18	.de	63.8%	2.6%	German
Greece	31.79	0.04	.gr	59.9%	0.7%	Greek
Iceland	215.47	0.18	.is	65.6%	0.0%	Icelandic
Ireland	49.41	0.06	.ie	100.0%	59.8%	English
Italy	39.56	0.05	.it	55.3%	0.9%	Italian
Latvia	43.12	0.06	.lv	56.9%	0.1%	Latvian
Luxembourg	90.30	0.15	.lu	64.0%	2.6%	German
Mexico	4.80	0.01	.mx	49.0%	4.0%	Spanish
Netherlands	64.42	0.31	.nl	70.3%	0.6%	Dutch
New Zealand	56.49	0.14	.nz	100.0%	59.8%	English
Norway	81.14	0.14	.no	67.9%	0.1%	Norwegian
Portugal	41.72	0.03	.pt	63.1%	2.0%	Portuguese
Spain	31.88	0.04	.es	55.5%	4.0%	Spanish
Sweden	68.11	0.14	.se	68.7%	0.3%	Swedish
Switzerland	90.10	0.24	.ch	60.2%	2.6%	German
United Kingdom	42.00	0.15	.uk	100.0%	59.8%	English
United States	112.96	0.53	.us/.com/.net/.org	100.0%	59.8%	English
Analysis	Both	Both	Both	Both	Both	Both
Source	Google	Domain Tools		Education First	W3Techs	
Year	2020	2020		*	2020	
Unit	Webpages by TLD Per Capita	Domains by TLD Per Capita		%	%	
Loading Factor	0.0227	0.3524		0.6728	0.6501	

APPX. G-4
High-Speed Broadband Deployment Comparison with Europe

1. In this Appendix, we compare fixed high-speed and mobile broadband deployment[176] in the United States[177] and 26 European comparison countries (EU26).[178] To conduct the comparison, we rely on the European Commission (EC) deployment data published in the *2019 Broadband Coverage in Europe Report*. To match the EC definition of fixed high-speed broadband, we examine U.S. fixed broadband deployment with download speeds of 30 Mbps or higher.[179] To match the fixed technologies used in the *2019 Broadband Coverage in Europe Report*, we do not include satellite technology.[180] We also compare mobile high-speed broadband deployment in the United States and EU26 by focusing exclusively on 4G LTE, which is the baseline industry standard for the marketing of mobile broadband service.[181] For our primary fixed and mobile deployment analysis, we rely on data gathered by the FCC and the EC in June 2018, December 2018 (US), and June 2019. We also present a historical overview of fixed deployment in the United States and the EU26 countries from 2015 to 2019. Finally, we provide maps that show fixed high-speed broadband deployment in the United States and Europe.

[176] Prior *International Broadband Data Reports* released by the International Bureau, as part of the annual *Broadband Deployment Report* and the *2018 Communications Marketplace Report*, included comparisons of broadband deployment in the United States and Europe. *See, e.g., 2018 Communications Marketplace Report*; *see also* RAY BAUM'S Act.

[177] We note that our analysis does not include U.S. Territories until December 2018, due to anomalies in the historical data for Puerto Rico and the U.S. Virgin Islands, whose population account for over 92% of the total combined population of the U.S. Territories. The historical data suggest a 21.7 percentage point increase in deployment between 2015 and 2016. *2020 Broadband Deployment Report*, GN Docket No. 19-285, Report, 35 FCC Rcd 8986, 8998, para. 25 & n.90 (2020). The year-end 2017 deployment data most likely significantly overstate deployment in Puerto Rico and the U.S. Virgin Islands at that time because the data do not reflect infrastructure damage caused by Hurricanes Maria and Irma. We include data from the U.S. Territories in figures that report data since 2018 only as we believe these FCC Form 477 data collections provide reliable estimates for the U.S. Territories.

[178] We refer to the set of countries that we compare here as the EU26, as we selected only 26 of the 31 European countries addressed in the *2019 Broadband Coverage in Europe Report* for our analysis. The *2019 Broadband Coverage in Europe Report* discusses the 28 member countries of the European Union (EU), as well as Iceland, Norway, and Switzerland. The 26 countries included in our analysis are: Austria (AT), Belgium (BE), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Poland (PL), Portugal (PT), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), United Kingdom (UK), Iceland (IS), Norway (NO), and Switzerland (CH).

[179] *2019 Broadband Coverage in Europe Report* at 19. We rely on the same data sources, technologies, and methodology as described in the *2018 Communications Marketplace Report International Broadband Data Report Appendices*. *Communications Marketplace Report*, 33 FCC Rcd at 12558, Appx. E-4. As in the *2018 Communication Marketplace Report*, we rely on the FCC's Form 477 fixed and mobile 4G LTE deployment data to estimate U.S. broadband deployment as of June 2018, December 2018, and June 2019. FCC, *Fixed Broadband Deployment Data from FCC Form 477*, https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477 (last visited Oct. 27, 2020); FCC, *Mobile Deployment Form 477 Data*, https://www.fcc.gov/mobile-deployment-form-477-data (last visited Oct. 27, 2020). For fixed historical analysis, we also rely on data from the Form 477 data collection. For U.S. fixed technologies capable of at least 30 Mbps download speed, we include: DSL—Asymmetric xDSL, ADSL2, symmetric xDSL, VDSL; Cable Modem—DOCSIS 1, 1.1, 2, 3.0, and 3.1; Optical Carrier/Fiber to the End User; Copper Wireline; and Fixed Wireless.

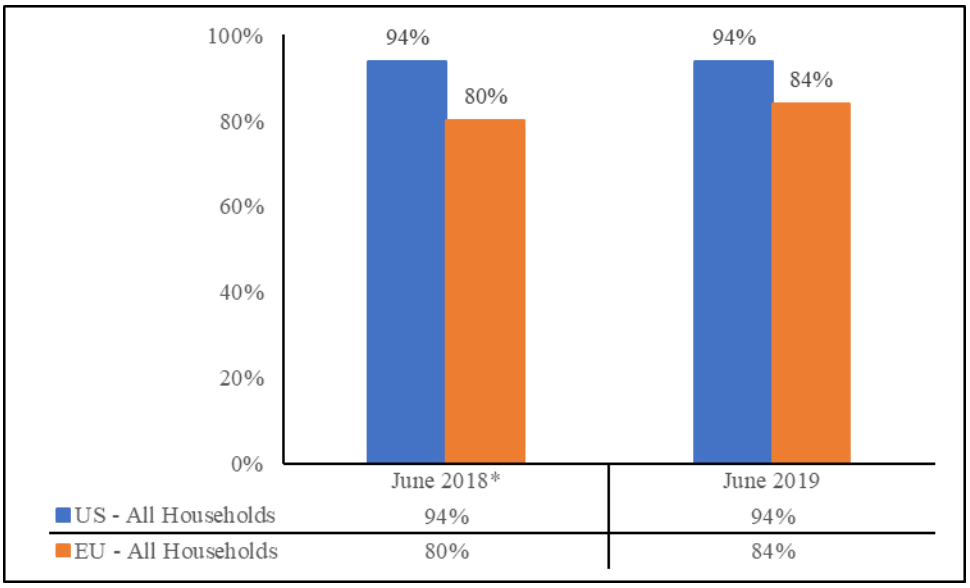
[180] *2019 Broadband Coverage in Europe Report* at 7, 17, 24.

[181] *2018 Communications Marketplace Report*, 33 FCC Rcd at 12684, paras. 239-40. In this Appendix, we analyze mobile 4G LTE coverage regardless of minimum advertised speeds or actual speeds to match the *2019 Broadband Coverage in Europe Report*.

I. FIXED HIGH-SPEED BROADBAND COMPARISON

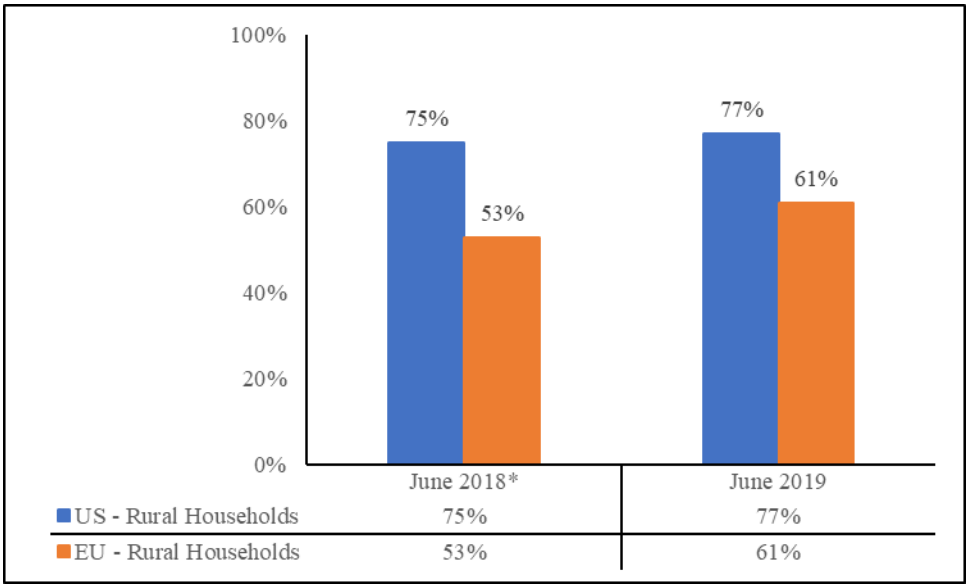
A. Total and Rural Household Fixed High-Speed Broadband Deployment

Fig. G-45: Fixed High-Speed Broadband Deployment, All Households (EU June 2018, US December 2018, and US/EU June 2019)



*****EU data from June and US data from December.

Fig. G-46: Fixed High-Speed Broadband Deployment, All Rural[182] Households (EU June 2018, US December 2018, and US/EU June 2019)[183]



*****EU data from June and US data from December.

[182] Within the United States, the designation of a census block as urban is based upon the 2010 Census. An urban census block encompasses all population, housing, and territory included within a census block categorized as in an urban area or urban cluster. A rural census block encompasses all population, housing, and territory not included within urban census blocks. The European Commission defines rural households in square kilometers with a population of less than one hundred. U.S. Census, *Urban and Rural*, https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html (last visited Oct. 27, 2020); *2019 Broadband Coverage in Europe Report* at 22.

[183] The *2019 Broadband Coverage in Europe Report* presents broadband connections capable of at least 30 Mbps at a national level, defined as follows: "This category encompassed VDSL (including VDSL2 Vectoring), FTTP, FWA (4G TD LTE standard) and DOCSIS 3.0 (including DOCSIS 3.1) cable broadband access technologies. However, as not all connections utilizing these technologies can achieve 30 Mbps and higher actual download speeds (for example, VDSL connections with distance from the exchange point higher than 500m see radical decrease in actual speeds), respondents were asked to exclude those connections which did not meet the criteria from their answers." However, this category is not available for rural areas. Therefore, in these areas, we consider next-generation access (NGA) availability. "The NGA combination category is comprised of VDSL (including VDSL 2 Vectoring), FTTP, and cable modem DOCSIS 3.0 (including DOCSIS 3.1) technologies, all typically capable of delivering a service speed of at least 30 Mbps." *2019 Broadband Coverage in Europe Report* at 24, 33.

B. High Speed Rural and Non-Rural Household Broadband Deployment

Fig. G-47: United States and EU26 Rural vs. Non-Rural (Households) Fixed High-Speed Broadband Deployment (June 2018)

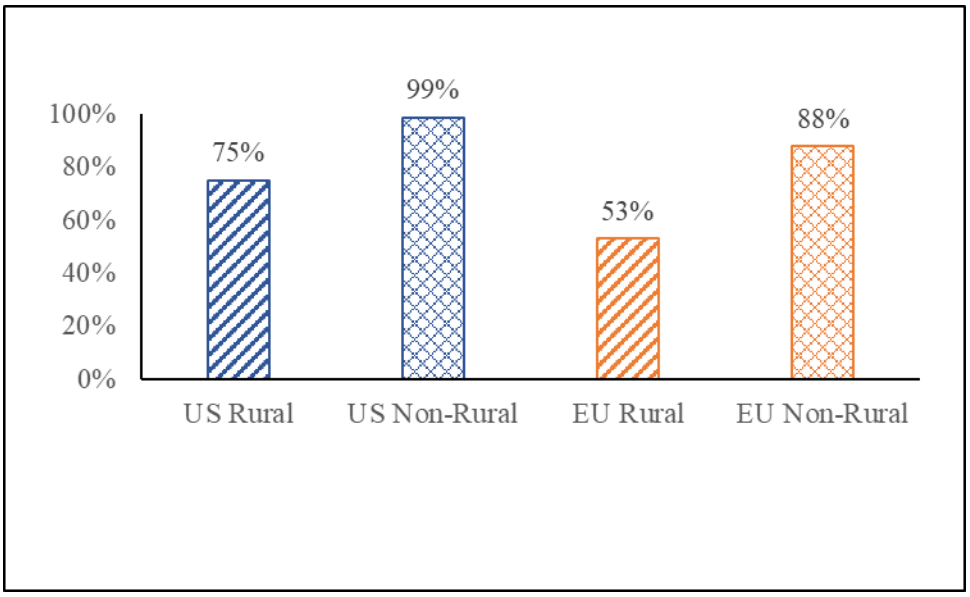
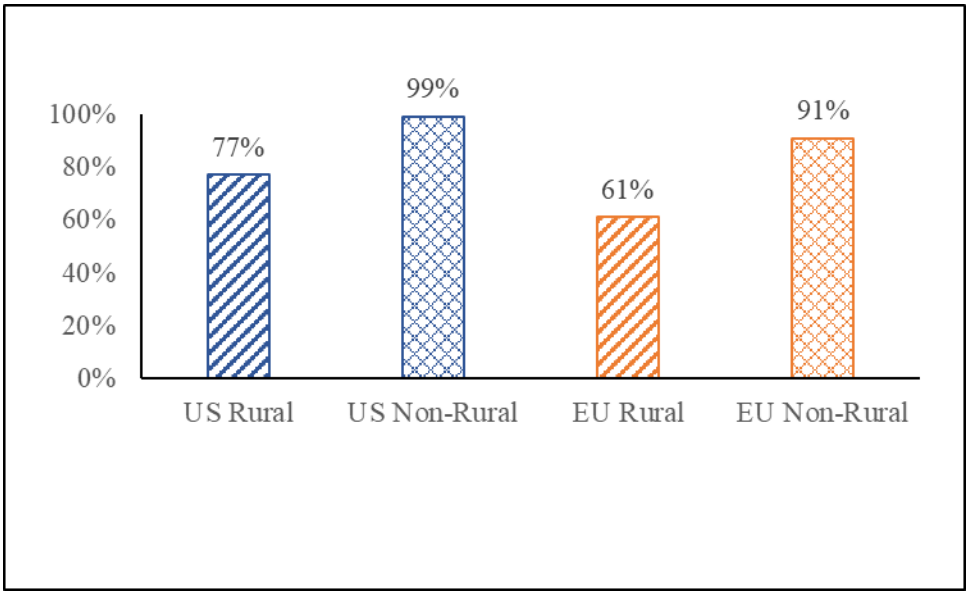
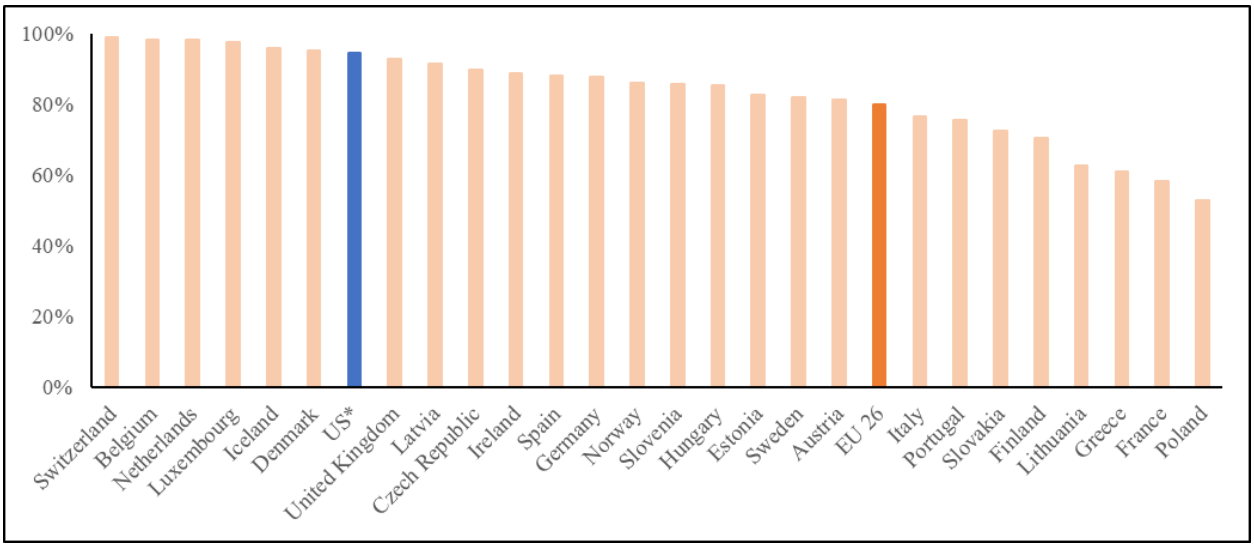


Fig. G-48: United States and EU26 Rural vs. Non-Rural Households, Fixed High-Speed Broadband Deployment (June 2019)



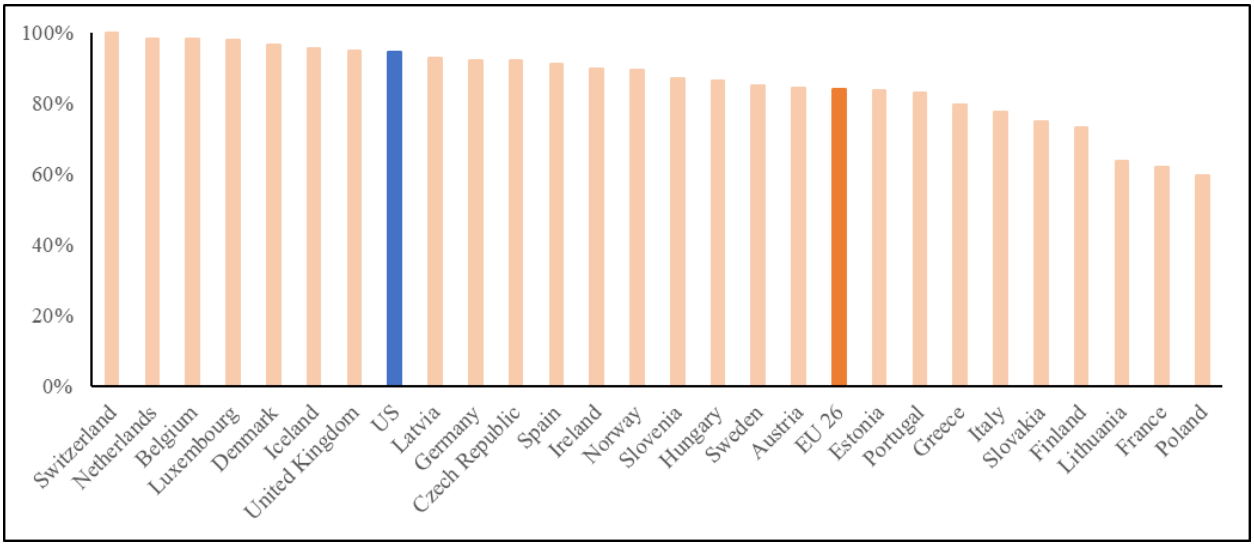
C. Total High-Speed Broadband Deployment by Country

Fig. G-49: Fixed High-Speed Broadband Deployment by Country for All Households (EU June 2018 and US December 2018)



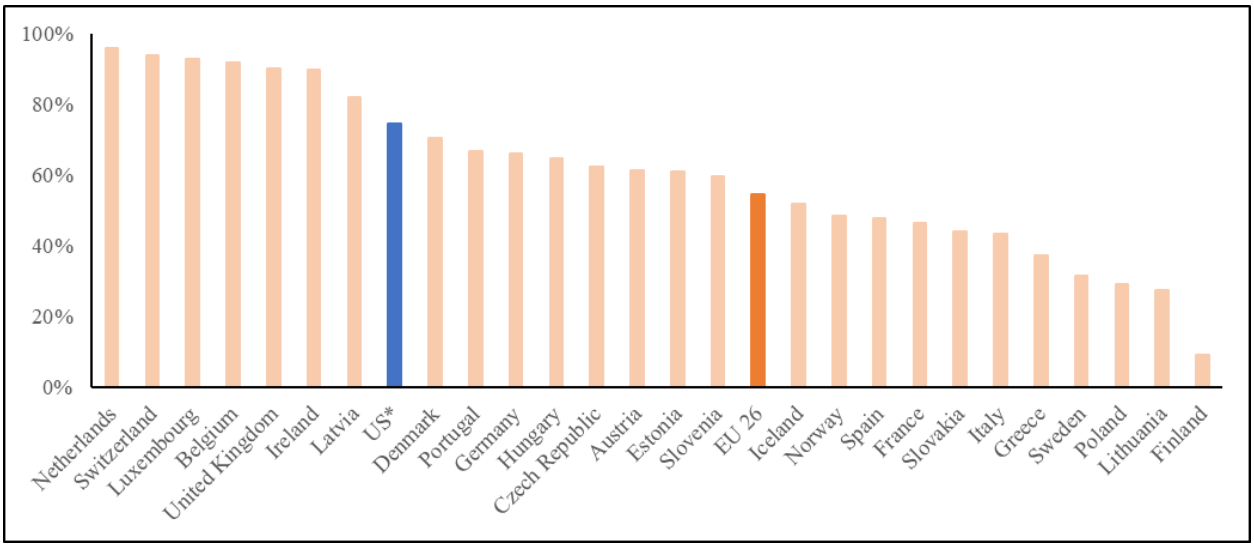
*****EU data from June and US data from December.

Fig. G-50: Fixed High-Speed Broadband Deployment by Country for All Households (EU and US June 2019)



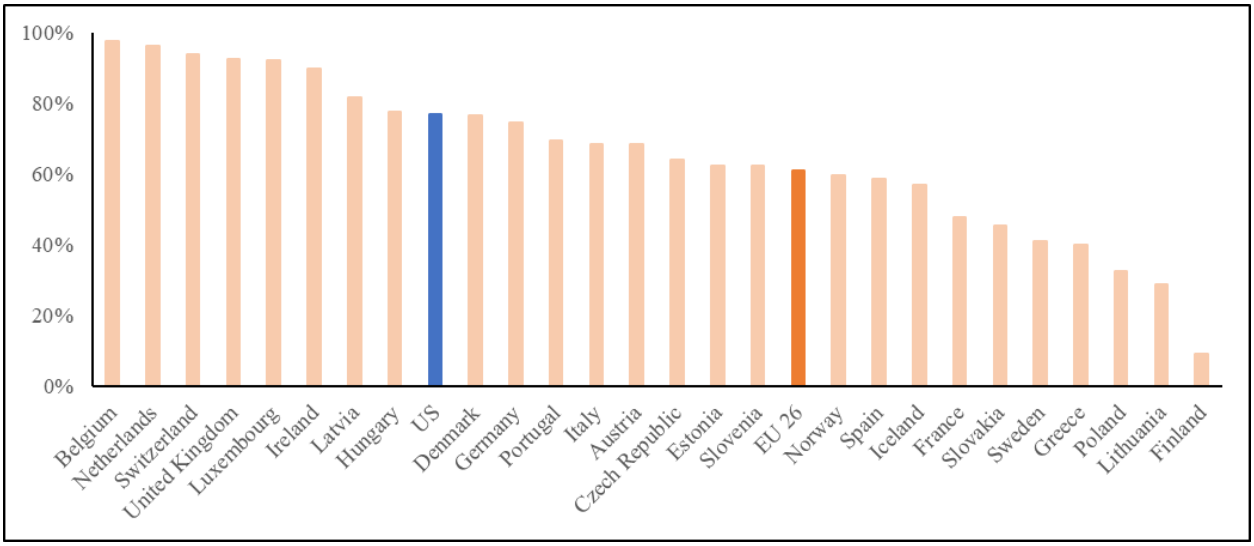
D. Rural High-Speed Broadband Deployment by Country

Fig. G-51: Fixed High-Speed Broadband Deployment by Country for All Rural Households (EU June 2018 and US December 2018)



***EU data from June and US data from December.

Fig. G-52: Fixed High-Speed Broadband Deployment by Country for All Rural Households (EU and US June 2019)



E. Comparison of 2 Mbps, 30 Mbps, and 100 Mbps Fixed Broadband Deployment in the United States and the EU26

Fig. G-53: Fixed High-Speed Broadband Deployment for All Households by Speed (EU June 2018 and US December 2018)

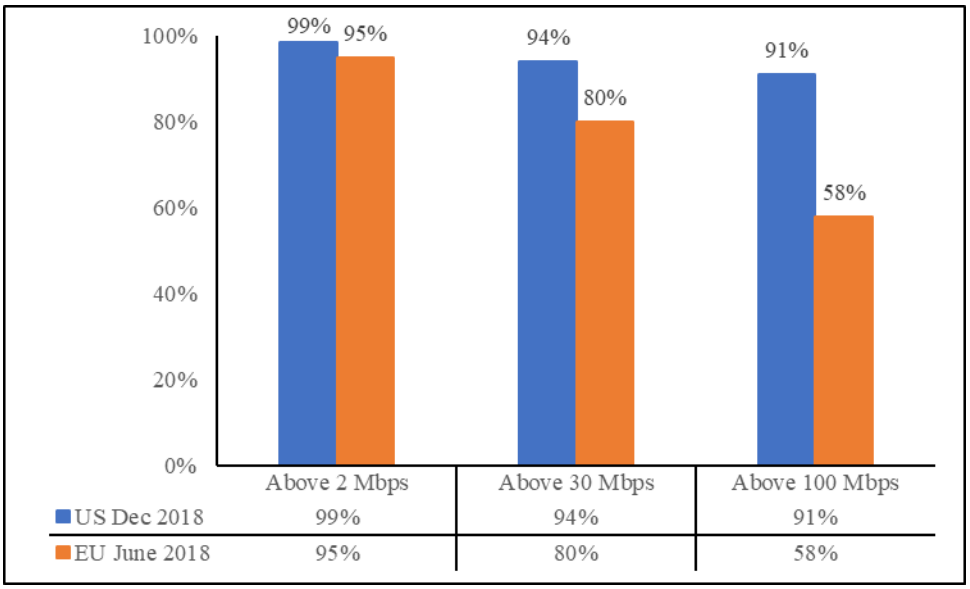
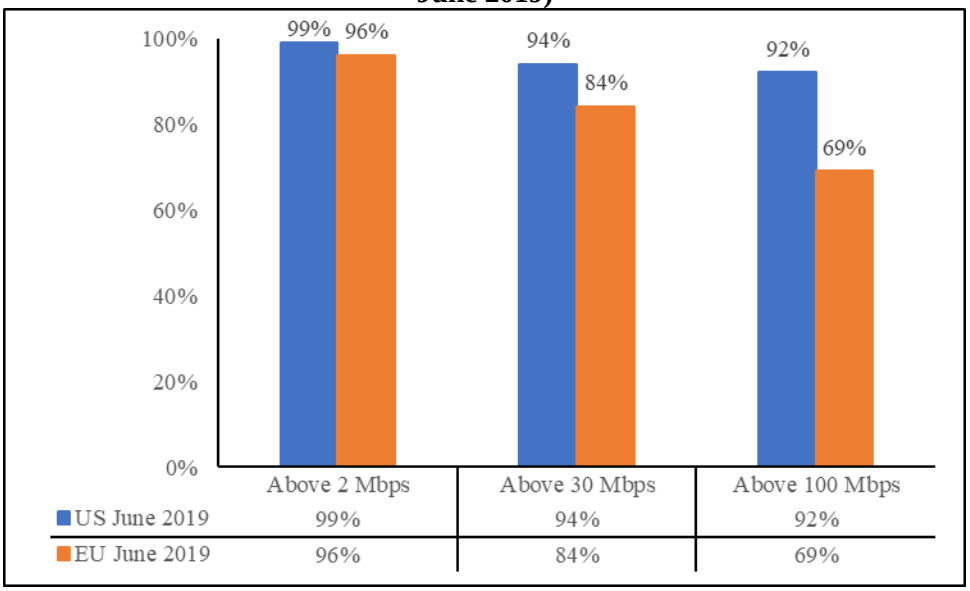
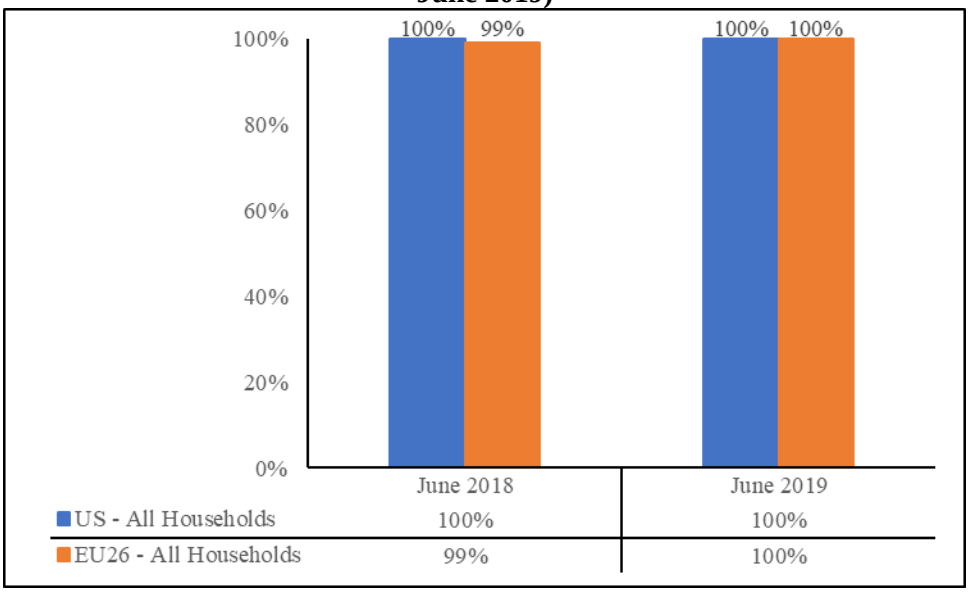


Fig. G-54: Fixed High-Speed Broadband Deployment for All Households by Speed (EU and US June 2019)



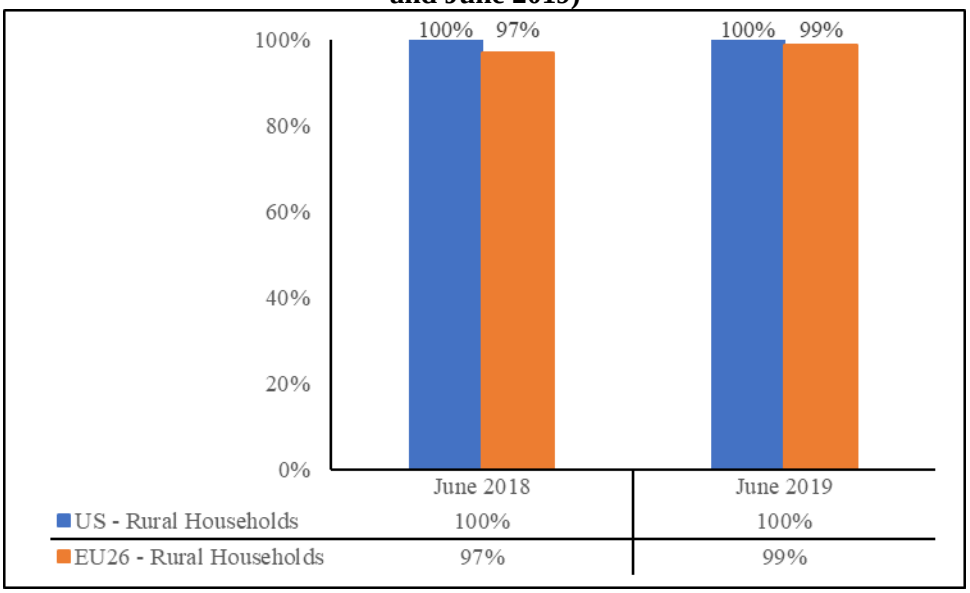
II. MOBILE HIGH-SPEED BROADBAND COMPARISON

Fig. G-55: 4G LTE Mobile Broadband Coverage for All Households (EU and US June 2018 and June 2019)



Note: Due to rounding, values of 100% should be interpreted as at least 99.5%.

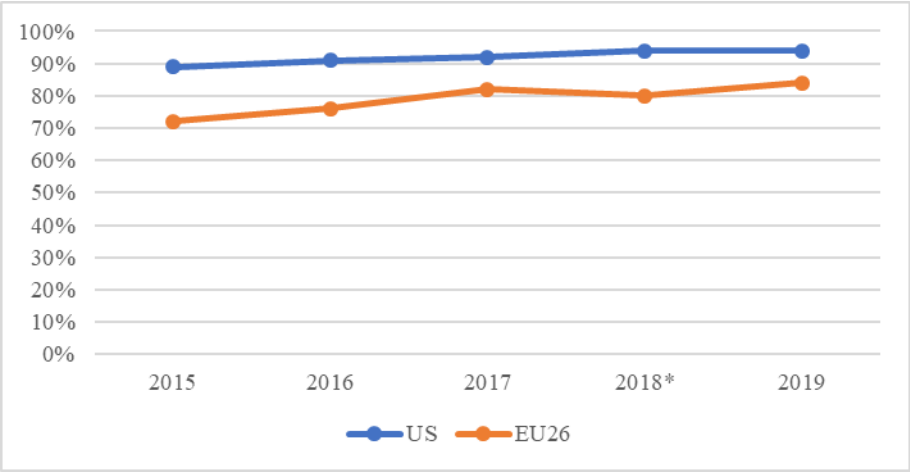
Fig. G-57: 4G LTE Mobile Broadband Coverage for All Rural Households (EU and US June 2018 and June 2019)



Note: Due to rounding, values of 100% should be interpreted as at least 99.5%.

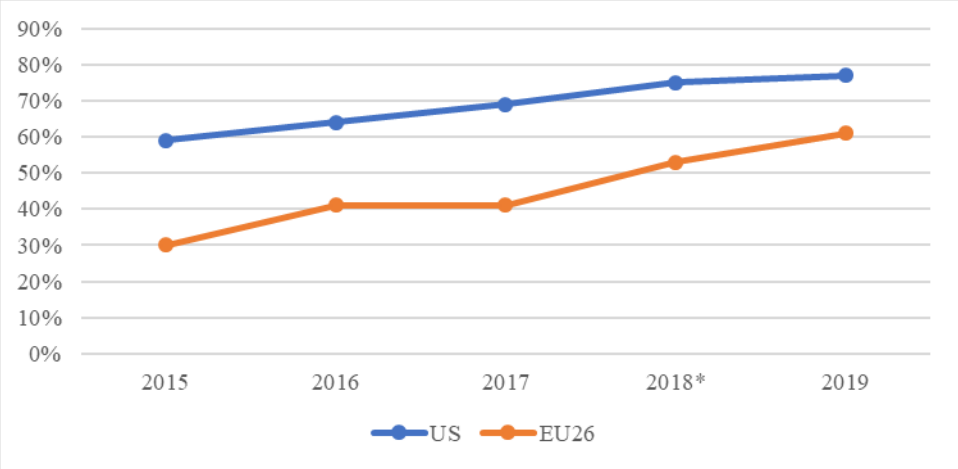
III. HISTORICAL OVERVIEW OF FIXED HIGH-SPEED DEPLOYMENT, 2015-2019

Fig. G-59: Fixed High-Speed Deployment, All Households



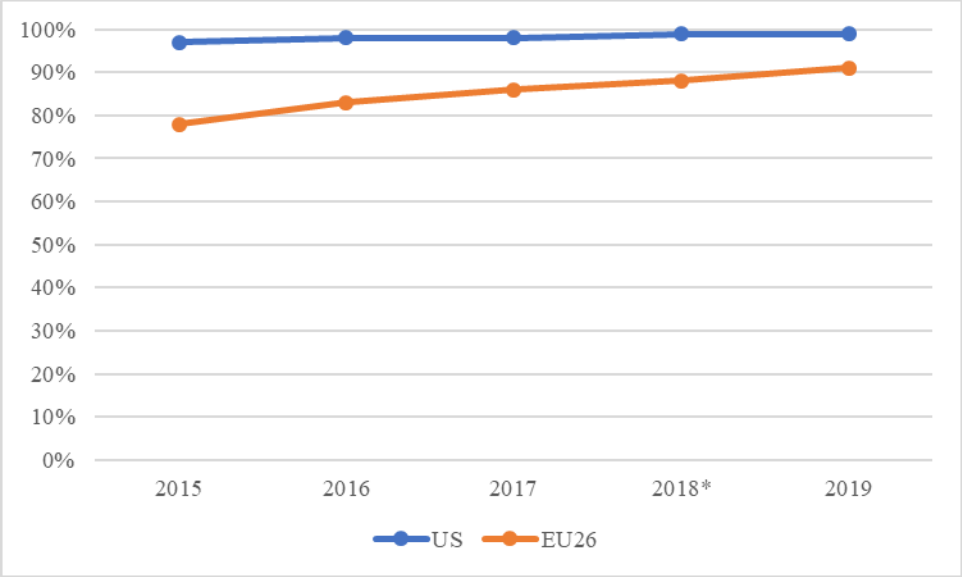
*****EU data from June and US data from December.

Fig. G-60: Fixed High-Speed Deployment, All Rural Households



*****EU data from June and US data from December.

Fig. G-61: Fixed High-Speed Deployment, Non-Rural Households



***EU data from June and US data from December.