APPENDIX G
INTERNATIONAL BROADBAND DATA REPORT

Section I. Country List

Section II. Broadband Deployment Comparisons

Section III. Broadband Speed and Performance Comparisons

Section IV. Broadband Pricing Comparisons

I. 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] The Commission 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 table below, we list the United States and 35 Organisation for Economic Co-operation and Development (OECD) comparison countries that meet the aforementioned criteria with consistent data for purposes of this *International Broadband Data Report* (*2024 IBDR*) and identify the countries that are included in each section with an "X" mark.[4] We refer to these countries as the "comparison countries." For the fixed and mobile deployment comparisons, we rely on 26 European comparison countries. For the fixed and mobile speed and performance comparison, we rely on 35 comparison countries. For the fixed and mobile broadband pricing comparisons, we rely on a smaller subset of 25 comparison countries.[5]

[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, Pub. L. No. 115-141, 132 Stat. 1087 (codified at 47 U.S.C. § 163) (2018) (RAY BAUM'S Act).

[2] 47 U.S.C. § 1303(b)(2).

[3] *Id*.

[4] For previous reports*, see, e.g.*, *Communications Marketplace Report et al.*, GN Docket No. 22-203, Report, 37 FCC Rcd 15514, Appx. G: International Broadband Data Report (2022) (*2022 International Broadband Data Report*); *Communications Marketplace Report et al.*, GN Docket No. 20-60, Report, 36 FCC Rcd 2945, Appx. G: International Broadband Data Report (2020) (*2020 International Broadband Data Report*); *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) (*Sixth International Broadband Data Report*).

[5] The OECD 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 *2022 International Broadband Data Report*. *See 2022 Communications Marketplace Report*, 37 FCC Rcd at 16336, Appx. G-1: International Broadband Data Report, para. 2.

Fig. I.A.1
Country List

Country	Section II. Deployment	Section III. Speed & Performance	Section IV. Price
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

II. BROADBAND DEPLOYMENT COMPARISON

3. In this section, we present fixed and mobile broadband deployment data for the United States and 26 European comparison countries[6] (Europe26).[7] Similar to the *2020 International Broadband Data Report* and the *2022 International Broadband Data Report*, we use the European Commission's (EC) 2023 Broadband Coverage in Europe Report and data[8] to compare the broadband deployment of 26 European countries with that of the United States, for which we rely upon the Broadband Data Collection (BDC) and FCC Form 477 data.[9] We present various figures on fixed broadband deployment by speed tier and by technology and on mobile deployment by technology, for individual countries and also for an aggregate Europe26 grouping of the 26 European OECD countries.

A. Comparison of European OECD Countries and United States

4. Figure II.A.1 presents the percentage of total households during 2023 with access to fixed broadband at a given download speed tier by country. Although most countries had extensive fixed broadband coverage at lower download speed tiers, the variation of fixed broadband availability across countries widened at higher download speed tiers. For instance, between approximately 68% and 100% of households had access to fixed broadband with a download speed greater than 30 Mbps. However, the percentage of households with access to fixed broadband with a download speed greater than 1 Gbps ranged from a low of 0% in Latvia to a high of approximately 98% in the Netherlands. Compared to its European counterparts, the United States ranked 17th, 10th, and 8th out of 27 countries (excluding the aggregate Europe26 grouping) in the percentage of households with access to fixed broadband with a download speed greater than 30 Mbps, 100 Mbps, and 1 Gbps, respectively.

[6] There is no comparable data for the other OECD countries. The OECD countries excluded from the deployment analysis are Australia, Canada, Chile, Israel, Japan, Mexico, New Zealand, South Korea, and Turkey.

[7] In all figures, Europe26 represents all 26 European OECD countries regardless of whether individual countries are excluded from the figures due to no reported deployment in the country (i.e., the households for countries with zero deployment are included in the Europe26 denominator).

[8] *See generally* European Commission, Broadband Coverage in Europe 2023 (July 2024), https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-broadband-coverage-europe-2023 (2023 Broadband Coverage in Europe Report) (the report and associated data (Broadband Coverage in Europe 2023 Data) can be accessed by clicking on the appropriate item listed under the "Downloads" sub header).

[9] Specifically, we use FCC Form 477 data for 2019 to 2021 and BDC data for 2022 to 2023; changes in deployment between 2021 and 2022 may be due to differences in the data source. For additional details, *see infra* section II.C.

Fig. II.A.1
Availability of Fixed Broadband by Download Speed Tier – Percentage of Total Households (2023)

Country	≥ 30 Mbps		≥ 100 Mbps		≥ 1000 Mbps	
	Rank	%	Rank	%	Rank	%
Austria	19	94.2%	17	87.5%	21	65.1%
Belgium	8	97.8%	4	96.9%	2	95.7%
Czech Republic	7	98.2%	13	91.1%	24	40.3%
Denmark	6	98.8%	3	98.0%	5	94.6%
Estonia	1	100.0%	21	84.4%	20	67.0%
Finland	26	81.0%	24	78.0%	18	71.0%
France	25	86.5%	22	82.1%	12	81.7%
Germany	14	96.1%	11	92.9%	16	73.6%
Greece	9	97.5%	27	60.7%	25	39.5%
Hungary	15	96.0%	9	95.1%	11	82.4%
Iceland	4	99.1%	14	89.3%	9	88.6%
Ireland	20	92.1%	12	91.6%	17	73.2%
Italy	18	94.2%	18	87.1%	23	59.6%
Latvia	27	68.3%	26	63.6%	27	0.0%
Lithuania	24	86.9%	19	86.9%	13	78.0%
Luxembourg	11	97.3%	8	95.4%	4	94.7%
Netherlands	5	98.9%	1	98.7%	1	98.2%
Norway	2	99.8%	5	96.6%	3	95.1%
Poland	23	86.9%	23	81.5%	15	75.1%
Portugal	16	95.7%	6	95.7%	7	89.5%
Slovakia	10	97.4%	20	84.7%	22	60.9%
Slovenia	21	91.9%	15	89.0%	26	10.9%
Spain	13	96.2%	7	95.7%	6	92.6%
Sweden	22	90.8%	16	89.0%	10	88.5%
Switzerland	3	99.8%	2	98.6%	19	68.3%
United Kingdom	12	97.2%	25	77.1%	14	75.1%
Europe26	-	93.9%	-	87.4%	-	75.6%
United States	**17**	**95.7%**	**10**	**94.6%**	**8**	**88.8%**

Source: BDC 2023 Data; Broadband Coverage in Europe 2023 Data.

5. Figures II.A.2 and II.A.3 present the percentage of total and rural households,[10] respectively, with access to fixed broadband using Fiber to the Premises (FTTP) technology by country over time. In general, the percentage of households with access to FTTP increased in all countries over time, even in rural areas. In the United States, the percentage of total households with access to FTTP increased from 38% in 2022 to approximately 42% in 2023, and the percentage of rural households with access to FTTP increased from approximately 24% in 2022 to approximately 30% in 2023. Compared to its European counterparts, in 2023, the United States ranked 22nd out of 27 countries in the percentage of total households with access to FTTP and 20th in the percentage of rural households with access to FTTP.

Fig. II.A.2
Availability of Fixed Broadband - FTTP – Percentage of Total Households (2019-2023)[11]

Country	2019		2020		2021		2022		2023	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Austria	23	13.8%	23	20.5%	23	26.6%	23	36.6%	23	41.0%
Belgium	27	3.6%	27	6.5%	27	10.1%	27	17.2%	27	25.0%
Czech Republic	22	29.3%	22	33.3%	22	35.8%	22	37.4%	25	36.0%
Denmark	7	66.9%	8	70.1%	8	74.1%	7	77.9%	5	84.0%
Estonia	11	57.4%	7	70.9%	9	73.4%	8	76.3%	13	76.9%
Finland	18	35.2%	19	37.7%	21	40.0%	19	50.3%	18	61.1%
France	13	43.8%	12	52.6%	12	63.4%	11	73.4%	7	81.4%
Germany	24	10.5%	25	13.8%	26	15.4%	26	19.3%	26	29.8%
Greece	26	7.1%	26	10.2%	25	19.8%	25	27.8%	24	38.4%
Hungary	14	42.6%	14	48.6%	11	64.2%	13	70.1%	14	76.2%
Iceland	1	80.4%	2	83.5%	3	87.6%	3	88.2%	3	91.0%
Ireland	17	35.4%	15	47.7%	14	62.2%	12	72.1%	10	78.5%
Italy	21	30.0%	21	33.7%	19	44.2%	18	53.7%	19	59.6%
Latvia	10	58.3%	11	59.8%	15	60.7%	16	60.9%	17	61.9%
Lithuania	9	61.0%	9	67.1%	5	78.2%	6	78.0%	11	78.1%
Luxembourg	6	67.5%	6	72.1%	7	75.2%	9	76.2%	8	78.9%
Netherlands	20	34.4%	20	35.6%	16	51.9%	15	63.4%	12	77.7%
Norway	5	71.4%	5	73.7%	6	75.3%	4	81.9%	4	87.2%
Poland	16	38.3%	16	44.6%	17	51.9%	17	59.5%	15	75.4%
Portugal	4	76.6%	3	82.3%	2	87.6%	2	90.8%	2	92.3%
Slovakia	12	44.3%	13	49.2%	13	62.3%	14	66.9%	16	64.2%
Slovenia	8	63.8%	10	65.6%	10	72.5%	10	75.5%	9	78.5%
Spain	2	80.4%	1	84.9%	1	88.9%	1	91.0%	1	95.2%
Sweden	3	77.1%	4	80.5%	4	82.5%	5	81.5%	6	83.9%
Switzerland	19	34.9%	18	39.7%	20	40.2%	20	43.1%	21	45.8%
United Kingdom	25	8.5%	24	14.5%	24	23.3%	24	36.3%	20	51.6%
Europe26	-	32.6%	-	37.6%	-	44.7%	-	51.9%	-	60.9%
United States	**15**	**41.1%**	**17**	**42.4%**	**18**	**44.7%**	**21**	**38.0%**	**22**	**42.2%**

Source: BDC 2022-2023 Data; FCC Form 477 2019-2021 Data; Broadband Coverage in Europe 2023 Data.

[10] The 2023 Broadband Coverage in Europe Report defines rural areas using a methodology that incorporates "the Corine land cover database" and "creates a database of population and land type in every square kilometre across Europe." 2023 Broadband Coverage in Europe Report at 26. Households "in square kilometres with a population of less than one hundred" are classified as rural. *Id.*

[11] In contrast, The Free State Foundation reports that 51.5% of U.S. homes have FTTP access as of 2023 based on analyst reports. FSF Comments at 2; FSF Reply at 2.

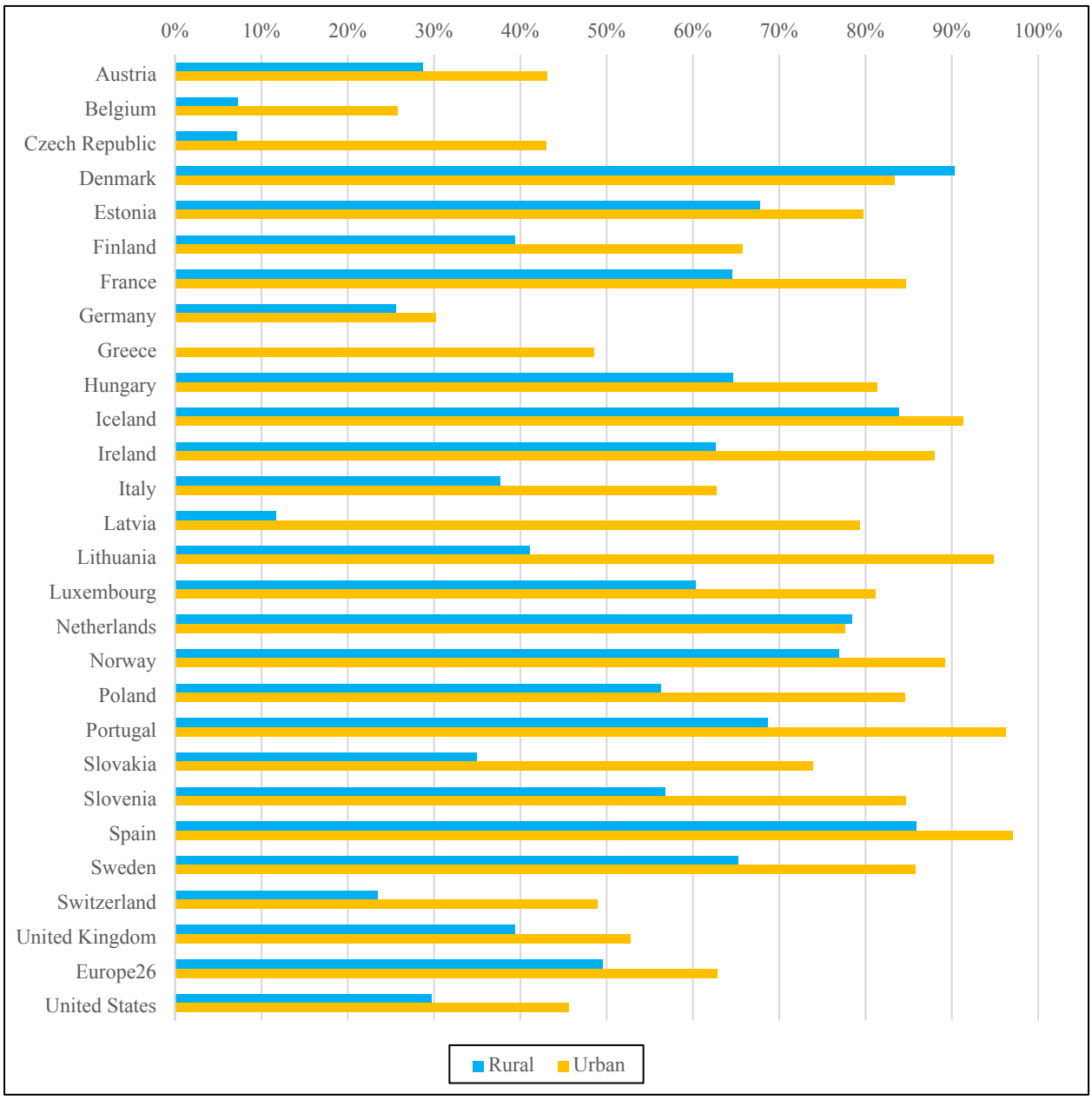
Fig. II.A.3
Availability of Fixed Broadband - FTTP – Percentage of Rural Households (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Austria	18	10.0%	20	10.6%	21	14.9%	21	22.6%	21	28.7%
Belgium	26	0.1%	26	0.4%	26	0.7%	26	1.3%	25	7.3%
Czech Republic	23	5.9%	25	6.4%	25	6.9%	25	8.1%	26	7.2%
Denmark	1	65.8%	1	70.9%	2	77.8%	1	87.0%	1	90.3%
Estonia	13	19.8%	15	20.5%	17	21.1%	14	33.9%	7	67.8%
Finland	20	9.1%	23	9.4%	22	12.4%	19	25.4%	17	39.3%
France	17	12.4%	17	18.4%	14	28.8%	12	45.9%	10	64.6%
Germany	24	5.6%	21	10.6%	23	11.3%	23	16.9%	22	25.6%
Greece	27	0.0%	27	0.0%	27	0.0%	27	0.0%	27	0.0%
Hungary	9	28.9%	9	35.6%	11	37.9%	10	52.4%	9	64.7%
Iceland	2	54.7%	2	66.3%	1	78.4%	2	78.7%	3	83.9%
Ireland	16	13.5%	14	20.6%	10	43.1%	9	54.3%	11	62.7%
Italy	25	2.1%	24	8.4%	20	17.3%	18	26.0%	18	37.7%
Latvia	19	9.2%	22	10.0%	24	11.0%	24	11.2%	24	11.7%
Lithuania	11	22.5%	13	23.3%	12	37.5%	13	39.5%	15	41.1%
Luxembourg	6	41.5%	6	48.5%	8	51.1%	8	58.2%	12	60.3%
Netherlands	10	26.4%	10	27.2%	6	54.5%	3	76.4%	4	78.4%
Norway	5	44.8%	4	56.3%	4	64.0%	5	70.4%	5	77.0%
Poland	14	17.9%	11	24.1%	13	32.6%	15	32.1%	14	56.3%
Portugal	3	49.1%	5	51.2%	5	60.7%	6	65.1%	6	68.7%
Slovakia	15	15.3%	18	18.0%	16	21.6%	16	31.2%	19	35.0%
Slovenia	8	38.0%	8	39.0%	9	46.4%	11	51.0%	13	56.8%
Spain	4	46.4%	3	59.5%	3	68.9%	4	73.9%	2	85.9%
Sweden	7	40.6%	7	48.1%	7	54.3%	7	59.6%	8	65.2%
Switzerland	21	8.6%	16	20.4%	18	21.1%	22	21.3%	23	23.5%
United Kingdom	22	8.1%	19	11.9%	19	20.2%	17	29.5%	16	39.4%
Europe26	-	17.0%	-	22.9%	-	29.9%	-	37.3%	-	49.5%
United States	**12**	**20.9%**	**12**	**23.9%**	**15**	**28.0%**	**20**	**24.1%**	**20**	**29.7%**

Source: BDC 2022-2023 Data; FCC Form 477 2019-2021 Data; Broadband Coverage in Europe 2023 Data.

6. Figure II.A.4 provides a side-by-side comparison of the percentages of households with access to FTTP in rural versus urban areas by country in 2023. With the exception of Denmark and the Netherlands, where rural households had slightly greater access to FTTP than urban households, the disparity in access to FTTP between rural and urban areas remained substantial in all countries in 2023.

Fig. II.A.4
Availability of Fixed Broadband - FTTP - Percentage of Rural and Urban Households (2023)



Source: BDC 2023 Data; Broadband Coverage in Europe 2023 Data.

7. Figure II.A.5 presents the percentage of total households with access to fixed broadband through either Data Over Cable Service Interface Specification (DOCSIS) 3.0 or 3.1 technology by country for the years 2019 to 2023, and Figure II.A.6 presents the percentage of rural households with access to fixed broadband through either DOCSIS 3.0 or 3.1 technology for the years 2019 to 2023. Compared to its European counterparts in 2023, the United States ranked 4th out of 27 countries in the percentage of total households, and 5th out of 27 countries in the percentage of rural households, with access to fixed broadband through either DOCSIS 3.0 or 3.1 technology.

Fig. II.A.5
Availability of Fixed Broadband – DOCSIS 3.0/3.1 – Percentage of Total Households (2019-2023)[12]

Country	2019		2020		2021		2022		2023	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Austria	12	53.2%	12	58.3%	10	59.3%	10	59.3%	10	59.4%
Belgium	2	93.5%	2	93.6%	1	96.5%	1	95.7%	1	96.0%
Czech Republic	18	41.1%	18	41.6%	16	41.9%	16	42.1%	17	38.5%
Denmark	7	68.4%	8	68.1%	9	67.5%	8	66.2%	8	66.1%
Estonia	8	67.4%	6	76.7%	6	78.5%	7	79.0%	7	77.3%
Finland	19	36.9%	19	37.8%	20	36.9%	19	37.9%	21	32.4%
France	22	27.0%	22	27.0%	23	23.1%	24	20.0%	24	19.7%
Germany	9	66.3%	9	66.9%	8	67.9%	9	62.8%	9	63.5%
Greece	25	0.5%	25	0.6%	26	0.0%	26	0.0%	26	0.0%
Hungary	6	74.5%	7	76.0%	7	78.2%	6	81.2%	6	77.6%
Iceland	26	0.3%	26	0.3%	25	3.3%	25	3.1%	25	3.1%
Ireland	14	49.2%	14	49.8%	14	48.6%	13	48.6%	14	41.9%
Latvia	23	22.6%	23	22.6%	24	22.5%	23	22.3%	23	22.2%
Lithuania	24	17.9%	24	19.4%	22	27.1%	22	26.5%	22	25.6%
Luxembourg	5	83.9%	3	88.9%	3	90.2%	3	88.3%	3	87.6%
Netherlands	1	95.2%	1	95.2%	2	94.2%	2	94.1%	2	88.6%
Norway	16	45.1%	16	44.5%	17	40.3%	18	40.7%	16	40.8%
Poland	17	44.1%	17	43.4%	15	43.9%	15	43.4%	15	41.8%
Portugal	10	59.5%	10	59.4%	12	57.6%	12	57.5%	12	57.8%
Slovakia	21	32.2%	21	32.9%	18	39.4%	17	40.7%	18	37.8%
Slovenia	11	57.6%	11	58.7%	11	58.5%	11	58.4%	11	58.0%
Spain	15	48.9%	15	45.8%	19	38.4%	21	33.0%	20	32.8%
Sweden	20	35.7%	20	37.3%	21	35.8%	20	33.4%	19	33.5%
Switzerland	4	84.4%	5	84.3%	4	85.2%	5	85.2%	5	85.8%
United Kingdom	13	50.3%	13	50.3%	13	50.3%	14	48.2%	13	45.9%
Europe26	-	46.0%	-	46.1%	-	45.3%	-	43.3%	-	42.4%
United States	**3**	**88.4%**	**4**	**88.3%**	**5**	**84.5%**	**4**	**86.2%**	**4**	**87.3%**

Source: BDC 2022-2023 Data; FCC Form 477 2019-2021 Data; Broadband Coverage in Europe 2023 Data.

[12] The Broadband Coverage in Europe Reports from 2023, 2022, and 2021 indicate that Italy had no deployment of DOCSIS 3.0/3.1 from 2019 to 2023. 2023 Broadband Coverage in Europe Report at 142; European Commission, Broadband Coverage in Europe 2022 at 139 (Sept. 2023), https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2022 (2022 Broadband Coverage in Europe Report); European Commission, Broadband Coverage in Europe 2021 at 124 (July 2022), https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2021 (2021 Broadband Coverage in Europe Report). Europe26 includes all 26 countries, including Italy.

Fig. II.A.6
Availability of Fixed Broadband – DOCSIS 3.0/3.1 – Percentage of Rural Households (2019-2023)[13]

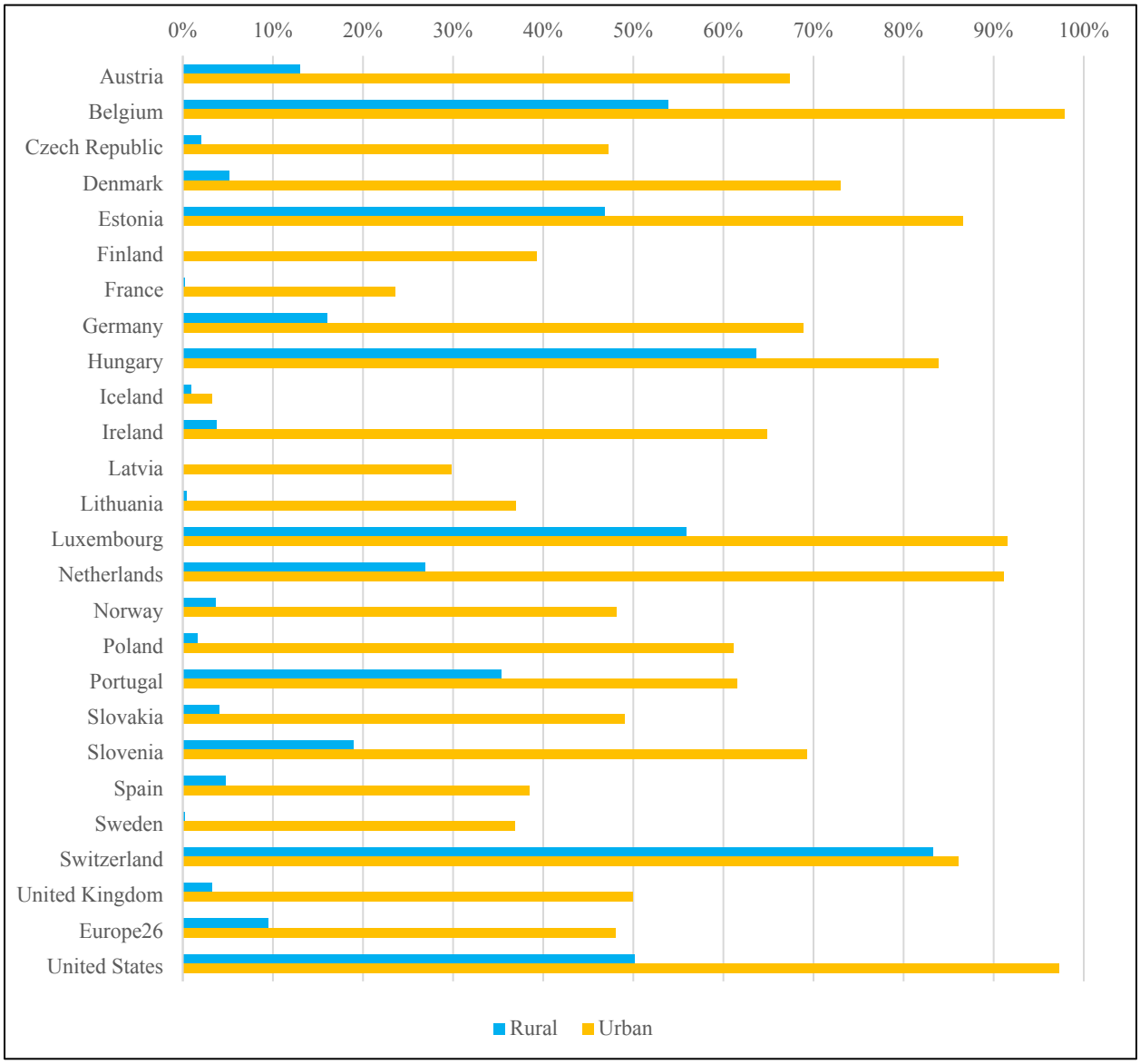
Country	2019		2020		2021		2022		2023	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Austria	9	20.4%	9	21.2%	11	12.6%	11	12.8%	11	13.1%
Belgium	3	48.3%	5	48.5%	5	54.6%	2	70.2%	4	53.9%
Czech Republic	15	3.4%	15	3.5%	15	3.6%	15	3.8%	18	2.0%
Denmark	13	5.9%	13	5.5%	13	5.3%	12	5.3%	12	5.1%
Estonia	8	23.5%	8	23.6%	8	23.7%	7	30.7%	6	46.8%
France	20	0.7%	20	0.7%	23	0.3%	23	0.3%	23	0.2%
Germany	11	16.9%	11	16.9%	10	17.5%	10	15.3%	10	16.0%
Hungary	4	47.1%	4	53.3%	3	57.7%	3	63.6%	2	63.7%
Iceland	23	0.0%	23	0.0%	20	1.0%	20	0.9%	20	0.9%
Ireland	14	3.7%	14	3.7%	14	3.8%	14	3.8%	15	3.8%
Lithuania	21	0.4%	21	0.5%	21	0.5%	21	0.5%	21	0.5%
Luxembourg	6	33.0%	2	62.9%	2	60.1%	4	57.3%	3	55.9%
Netherlands	7	28.5%	7	28.5%	7	28.5%	8	28.5%	8	26.9%
Norway	17	2.9%	18	1.5%	18	1.7%	19	1.1%	16	3.6%
Poland	18	1.5%	19	1.5%	19	1.6%	18	1.6%	19	1.7%
Portugal	5	43.5%	6	43.5%	6	43.3%	6	35.3%	7	35.3%
Slovakia	19	1.2%	17	1.7%	17	2.6%	17	2.9%	14	4.0%
Slovenia	10	19.7%	10	19.8%	9	19.3%	9	20.1%	9	19.0%
Spain	12	11.2%	12	10.8%	12	6.3%	13	4.6%	13	4.8%
Sweden	22	0.3%	22	0.3%	22	0.3%	22	0.3%	22	0.3%
Switzerland	1	79.8%	1	79.6%	1	82.2%	1	83.3%	1	83.3%
United Kingdom	16	3.1%	16	3.1%	16	3.2%	16	3.2%	17	3.3%
Europe26	-	9.7%	-	10.0%	-	9.8%	-	9.6%	-	9.5%
United States	**2**	**54.6%**	**3**	**54.6%**	**4**	**55.9%**	**5**	**50.1%**	**5**	**50.2%**

Source: BDC 2022-2023 Data; FCC Form 477 2019-2021 Data; Broadband Coverage in Europe 2023 Data.

[13] The Broadband Coverage in Europe Reports from 2023, 2022, and 2021 indicate that Finland, Greece, Italy, and Latvia had no deployment of DOCSIS 3.0/3.1 for rural households from 2019 to 2023. 2023 Broadband Coverage in Europe Report at 106, 122, 142, 147; 2022 Broadband Coverage in Europe Report at 103, 119, 139, 144; 2021 Broadband Coverage in Europe Report at 92, 107, 124, 128. Europe26 includes all 26 countries, including Finland, Greece, Italy, and Latvia.

8. Figure II.A.7 provides a side-by-side comparison of the percentages of households with access to fixed broadband through either DOCSIS 3.0 or 3.1 technology in rural versus urban areas by country in 2023. Figure II.A.7 shows that the availability of either DOCSIS 3.0 or 3.1 technology is uniformly more widely available in urban areas than in rural areas.

Fig. II.A.7
Availability of Fixed Broadband - DOCSIS 3.0/3.1 – Percentage of Rural and Urban Households (2023)[14]



Source: BDC 2023 Data; Broadband Coverage in Europe 2023 Data.

[14] The 2023 Broadband Coverage in Europe Report indicates that Italy and Greece had no deployment of DOCSIS 3.0/3.1 in 2023. 2023 Broadband Coverage in Europe Report at 122, 142. Europe26 includes all 26 countries, including Italy and Greece.

9. Figure II.A.8 presents the percentage of total households with access to mobile broadband using 5G technology (5G) by country for the years 2021 to 2023, and Figure II.A.9 presents the percentage of rural households with access to 5G service by country over the same time period. In comparison to its European counterparts, the United States ranked 11th out of 27 countries in the percentage of total households, and 14th out of 27 countries in the percentage of rural households, with access to 5G networks in 2023. In 2023, 96.6% of total households and 85.1% of rural households in the United States had access to 5G networks.

Fig. II.A.8
Availability of Mobile Broadband – 5G – Percentage of Total Households (2021-2023)

Country	2021		2022		2023	
	Rank	%	Rank	%	Rank	%
Austria	7	76.8%	9	91.7%	12	96.0%
Belgium	25	4.2%	26	29.6%	27	40.4%
Czech Republic	13	49.4%	14	82.6%	14	94.6%
Denmark	3	98.0%	3	97.8%	1	100.0%
Estonia	20	18.3%	23	43.3%	19	87.5%
Finland	10	71.6%	6	94.7%	7	98.3%
France	8	74.4%	11	88.8%	15	93.2%
Germany	6	86.5%	8	93.2%	8	98.1%
Greece	11	66.1%	12	85.7%	10	98.1%
Hungary	22	17.6%	20	57.9%	21	83.7%
Iceland	14	41.0%	25	41.6%	17	91.6%
Ireland	9	72.1%	13	83.9%	20	85.3%
Italy	1	99.7%	2	99.7%	4	99.5%
Latvia	26	0.0%	24	42.0%	26	53.1%
Lithuania	18	33.3%	10	90.1%	5	98.9%
Luxembourg	24	12.7%	7	93.2%	3	99.6%
Netherlands	4	97.0%	1	100.0%	2	100.0%
Norway	19	23.8%	16	81.5%	13	95.3%
Poland	17	34.2%	19	63.4%	25	71.9%
Portugal	26	0.0%	17	70.1%	9	98.1%
Slovakia	23	13.8%	22	55.3%	24	79.0%
Slovenia	16	36.6%	18	63.9%	22	82.1%
Spain	12	58.9%	15	82.3%	16	92.3%
Sweden	21	17.7%	27	20.5%	18	90.3%
Switzerland	5	94.6%	4	96.8%	6	98.5%
United Kingdom	15	37.9%	21	57.2%	23	80.9%
Europe26	-	64.0%	-	80.2%	-	90.6%
United States	**2**	**99.3%**	**5**	**95.7%**	**11**	**96.6%**

Source: BDC 2022-2023 Data; FCC Form 477 2021 Data; Broadband Coverage in Europe 2023 Data.

Fig. II.A.9
Availability of Mobile Broadband – 5G – Percentage of Rural Households (2021-2023)

Country	2021		2022		2023	
	Rank	%	Rank	%	Rank	%
Austria	9	36.3%	11	68.9%	15	82.0%
Belgium	25	0.0%	20	21.2%	25	28.9%
Czech Republic	8	43.3%	6	78.0%	16	72.7%
Denmark	2	98.0%	3	99.2%	1	100.0%
Estonia	21	1.5%	19	32.5%	12	87.0%
Finland	12	18.9%	7	77.6%	8	92.4%
France	7	48.2%	10	73.5%	10	91.2%
Germany	6	49.4%	9	74.8%	7	92.8%
Greece	13	17.3%	14	57.8%	9	92.1%
Hungary	14	7.0%	18	33.8%	21	57.5%
Iceland	15	6.7%	24	7.9%	26	11.8%
Ireland	10	36.2%	13	58.3%	19	62.3%
Italy	1	99.8%	2	99.8%	3	98.3%
Lithuania	23	0.8%	8	75.6%	5	96.4%
Luxembourg	16	6.7%	16	46.7%	4	96.9%
Netherlands	3	96.8%	1	100.0%	2	100.0%
Norway	17	4.5%	12	59.8%	13	85.4%
Poland	22	1.1%	25	2.8%	20	58.5%
Portugal	25	0.0%	21	20.8%	11	87.5%
Slovakia	20	2.4%	17	39.3%	23	46.1%
Slovenia	19	2.8%	22	14.1%	24	45.5%
Spain	11	24.8%	15	48.3%	17	67.4%
Sweden	24	0.5%	26	0.5%	18	67.0%
Switzerland	4	88.8%	4	90.0%	6	93.0%
United Kingdom	18	4.4%	23	10.0%	22	52.4%
Europe26	-	32.5%	-	51.0%	-	76.5%
United States	**5**	**86.0%**	**5**	**81.9%**	**14**	**85.1%**

Source: BDC 2022-2023 Data; FCC Form 477 2021 Data; Broadband Coverage in Europe 2023 Data.

10. Figure II.A.10 provides a side-by-side comparison of the percentage of households with access to mobile broadband service through 5G networks in rural versus urban areas by country in 2023. While the deployment of 5G networks increased substantially between 2021 and 2023 in most countries, Figure II.A.10 shows that 5G deployment in rural areas still lagged behind that in urban areas.

Fig. II.A.10
Availability of Mobile Broadband – 5G – Percentage of Rural and Urban Households (2023)

Source: BDC 2023 Data; Broadband Coverage in Europe 2023 Data.

B. Summary of 2023 Broadband Coverage in Europe Report Methodology

11. For the 2023 Broadband Coverage in Europe Report, a survey of national regulators and broadband network operators was conducted and validated against other available data (e.g., market reports, Internet service providers' financial reports and press releases, etc.).[15] Survey respondents were asked to submit the number of total and rural households in each Nomenclature of Territorial Units for Statistics (NUTS) 3 region[16] covered by a technology or set of technologies.[17] In addition, respondents were also asked to provide the number of households covered by networks that are able to achieve download speeds of at least 30 Mbps, 100 Mbps, and 1 Gbps.[18]

12. Survey respondents were provided with estimates of the number of total households and rural households in each NUTS 3 region by using the NUTS 3 level population data and average household size data published annually by Eurostat for each country.[19] To calculate the number of rural households in each NUTS 3 region, the Corine land cover database was used to determine the population and land type of each square kilometer in Europe; households in square kilometers with a population of less than 100 (i.e., a population density of less than 100 per square kilometer) are classified as rural.[20] Data integration was done country-by-country.[21] First, estimates were obtained for each technology at the NUTS 3 level, which were then used to estimate technology combinations.[22] Second, the regional data were summed to the national level.[23] The integration process accounted for areas in which coverage of the same technology was provided by multiple operators to avoid double counting households.[24]

13. To estimate coverage by download speed tier, the survey included questions asking respondents to report the number of households at the country level "having technical access to one or more networks supporting at least the relevant download/upload speed."[25] A household was defined as having technical access "if the connection's broadband speed was capable of achieving the relevant speed during the whole peak time period – i.e., the time of the day with a typical duration of one hour when the network load is at its maximum."[26] For each speed tier (i.e., at least 30 Mbps, 100 Mbps, or 1 Gbps), the set of technologies capable of reaching the speed were specified and respondents were asked to exclude connections that did not meet the criteria.[27] Regarding 5G coverage, the EC's research team used official

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[15] 2023 Broadband Coverage in Europe Report at 25.

[16] NUTS 3 level areas are regional units of 150,000 to 800,000 inhabitants. 2023 Broadband Coverage in Europe Report at 22.

[17] 2023 Broadband Coverage in Europe Report at 25.

[18] *Id*.

[19] *Id.* at 26. Updated annual household values are not available for all relevant countries. Therefore, the 2023 Broadband Coverage in Europe Report estimates annual number of households using NUTS 3 population and average household size data and uses these estimates for all countries for consistency. *Id*.

[20] *Id*; *see also* Copernicus Land Monitoring Service, *Corine Land Cover*, https://land.copernicus.eu/en/products/corine-land-cover (last visited Sept. 24, 2024).

[21] 2023 Broadband Coverage in Europe Report at 26.

[22] *Id*.

[23] *Id*.

[24] *Id.* at 26-27.

[25] *Id*. at 29.

[26] *Id*.

[27] *Id.* at 28-29. For the 30 Mbps tier, the category included Very-high-bit-rate Digital Subscriber Line (VDSL, including VDSL2 Vectoring), FTTP, Fixed Wireless Access (FWA, including 4G TD LTE standard and 5G FWA), (continued….)

regulatory data on 5G rollouts in addition to reviewing information published by network operators on the cities and areas where their 5G networks and services had been launched.[28]

C. Summary of Methodology to Compare BDC and FCC Form 477 Data with Broadband Coverage in Europe 2023 Data

14. For our comparative analysis of European OECD countries with the United States,[29] we rely upon FCC Form 477 fixed broadband and mobile broadband deployment data,[30] and, for the first time, we use the more precise, granular data from the Commission's BDC. Although the Broadband Coverage in Europe 2023 Data and the BDC and FCC Form 477 data are collected under different methodologies and definitions, we use the BDC data and the census block level FCC Form 477 data to recreate the statistics by technology and speed tiers at overall and rural breakdowns for the United States. Below, we describe our methodology for using the BDC and FCC Form 477 data to make the most accurate comparison with the EC statistics as possible.

15. For fixed broadband comparisons, we use the FCC Form 477 data at three vintage points—June 2019, June 2020, and June 2021. FCC Form 477 fixed broadband data indicate whether a provider deploys a specific technology to at least one location in each census block, along with the associated maximum download and upload speeds.[31] Additionally, we use BDC data at two vintage points—June 2022 and June 2023. As part of the BDC, the Commission creates a Broadband Serviceable Location Fabric (fabric) which contains all locations in the United States where broadband either can be or has been installed. Providers of fixed broadband services are subsequently required to report each location where they can make service available along with the corresponding technology, download speed, and upload speed.[32]

16. For figures presenting deployment by technology (or set of technologies) using FCC Form 477 data, we identify each block that is covered by at least one provider with the technology (or set

and DOCSIS 3.0/3.1 cable broadband. 2023 Broadband Coverage in Europe Report at 28. For the 100 Mbps tier, the category included VDSL2 Vectoring, FTTP, DOCSIS 3.0/3.1 cable broadband, and 5G FWA (if speeds higher than 100 Mbps are attainable over 5G FWA). *Id.* at 29. For the 1 Gbps tier, the category included FTTP and DOCSIS 3.1 cable broadband. *Id*.

[28] 2023 Broadband Coverage in Europe Report at 29.

[29] Our analysis includes the 50 U.S. states and Washington, D.C. (i.e., we do not include any U.S. territories).

[30] FCC, *Form 477 Resources*, https://www.fcc.gov/economics-analytics/industry-analysis-division/form-477-resources (last visited July 15, 2024). All FCC Form 477 data used in this *2022 IBDR* have been certified as accurate by the filers. We note that the *2022 IBDR*'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 July 15, 2024) (describing quality and consistency checks performed on providers' submitted data and explaining any adjustments made to the FCC Form 477 data as filed).

[31] Census block populations range from 0 to about 19,000, and households range from 0 to about 2,600.

[32] *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion*, GN Docket No. 22-270, 2024 Section 706 Report, FCC 24-27, at 27-29, paras. 52, 54 (Mar. 18, 2024) (*2024 Section 706 Report*).

of technologies),[33] and assume that all households in the census block are covered.[34] Then, we aggregate block-level coverage to the national level for total, urban, and rural[35] households and divide them, respectively, by total, urban, and rural households to calculate the percentage of covered households.[36] For figures presenting deployment by technology (or set of technologies) using BDC data, we identify all locations that are served by at least one provider with that technology (or set of technologies),[37] estimate the number of households in each these locations, aggregate this value to the national level for total, urban, and rural[38] households and divide them, respectively, by total, urban, and rural households to calculate the percentage of covered households.

17. For figures presenting deployment by download speed tier, we follow a similar approach as described above for figures presenting deployment by technology or set of technologies. For download speed tiers, the 2023 Broadband Coverage in Europe Report categorizes households by technology and download speed so households with a particular technology deployed, but not at the download speed threshold, are excluded from the household count; therefore, we use the technology codes to identify census blocks and locations with the relevant technology (or set of technologies) deployed but exclude census blocks and locations that do not meet the download speed threshold.

18. For mobile broadband comparisons, we use the most recent version of FCC Form 477 Actual Area methodology deployment data from June 2021 to estimate the number of households covered by at least one provider with 5G technology. For each census block, we use the percentage of area covered and assume households are uniformly distributed within the census block (i.e., if 10% of the census block is covered by at least one provider, we assumed 10% of households in that block are covered). For annual block level estimates of households, we use the FCC's Staff Block Estimates.[39] We then aggregate the data to the national level (total, urban, and rural) to estimate the number of households covered by each mobile broadband technology. Additionally, we use BDC mobile availability data from

[33] We match the broadband technologies collected in the 2023 Broadband Coverage in Europe Report with the FCC Form 477 technology codes described below. To match the EC Cable Modem DOCSIS 3.0 definition, which includes DOCSIS 3.1, we use the FCC Form 477 technology codes 42 (Cable Modem – DOCSIS 3.0) and 43 (Cable Modem DOCSIS 3.1), but do not include 41 (Cable Modem – DOCSIS 1, 1.1, and 2.0) or 44 (Cable Modem – DOCSIS 4.0). To match the European FTTP definitions, we use the FCC Form 477 technology code 50 (Optical Carrier / Fiber to the End User).

[34] A block is defined as covered by a set of technologies if the block is covered by at least one of the technologies in the set.

[35] For the FCC Form 477 data between 2019 and 2021, we use the U.S. Census Bureau classifications of Urbanized Area and Urban Clusters to identify each census block as urban, with non-urban blocks being classified as "rural." U.S. Census Bureau, *2010 Census Urban and Rural Classification and Urban Area Criteria* (Oct. 28, 2021), https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html.

[36] June 2021 FCC Form 477 data use 2010 census definitions. As such, 2021 household estimates are calculated using 2020 data, which also rely on 2010 census definitions. *See* FCC, *Staff Block Estimates*, https://www.fcc.gov/economics-analytics/industry-analysis-division/staff-block-estimates (last visited Aug. 1, 2024) (Staff Block Estimates).

[37] To match the EC Cable Modem DOCSIS 3.0 definition, which includes DOCSIS 3.1, we use BDC technology code 40 (Coaxial Cable / Hybrid-Fiber Coax). Unlike the Form 477 data collection which utilized distinct technology codes for various types of DOCSIS (e.g., 42 for DOCSIS 3.0 and 43 for DOCSIS 3.1), the BDC does not make these distinctions and collects all cable technologies using a single category. To match the European FTTP definitions, we use the BDC technology code 50 (Optical Carrier / Fiber to the Premises).

[38] For the BDC data between 2022 and 2023, we rely on the 2020 Census block geographies to identify each Census block as "urban", with non-urban blocks being classified as "rural." U.S. Census Bureau, *Urban and Rural* (Sept. 26, 2023), https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html.

[39] *See generally* Staff Block Estimates.

the two vintages – June 2022 and June 2023 – to estimate the number of households covered by at least one provider with 5G New Radio (5G-NR) technology. The BDC requires providers to submit coverage polygons that indicate the exact areas where they can provide service using 5G-NR with a minimum expected speed of 7/1 Mbps. To estimate the availability of this service, we intersect the fabric with coverage polygons submitted by mobile broadband providers and the H3 geospatial indexing system.[40] We consider all locations within a resolution 9 hexagon to be served if the centroid of the hexagon falls within the polygon indicating availability.[41] We then estimate the number of households within these locations, aggregate these values to the national level and divide them, respectively, by total, urban, and rural households to calculate the percentage of covered households.

D. Caveats to Broadband Coverage in Europe Data and BDC and FCC Form 477 Data Comparisons

19. Given that the European data source and the two U.S. data sources used for the European and U.S. comparisons are independent data collections undertaken by distinct entities for different purposes, any comparisons should be interpreted carefully because definitions used by the European data source and the two U.S. data sources are not necessarily the same for various elements of the data collections. For instance, the definitions of rural areas are different between the Broadband Coverage in Europe 2023 Data and the U.S. data. As described above, the EC classifies a household in Europe as rural if the square kilometer where the household is located has a population of fewer than 100 persons, whereas the U.S. analysis uses the U.S. Census Bureau's classification of "urban" to define "non-urban" (i.e., rural) areas at the census block level.[42] It is not clear how use of a consistent definition of rural households would affect the deployment estimates for the various countries. Also, differences in the definitions of deployed technologies between the Broadband Coverage in Europe 2023 Data and the BDC and FCC Form 477 data may also make the comparisons imperfect. Similarly, the definition of "households" may not be identical between the U.S. Census Bureau and the EC.[43]

20. Despite these caveats, the comparisons between the European comparison countries and the United States are the best possible given the available data on broadband deployment. Where possible, we have matched the national level statistics from the Broadband Coverage in Europe 2023 Data by following the most similar definitions used by the U.S. data.

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[40] Isaac Brodsky, Uber, *H3: Uber's Hexagonal Hierarchical Spatial Index* (June 27, 2018), https://eng.uber.com/h3/. In other words, three different maps, one of hexagons, one of latitudes and longitudes, and one of mobile coverage, are overlayed to deduce overlap.

[41] In other words, we consider a hexagon to be served if the mobile coverage map covers the center of the hexagon, and we then consider a location, i.e., a latitude and a longitude, to be served if the location is inside of a served hexagon. The size of a resolution 9 hexagon is relatively small with the average hexagon being 0.105 km^2. H3, *Table of Cell Statistics Across Resolutions*, https://h3geo.org/docs/core-library/restable (last visited Nov. 1, 2024).

[42] Starting in 2020, the U.S. Census defines an area as urban if the territory identified encompasses at least 2,000 housing units or has a population of at least 5,000. U.S. Census Bureau, *Urban and Rural* (Sept. 26, 2023), https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html. This definition differs from the 2010 U.S. Census definition that we rely upon for the FCC Form 477 Data between 2019 and 2021 which defined an area as urban if the territory identified encompassed at least 2,500 people, at least 1,500 of which resided outside institutional group quarters. U.S. Census Bureau, *2010 Census Urban and Rural Classification and Urban Area Criteria* (Oct. 28, 2021), https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html.

[43] Eurostat, *Glossary: Household – Social Statistics,* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Household_-_social_statistics (last visited May 9, 2024); U.S. Census Bureau, *Subject Definitions*, https://www.census.gov/programs-surveys/cps/technical-documentation/subject-definitions.html#household (last visited May 9, 2024).

III. BROADBAND SPEED AND PERFORMANCE COMPARISONS

21. This section of the *International Broadband Data Report* presents a comparison of fixed broadband and mobile wireless broadband performance metrics in terms of data transmission speeds (download and upload speeds) and latency for the United States and 35 comparison countries. The main analysis relies solely on user-initiated Ookla Speedtest datasets for both speed and latency.[44] For fixed broadband, we consider any technologies reported in the Ookla Speedtest datasets, and for mobile broadband, we consider 4G Long-Term Evolution (LTE) and 5G, separately. In this *Report*, we present an analysis of download and upload speeds, as well as an analysis of latency,[45] with a five-year time horizon for fixed broadband services and mobile 4G LTE broadband services and a three-year time horizon for mobile 5G broadband services.[46] We rank speeds from the fastest (1st) to the slowest (36th) and latency from the lowest (1st) to the highest (36th).

A. Fixed Broadband Speed and Latency Results

22. Figure III.A.1 compares the mean fixed broadband download speeds by country for the years 2019 to 2023. The U.S. mean download speed ranking rose to 6th among the 36 countries for 2022 and 2023, up from a ranking of 9th in 2021. In 2023, the mean download speed for the United States was 271.4 Mbps, more than double the 2019 mean download speed of 119.6 Mbps. Chile had the fastest mean download speed in 2023 at 307.2 Mbps.

[44] Ookla, *Ookla's Speedtest Methodology* (June 24, 2024), https://www.ookla.com/resources/guides/speedtest-methodology.

[45] Latency is the measure of the time it takes a packet of data to travel from one point in the network to another, and is typically measured by round-trip time in milliseconds (ms).

[46] For the mobile 5G analysis, we only present data for the years 2021 to 2023.

Fig. III.A.1
Fixed Broadband Mean Download Speed by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	33	38.7	33	49.3	33	76.9	33	82.4	33	99.3
Austria	32	43.8	30	64.7	27	102.1	30	123.5	30	149.0
Belgium	23	72.2	25	87.6	25	110.9	27	135.6	24	166.0
Canada	7	114.3	10	136.0	10	173.8	11	212.2	9	256.0
Chile	19	77.2	13	124.6	5	200.9	2	267.3	1	307.2
Czech Republic	31	50.4	32	62.4	31	82.8	31	103.6	31	127.9
Denmark	12	103.3	3	154.5	4	207.3	4	243.1	5	280.4
Estonia	29	55.4	29	66.7	32	78.7	32	93.1	32	110.3
Finland	25	66.0	24	93.5	24	119.8	22	153.3	22	176.2
France	9	114.0	4	151.8	8	197.3	5	242.2	3	291.8
Germany	24	71.1	22	98.0	23	122.1	24	144.2	29	155.0
Greece	35	23.8	35	29.8	35	37.8	36	49.0	36	68.8
Hungary	3	124.3	6	149.6	6	200.2	8	231.2	8	258.1
Iceland	1	164.1	1	208.3	1	253.1	1	268.8	4	289.4
Ireland	20	76.4	23	93.9	22	122.4	23	147.1	23	175.3
Israel	21	76.3	20	105.9	16	155.6	13	193.4	11	247.7
Italy	30	52.2	31	64.7	29	95.6	28	128.0	27	163.5
Japan	13	97.7	15	116.8	12	168.3	7	231.6	10	253.4
Latvia	16	90.6	18	113.8	20	138.7	21	163.1	20	189.3
Lithuania	17	89.5	19	112.4	21	136.3	20	165.3	19	196.9
Luxembourg	10	109.1	12	130.3	13	164.5	16	186.0	15	216.9
Mexico	34	31.5	34	39.8	34	50.5	34	69.8	34	89.7
Netherlands	14	96.4	14	118.2	17	151.5	15	186.5	13	228.1
New Zealand	15	91.1	16	116.6	14	160.5	12	204.7	14	221.4
Norway	11	105.8	11	130.4	15	157.9	19	171.7	21	188.1
Poland	22	76.0	21	102.3	19	140.0	18	172.0	18	198.8
Portugal	18	88.4	17	115.9	18	150.5	17	185.9	16	215.8
Slovakia	27	58.6	26	80.4	28	101.3	25	138.7	28	162.7
Slovenia	28	57.4	27	77.1	26	103.6	26	137.4	26	164.7
South Korea	2	151.6	7	148.2	3	208.0	10	212.2	12	232.4
Spain	8	114.1	9	146.7	7	199.8	9	228.4	7	266.6
Sweden	6	118.4	8	147.3	11	170.1	14	186.6	17	202.3
Switzerland	4	120.6	2	164.8	2	211.7	3	254.1	2	291.9
Turkey	36	22.8	36	26.5	36	36.5	35	55.2	35	73.5
United Kingdom	26	61.0	28	71.3	30	93.2	29	126.8	25	165.4
United States	**5**	**119.6**	**5**	**150.5**	**9**	**195.5**	**6**	**233.7**	**6**	**271.4**

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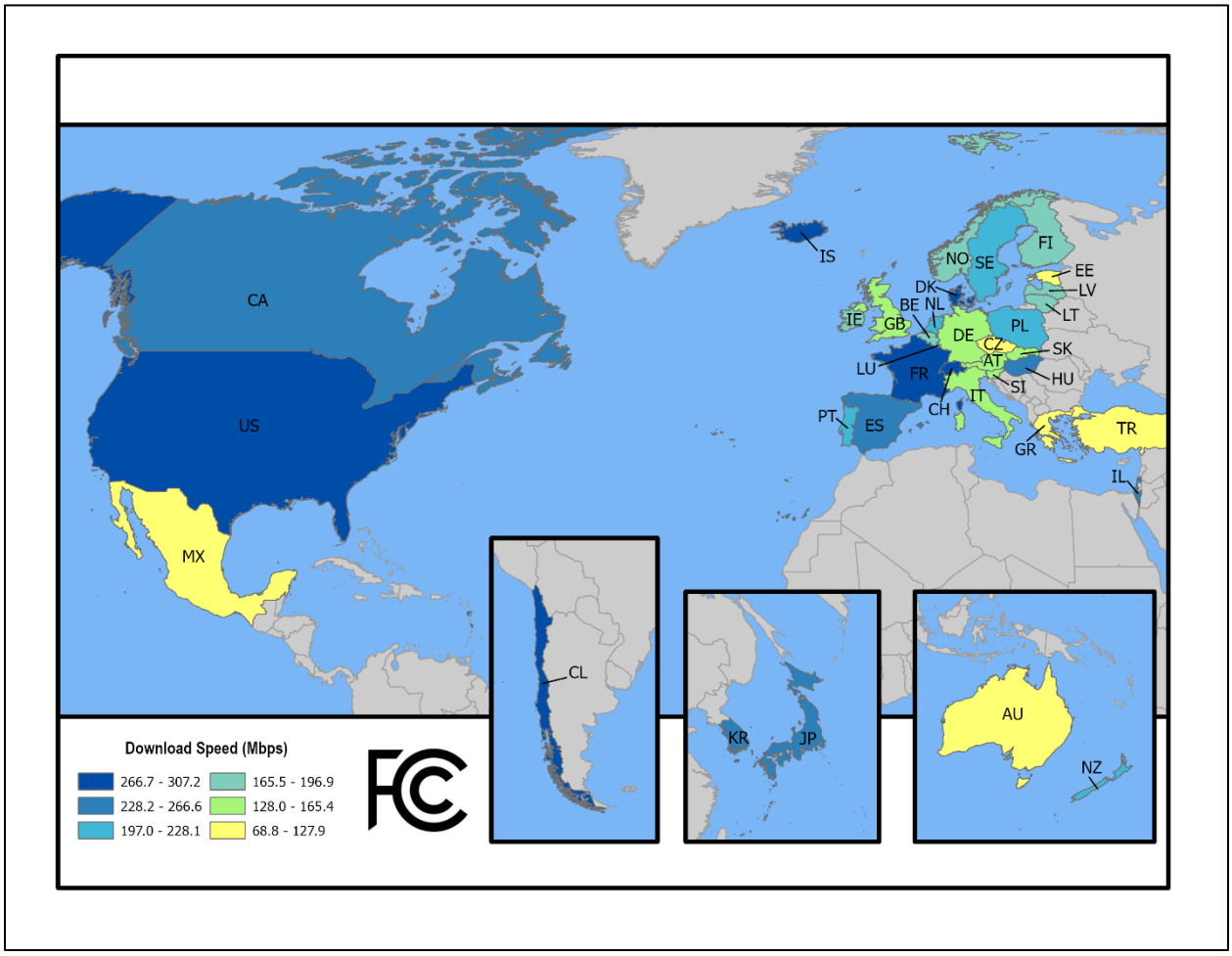
23. Figure III.A.2 presents a map of the mean fixed broadband download speeds by country in 2023.[47] The mean download speeds in North America ranged from 89.7 to 271.4 Mbps in 2023. The six countries with the highest mean download speeds in 2023 were the United States, Denmark, Iceland, France, Switzerland, and Chile with mean download speeds among these countries ranging from 271.4 to 307.2 Mbps. The six countries with the lowest mean download speeds in 2023 were Greece, Turkey, Mexico, Australia, Estonia, and the Czech Republic with mean download speeds ranging from 68.8 to 127.9 Mbps. Western Europe and Scandinavia generally had higher mean download speeds than Eastern and Southern Europe in 2023.

Fig. III.A.2
Fixed Broadband Mean Download Speed by Country (2023)



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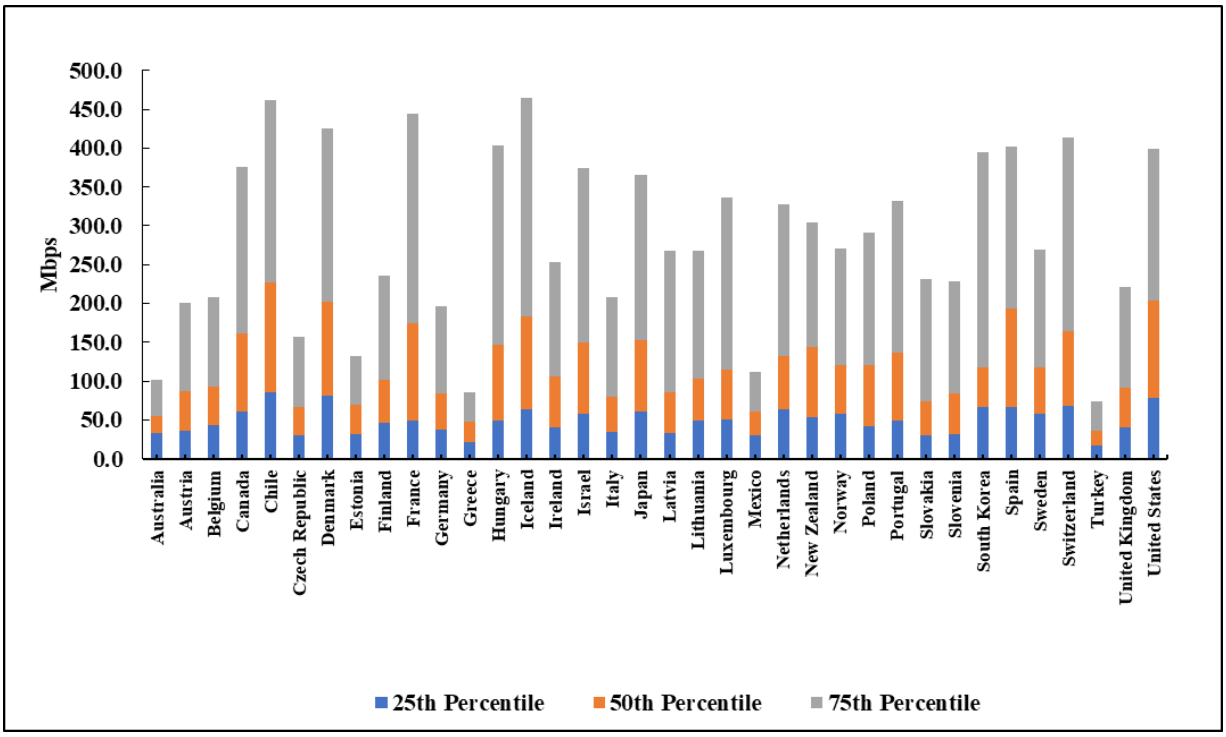
24. Figure III.A.3 shows the distribution of fixed broadband download speeds across cities for each country in 2023. The top of each color bar represents the corresponding 25th, 50th, and 75th

[47] Each country's mean fixed broadband download speed values are reported in Figure III.A.1. *See supra* Fig. III.A.1.

download speed percentiles.[48] The 25th, 50th, and 75th percentiles of download speeds in the United States in 2023 were 77.6 Mbps, 203.9 Mbps, and 398.8 Mbps, respectively.

Fig. III. A.3
Fixed Broadband Download Speed Percentiles (2023)



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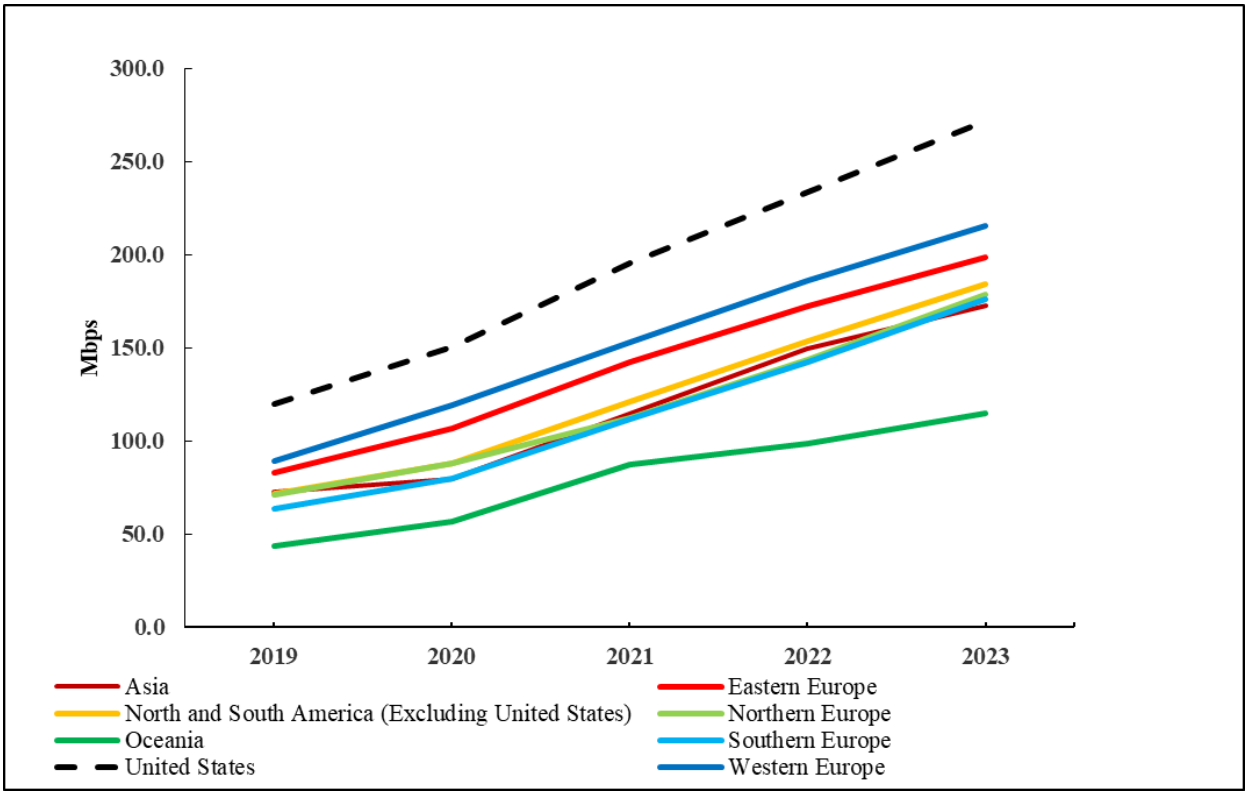
25. Figure III.A.4 depicts the mean fixed broadband download speeds by region versus the United States from 2019 to 2023.[49] Following a similar trajectory as other country groups, U.S. mean download speed increased from 119.6 Mbps in 2019 to 271.4 Mbps in 2023 and is consistently higher than all the other country groups.

[48] Speed percentiles measure the distribution of speeds across cities in each country. These values can be interpreted, for example, as 75% of speed tests have a download speed of at or below 398.8 Mbps on average in the United States. We calculate the country-level mean percentiles from the city level percentiles using sample counts as weights. Ookla defines a sample as an average across a set of tests from a single user/device for a given geography, time period, platform, and technology. This methodology is employed to prevent any single user/device with a disproportionate number of tests from having an outsized effect on the overall average.

[49] We aggregate countries by continent or regions within continents. North and South America (excluding the United States) includes Canada, Chile, and Mexico. Oceania includes Australia and New Zealand. Asia includes Israel, Japan, South Korea, and Turkey. Southern Europe includes Greece, Italy, Portugal, Slovenia, and Spain. Northern Europe includes Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, and the United Kingdom. Western Europe includes Austria, Belgium, France, Germany, Luxembourg, the Netherlands, and Switzerland. Eastern Europe includes Czech Republic, Hungary, Poland, and Slovakia.

Fig. III.A.4
Fixed Broadband Mean Download Speed by Region vs. the United States (2019-2023)



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26. Figure III.A.5 compares the mean fixed broadband download speeds by country capital cities and U.S. state capital cities for the years 2019 to 2023. In 2023, the mean download speed in Washington D.C. was 234.2 Mbps, ranking 51st among the 86 country and state capital cities. The highest ranked U.S capital city in 2023 was Raleigh, North Carolina, which ranked 1st with a mean download speed of 330.6 Mbps. Other U.S. capital cities in the top ten in 2023 included Dover, Delaware (2nd – 320.4 Mbps); Olympia, Washington (3rd – 317.4 Mbps); Salem, Oregon (4th – 316.9 Mbps); Concord, New Hampshire (5th - 310.4 Mbps); Austin, Texas (6th – 310.2 Mbps); Salt Lake City, Utah (8th – 300.4 Mbps); Oklahoma City, Oklahoma (9th – 300.0 Mbps); and Hartford, Connecticut (10th – 299.7 Mbps).

Fig. III.A.5
Fixed Broadband Mean Download Speed by Country Capital and U.S. State Capital Cities (2019-2023)

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Canberra, Australia	81	53.2	84	46.4	83	71.1	84	71.6	84	82.3
Vienna, Austria	82	51.7	75	86.8	67	138.8	66	176.5	65	206.4
Brussels, Belgium	79	61.4	78	79.4	79	101.0	81	122.4	80	147.8
Ottawa, Canada	8	147.2	24	151.6	43	182.8	32	233.3	17	289.3
Santiago, Chile	72	71.5	54	121.1	35	187.4	30	241.3	21	279.9
Prague, Czech Republic	78	62.6	80	76.8	80	99.4	80	122.6	81	146.4
Copenhagen, Denmark	35	113.1	15	169.5	9	227.3	12	261.2	26	276.6
Tallinn, Estonia	74	70.8	76	83.7	81	98.0	82	109.8	82	125.6
Helsinki, Finland	76	65.8	73	89.5	76	110.3	78	137.4	78	161.2
Paris, France	2	163.6	2	206.4	3	241.3	13	260.6	23	278.5
Berlin, Germany	65	84.2	65	106.6	66	139.4	71	158.0	77	170.3
Athens, Greece	86	23.5	86	28.9	86	37.3	86	49.9	86	71.3
Budapest, Hungary	18	132.3	22	161.7	21	208.4	28	243.7	24	277.9
Reykjavik, Iceland	1	169.5	1	214.7	1	262.0	2	273.6	18	286.1
Dublin, Ireland	63	87.1	66	106.2	68	134.7	72	155.1	75	179.1
Jerusalem, Israel	83	48.6	82	57.1	82	97.8	79	134.1	79	153.6
Rome, Italy	80	56.5	81	75.4	75	116.1	75	150.5	68	197.8
Tokyo, Japan	48	102.5	67	100.3	40	185.0	4	272.8	7	306.2
Riga, Latvia	45	105.1	42	134.4	54	162.0	59	188.3	59	215.8
Vilnius, Lithuania	47	102.7	52	126.0	61	150.3	65	180.8	58	216.6
Luxembourg City, Luxembourg	36	112.4	46	131.6	58	158.1	63	183.8	60	215.2
Mexico City, Mexico	84	40.7	83	47.9	84	61.9	83	84.8	83	101.7
Amsterdam, Netherlands	56	92.0	55	120.9	55	161.6	61	187.0	66	203.8
Wellington, New Zealand	31	118.1	32	146.6	26	199.0	21	252.2	34	264.8
Oslo, Norway	41	107.7	39	138.6	53	163.7	67	174.6	72	186.4
Warsaw, Poland	55	93.9	44	132.6	47	180.0	53	197.2	63	210.0
Lisbon, Portugal	59	90.4	64	109.8	69	134.3	69	167.5	70	190.1
Bratislava, Slovakia	62	88.8	57	115.0	65	139.4	68	174.1	69	196.6

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Ljubljana, Slovenia	75	68.4	74	88.8	73	118.9	74	153.8	74	179.2
Seoul, South Korea	7	150.2	31	147.9	19	214.3	42	216.8	55	228.6
Madrid, Spain	11	140.8	20	162.9	10	224.9	17	254.5	12	294.9
Stockholm, Sweden	21	130.9	19	163.3	39	185.5	47	206.9	57	216.7
Bern, Switzerland	38	110.8	28	150.9	23	202.5	15	259.3	14	290.5
Ankara, Turkey	85	25.3	85	32.0	85	40.1	85	62.9	85	71.8
London, United Kingdom	77	64.3	79	77.6	77	106.6	77	138.0	76	175.7
Albany, NY	54	96.1	63	111.2	57	160.4	50	201.0	53	231.2
Annapolis, MD	20	131.0	18	164.0	29	195.6	25	247.2	28	270.2
Atlanta, GA	14	138.6	9	173.9	15	217.7	24	247.5	73	181.3
Augusta, ME	69	73.5	71	90.2	74	117.4	58	188.8	39	254.8
Austin, TX	4	154.5	5	184.5	5	231.9	5	271.2	6	310.2
Baton Rouge, LA	39	108.8	35	144.5	37	186.6	33	232.4	32	267.9
Bismarck, ND	28	122.4	37	143.0	46	180.4	38	225.0	27	270.2
Boise, ID	58	91.2	59	114.2	30	194.8	34	231.5	37	258.6
Boston, MA	9	142.8	14	169.6	20	211.6	27	244.1	33	267.1
Carson City, NV	66	83.3	56	115.8	63	144.6	51	200.2	42	250.1
Charleston, WV	42	107.4	50	127.8	50	169.4	43	213.1	47	247.6
Cheyenne, WY	61	90.1	68	99.8	71	127.6	57	190.0	45	249.4
Columbia, SC	60	90.2	60	112.1	59	157.7	48	203.6	44	249.5
Columbus, OH	51	98.4	49	129.2	45	181.4	31	236.8	29	269.5
Concord, NH	24	129.8	21	162.6	18	215.4	8	269.8	5	310.4
Denver, CO	37	111.7	23	153.0	36	187.3	60	188.3	64	207.9
Des Moines, IA	57	92.0	62	111.4	52	164.0	54	197.0	41	251.1
Dover, DE	3	155.7	4	189.8	2	243.6	1	286.5	2	320.4
Frankfort, KY	71	72.8	77	81.6	78	101.2	76	146.2	71	187.9
Harrisburg, PA	32	117.5	33	146.6	48	179.9	49	203.3	50	236.9
Hartford, CT	50	98.6	43	134.2	28	196.6	26	244.4	10	299.7
Helena, MT	68	77.0	69	97.2	70	131.3	64	181.6	62	213.1
Honolulu, HI	26	126.7	27	151.0	33	188.5	40	219.8	38	255.3

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Indianapolis, IN	27	123.1	30	149.0	24	201.3	23	249.1	30	268.8
Jackson, MS	52	97.9	61	111.8	62	148.5	62	184.4	61	213.6
Jefferson City, MO	70	72.9	72	89.6	72	126.3	70	163.2	56	221.6
Juneau, AK	67	80.0	41	135.2	32	190.1	46	207.1	52	231.5
Lansing, MI	25	127.5	34	145.7	22	205.0	22	250.2	16	290.0
Lincoln, NE	6	151.1	3	191.7	6	230.2	16	256.2	15	290.1
Little Rock, AR	53	97.7	48	129.8	44	182.4	37	228.9	40	254.2
Madison, WI	34	113.2	38	138.6	41	184.9	39	221.2	35	263.2
Montgomery, AL	46	104.3	53	121.7	56	161.5	52	198.2	48	238.7
Montpelier, VT	73	71.1	70	94.9	60	155.9	73	154.0	67	203.8
Nashville, TN	15	138.1	10	173.0	14	218.3	18	253.9	20	282.1
Oklahoma City, OK	16	135.7	11	172.4	11	222.6	10	265.9	9	300.0
Olympia, WA	17	133.0	13	170.1	13	219.8	14	259.6	3	317.4
Phoenix, AZ	29	120.8	36	143.5	34	187.9	44	213.0	46	248.6
Pierre, SD	44	105.2	47	130.1	64	141.4	55	191.9	49	238.0
Providence, RI	23	129.9	12	172.0	7	229.5	6	270.5	11	298.4
Raleigh, NC	5	153.3	7	177.8	12	222.5	7	270.2	1	330.6
Richmond, VA	22	130.1	25	151.5	27	197.5	36	229.4	43	249.8
Sacramento, CA	19	131.2	17	165.1	16	216.2	19	253.9	31	268.0
Saint Paul, MN	43	106.7	58	114.3	49	170.2	41	217.1	36	260.7
Salem, OR	12	140.4	8	177.3	8	229.4	9	267.0	4	316.9
Salt Lake City, UT	10	141.5	6	181.5	4	240.9	3	273.1	8	300.4
Santa Fe, NM	64	85.9	51	126.1	51	169.0	56	190.5	54	230.0
Springfield, IL	33	115.6	26	151.1	25	200.0	20	252.2	13	291.2
Tallahassee, FL	40	108.8	40	137.3	31	190.2	29	241.5	22	279.8
Topeka, KS	49	101.6	45	132.6	42	184.2	35	230.4	25	277.0
Trenton, NJ	13	140.1	16	165.3	17	215.9	11	261.3	19	283.7
Washington, DC	30	119.6	29	149.4	38	185.9	45	211.0	51	234.2

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27. Figure III.A.6 compares the mean fixed broadband upload speeds by country for the years 2019 to 2023. U.S mean upload speeds more than doubled from 46.3 Mbps in 2019 to 111.8 Mbps in 2023. The U.S. ranking remained relatively stable, at 17th for 2019 to 2020 and 18th for 2021 to 2023. Between 2019 and 2023, Iceland had the highest upload speeds, reaching 280.2 Mbps in 2023.

Fig. III.A.6
Fixed Broadband Mean Upload Speed by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	30	16.9	31	20.7	31	24.2	33	27.2	35	30.3
Austria	33	14.9	33	17.4	32	23.8	31	30.0	33	36.2
Belgium	32	15.8	32	17.5	33	21.3	34	26.9	32	41.4
Canada	16	46.4	16	60.1	17	77.6	17	106.5	14	139.4
Chile	25	20.5	18	56.0	10	128.3	2	214.3	2	253.7
Czech Republic	23	25.9	23	30.5	25	36.9	25	52.7	24	71.5
Denmark	8	80.1	7	115.8	5	147.6	6	178.7	5	213.5
Estonia	19	40.3	20	51.0	20	60.2	20	75.2	20	89.2
Finland	20	29.0	21	39.4	21	50.3	21	71.3	21	86.8
France	12	66.6	10	105.9	6	141.5	7	176.5	4	219.8
Germany	28	18.6	27	24.8	29	30.7	30	36.7	30	43.0
Greece	36	6.0	36	7.4	36	9.0	36	12.1	36	19.2
Hungary	13	61.4	13	77.3	14	101.0	14	119.6	16	135.2
Iceland	1	169.4	1	215.7	1	250.6	1	263.7	1	280.2
Ireland	21	26.9	24	29.7	27	33.7	29	39.6	29	43.8
Israel	29	16.9	29	22.1	28	32.6	27	45.8	25	68.8
Italy	26	20.1	26	25.8	23	39.8	23	61.0	22	86.2
Japan	2	108.9	3	130.6	4	148.7	5	187.2	11	170.6
Latvia	5	92.2	6	116.5	9	137.9	9	158.0	9	174.6
Lithuania	7	82.7	9	108.1	11	125.5	11	152.4	8	177.6
Luxembourg	11	67.9	12	81.1	13	101.2	16	113.6	17	133.0
Mexico	34	13.2	34	16.5	34	20.2	32	28.7	31	41.7
Netherlands	15	48.6	15	68.7	16	86.9	15	114.7	13	150.3
New Zealand	14	55.2	14	75.2	15	98.3	13	126.8	15	137.1
Norway	9	79.0	11	102.0	12	120.9	12	140.9	12	156.9
Poland	22	26.2	22	35.4	22	47.8	22	62.6	23	74.0
Portugal	18	45.0	19	53.1	19	65.5	19	76.8	19	91.5
Slovakia	24	21.3	25	28.9	26	36.5	24	56.5	26	66.6
Slovenia	27	18.8	28	24.6	24	37.7	26	46.5	28	59.2
South Korea	3	105.1	2	149.0	2	195.5	4	195.5	7	191.1
Spain	4	98.9	4	130.1	3	176.0	3	206.7	3	244.4
Sweden	6	87.9	5	117.7	7	139.6	10	156.5	10	172.9
Switzerland	10	77.1	8	108.7	8	139.5	8	169.0	6	193.6
Turkey	35	7.0	35	7.7	35	11.9	35	21.1	34	32.3
United Kingdom	31	16.5	30	21.1	30	27.2	28	39.7	27	61.3
United States	**17**	**46.3**	**17**	**58.1**	**18**	**72.9**	**18**	**91.4**	**18**	**111.8**

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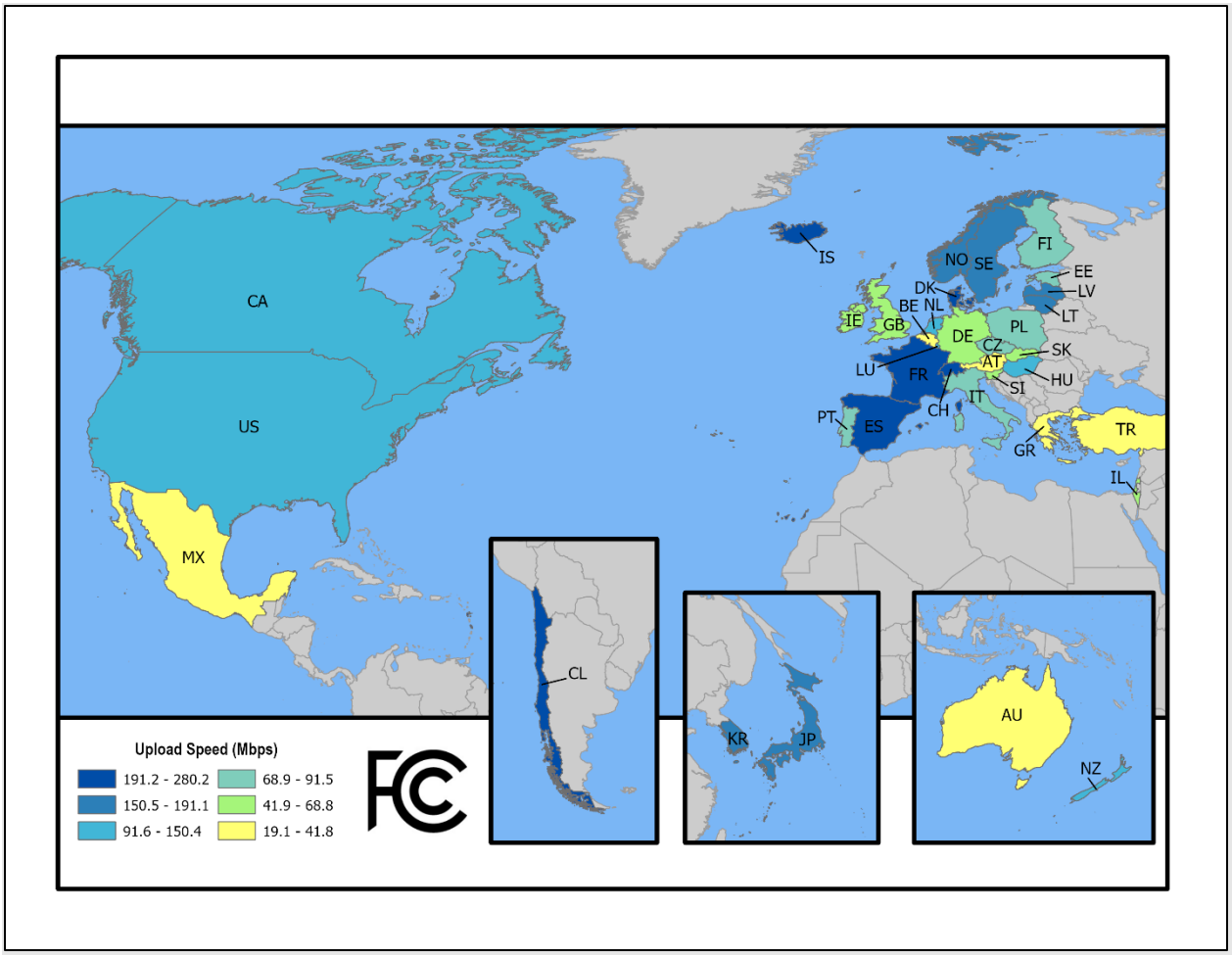
28. Figure III.A.7 presents a map of the mean fixed broadband upload speeds by country in 2023.[50] The mean upload speeds in North America ranged from 41.7 to 139.4 Mbps in 2023. The six countries with the highest mean upload speeds in 2023 were Switzerland, Denmark, France, Spain, Chile, and Iceland, and they had upload speeds ranging from 193.6 to 280.2 Mbps. The six countries with the lowest mean upload speeds in 2023 were Greece, Australia, Turkey, Austria, Belgium, and Mexico, and they had upload speeds ranging from 19.2 to 41.7 Mbps. Scandinavian and Western European countries generally had higher upload speeds than Eastern European countries in 2023.

Fig. III.A.7
Fixed Broadband Mean Upload Speed by Country (2023)



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29. Figure III.A.8 compares the mean fixed broadband latency by country for the years 2019 to 2023. U.S. mean latency ranking slipped from 24th in 2019 to between 29th and 31st in 2020 to 2023. U.S. mean latency decreased from 23.7 milliseconds (ms) in 2019 to 20.6 ms in 2023. In comparison, Denmark had a mean latency of 12.0 ms, ranking 1st out of the 36 countries in 2023.

[50] Each country's mean fixed broadband upload speed values are reported in Figure III.A.6. *See supra* Fig. III.A.6.

Fig. III.A.8
Fixed Broadband Mean Latency by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	ms	Rank	ms	Rank	ms	Rank	ms	Rank	ms
Australia	30	24.7	28	23.1	31	21.5	34	22.1	34	22.7
Austria	28	24.2	18	20.7	22	19.2	22	18.4	22	18.6
Belgium	14	18.3	13	18.8	16	17.2	16	17.5	19	18.0
Canada	18	20.5	20	20.8	20	18.7	17	17.6	15	17.0
Chile	20	22.2	16	19.8	10	15.1	3	12.5	3	12.7
Czech Republic	16	19.4	15	19.2	19	18.6	18	18.0	16	17.5
Denmark	7	15.2	2	13.9	3	13.0	2	12.2	1	12.0
Estonia	12	16.7	10	15.6	12	15.1	9	14.4	9	14.4
Finland	27	24.1	22	21.3	24	19.5	24	19.0	27	20.2
France	34	31.6	32	27.3	34	24.3	35	22.1	28	20.3
Germany	23	23.6	25	22.3	26	20.9	27	19.7	25	19.6
Greece	36	36.8	36	34.0	36	28.5	36	24.1	35	23.8
Hungary	13	17.0	12	16.8	14	15.7	12	15.5	11	15.5
Iceland	2	14.4	7	15.1	1	10.8	1	11.5	30	20.6
Ireland	22	23.3	29	23.4	28	20.9	23	18.8	23	18.9
Israel	15	19.0	17	19.9	17	17.3	11	15.2	4	13.1
Italy	33	29.2	33	27.7	32	23.2	33	21.6	32	20.9
Japan	31	28.1	31	25.8	30	21.5	31	20.8	36	24.5
Latvia	1	14.2	9	15.6	13	15.4	14	15.8	14	16.3
Lithuania	3	14.5	1	13.1	5	13.2	4	12.7	2	12.0
Luxembourg	5	14.5	6	15.0	2	12.6	6	13.0	6	13.6
Mexico	35	32.3	35	29.7	35	24.5	26	19.6	18	17.7
Netherlands	6	15.2	5	14.5	6	14.2	7	13.4	7	13.8
New Zealand	19	21.9	19	20.8	21	18.8	21	18.2	21	18.5
Norway	11	16.6	4	14.2	9	15.1	10	14.6	12	16.1
Poland	26	23.8	24	22.2	23	19.3	20	18.1	20	18.3
Portugal	8	16.0	8	15.4	7	14.4	8	13.9	8	14.0
Slovakia	29	24.3	26	22.6	25	20.4	25	19.2	24	19.5
Slovenia	17	19.5	14	19.1	15	17.1	15	16.1	10	15.2
South Korea	4	14.5	27	22.8	8	14.4	28	19.7	33	21.0
Spain	25	23.7	21	21.0	18	18.4	19	18.1	17	17.6
Sweden	10	16.5	11	16.0	11	15.1	13	15.6	13	16.1
Switzerland	9	16.2	3	14.2	4	13.1	5	12.8	5	13.4
Turkey	32	29.0	34	27.7	33	23.5	30	20.8	26	19.8
United Kingdom	21	22.4	23	22.0	27	20.9	32	21.3	29	20.4
United States	**24**	**23.7**	**30**	**23.6**	**29**	**21.3**	**29**	**20.6**	**31**	**20.6**

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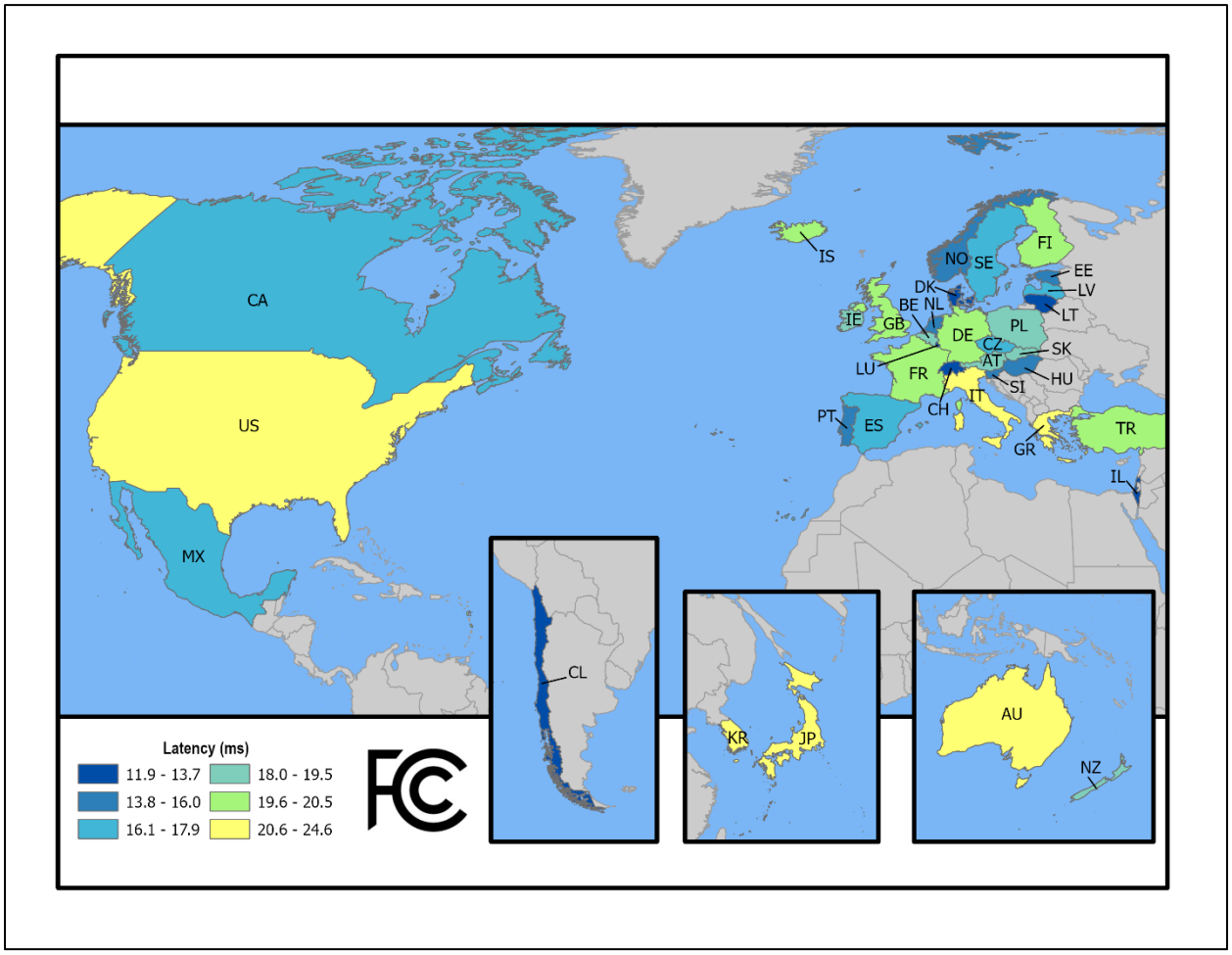
30. Figure III.A.9 presents a map of the mean fixed broadband latency by country in 2023.[51] Mean latency was between 17.0 and 20.6 ms for North America in 2023. The mean latency was the lowest in Denmark, Lithuania, and Chile, which had latencies ranging from 12.0 to 12.7 ms in 2023.

Fig. III.A.9
Fixed Broadband Mean Latency by Country (2023)



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31. Figure III.A.10 presents the number of tests in the sample for each country, as well as the number of cities with fixed broadband tests in each country, for the years 2019 to 2023. Test counts in the United States decreased by 33% from 207.4 million in 2020 to 138.4 million in 2023. The number of cities with fixed broadband tests remained roughly constant in the United States during the five-year time horizon. Year-to-year changes in download speeds, upload speeds, and latency may be not only due to changes in providers' networks over time but also due to changes in the composition of subscribed broadband technologies and geographic areas comprising the sample.[52]

[51] Each country's mean fixed broadband latency values are reported in Figure III.A.8. *See supra* Fig. III.A.8.

[52] For example, if a country experience deployment of better technologies (e.g., FTTP), we may see an increase in download and upload speeds and a decrease in latency.

Fig. III.A.10
Fixed Broadband City Count and Test Count by Country (2019-2023)

Country	Test Count (1000s)					City Count				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
Australia	27,127	25,689	20,673	17,546	16,880	13,246	9,775	10,000	11,013	11,504
Austria	4,732	4,824	4,381	3,537	3,609	1,422	2,260	2,265	2,244	2,242
Belgium	4,814	6,135	5,637	4,922	5,151	612	603	607	582	581
Canada	29,883	35,078	30,620	25,803	24,543	3,225	3,246	3,287	3,392	3,398
Chile	7,902	13,786	12,114	9,985	7,680	267	1,070	1,518	1,686	1,791
Czech Republic	4,870	5,170	4,940	4,084	4,014	5,955	5,897	5,884	5,838	5,802
Denmark	5,012	5,989	5,246	3,862	3,788	634	638	635	636	638
Estonia	1,163	1,126	981	910	897	3,629	3,319	3,374	3,285	3,404
Finland	3,989	3,421	3,362	2,980	3,041	330	1,361	2,189	2,152	2,218
France	21,586	26,725	26,133	24,012	22,453	35,309	34,422	33,996	33,775	33,769
Germany	37,640	43,713	40,624	35,671	33,761	11,642	11,563	11,591	11,386	11,271
Greece	7,984	10,154	10,092	8,913	8,128	7,775	7,668	7,709	8,011	7,967
Hungary	7,306	8,144	7,120	5,852	5,895	3,113	3,104	3,087	3,112	3,112
Iceland	235	232	183	159	124	106	106	103	103	100
Ireland	2,657	3,393	2,583	1,923	1,855	159	159	159	156	273
Israel	5,056	8,183	6,792	5,691	6,074	1,045	1,051	1,051	1,042	1,052
Italy	43,095	45,307	37,296	28,176	25,220	40,126	39,918	39,940	38,659	38,670
Japan	14,063	14,431	13,839	13,109	10,929	1,905	1,764	1,761	1,760	1,763
Latvia	1,093	1,231	1,408	1,232	1,166	1,305	1,260	1,318	1,432	1,468
Lithuania	1,303	1,438	1,420	1,147	1,130	2,760	2,501	2,581	2,323	2,466
Luxembourg	447	489	457	384	434	431	428	357	103	104
Mexico	44,245	64,283	51,291	44,065	37,425	11,034	13,846	14,478	14,750	24,172
Netherlands	15,106	16,517	14,789	12,575	12,503	2,458	2,457	2,455	2,456	2,457
New Zealand	3,551	3,044	2,973	2,609	2,416	2,268	2,236	2,200	2,154	2,204
Norway	3,212	3,449	2,692	2,364	2,304	1,941	2,193	2,195	4,009	4,084
Poland	12,537	14,648	11,969	9,869	9,684	9,734	14,692	14,424	14,146	14,298
Portugal	7,804	9,000	7,760	6,115	6,262	1,353	1,530	1,546	1,554	2,440

Country	Test Count (1000s)					City Count				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
Slovakia	3,464	3,684	3,655	3,236	3,166	2,806	2,805	2,814	2,800	2,817
Slovenia	1,813	2,204	1,853	1,593	1,459	5,553	5,487	5,511	5,526	5,596
South Korea	3,062	2,891	3,053	2,673	2,344	162	162	162	162	164
Spain	12,943	12,609	10,799	9,797	9,213	14,169	13,930	14,039	14,318	14,368
Sweden	1,921	2,331	2,288	1,893	1,913	507	555	570	567	566
Switzerland	5,228	6,077	5,646	4,853	4,504	2,593	2,557	2,544	2,574	2,476
Turkey	13,806	19,348	17,338	14,984	15,570	4,767	8,923	9,267	8,699	9,037
United Kingdom	51,881	62,628	55,331	45,391	44,350	6,624	11,323	11,305	11,304	11,305
United States	**171,306**	**207,452**	**159,066**	**145,414**	**138,398**	**27,952**	**27,744**	**27,773**	**27,995**	**28,106**

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B. Mobile Broadband – 4G LTE Speed and Latency Results

32. Figure III.B.1 compares the mean 4G LTE download speeds by country, for the years 2019 to 2023. For the mean 4G LTE download speeds, the United States' ranking fell to 26th among the 36 countries in 2023, returning to a ranking similar to its 2019 position of 25th, with a mean download speed of 51.3 Mbps. In 2023, Norway had the highest mean download speed at 111.8 Mbps, followed closely by Denmark with a mean download speed of 101.2 Mbps, while Chile had the lowest mean download speed at 27.6 Mbps.

Fig. III.B.1
Mobile Broadband – 4G LTE Mean Download Speed by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	5	62.7	6	57.8	9	62.2	11	61.3	15	63.8
Austria	17	45.6	12	51.5	16	53.2	15	54.7	12	67.2
Belgium	10	50.3	11	52.4	12	57.5	17	54.2	16	60.1
Canada	3	71.3	2	77.5	4	79.0	5	72.6	8	78.1
Chile	36	21.2	36	20.8	36	20.4	36	21.2	36	27.6
Czech Republic	16	46.4	18	45.7	22	46.3	22	46.0	25	51.7
Denmark	11	49.4	10	53.4	6	65.7	4	82.8	2	101.2
Estonia	19	44.2	17	46.6	14	54.3	13	56.1	10	74.3
Finland	14	47.5	15	49.5	10	60.0	6	66.4	6	83.7
France	15	46.8	16	48.7	15	54.0	18	54.0	14	65.9
Germany	27	35.7	24	37.8	20	48.5	19	52.3	21	54.3
Greece	18	44.2	22	40.1	17	52.5	14	55.2	18	58.9
Hungary	20	43.2	20	41.2	27	40.9	27	41.2	29	46.5
Iceland	1	78.6	1	80.2	2	85.9	3	85.3	4	90.0
Ireland	32	31.7	33	33.1	28	40.7	29	40.2	28	47.8
Israel	34	27.8	35	24.9	35	30.6	34	30.7	33	39.2
Italy	26	36.6	25	37.8	26	42.1	28	40.3	27	48.4
Japan	33	31.7	30	35.0	33	36.7	32	37.7	32	43.6
Latvia	29	34.3	31	35.0	30	40.4	24	45.0	17	59.2
Lithuania	13	48.3	13	51.5	13	57.3	12	57.8	9	76.7
Luxembourg	12	48.4	14	50.9	11	59.2	10	61.7	13	66.7
Mexico	35	27.4	34	32.1	34	33.2	35	30.4	35	35.2
Netherlands	6	61.2	4	72.7	3	82.8	2	88.4	3	97.8
New Zealand	9	52.0	9	53.5	18	50.5	20	51.7	19	58.2
Norway	2	74.5	3	75.4	1	92.1	1	103.4	1	111.8
Poland	28	35.4	28	37.1	21	46.7	25	42.9	24	52.1
Portugal	23	37.7	21	40.6	19	48.7	16	54.5	20	58.2
Slovakia	30	34.2	26	37.3	29	40.4	30	39.8	30	45.4

Country	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Slovenia	22	38.5	23	39.9	24	43.2	21	46.1	22	54.2
South Korea	4	63.2	5	64.3	5	68.1	7	64.9	7	81.4
Spain	24	37.4	29	35.6	31	39.0	31	37.7	31	44.3
Sweden	7	54.3	7	55.2	7	64.5	8	64.8	5	84.3
Switzerland	8	52.1	8	53.8	8	62.7	9	62.1	11	71.2
Turkey	21	38.6	27	37.1	25	42.5	26	42.0	23	53.8
United Kingdom	31	33.4	32	33.4	32	36.8	33	37.4	34	37.3
United States	**25**	**37.0**	**19**	**42.9**	**23**	**44.8**	**23**	**45.1**	**26**	**51.3**

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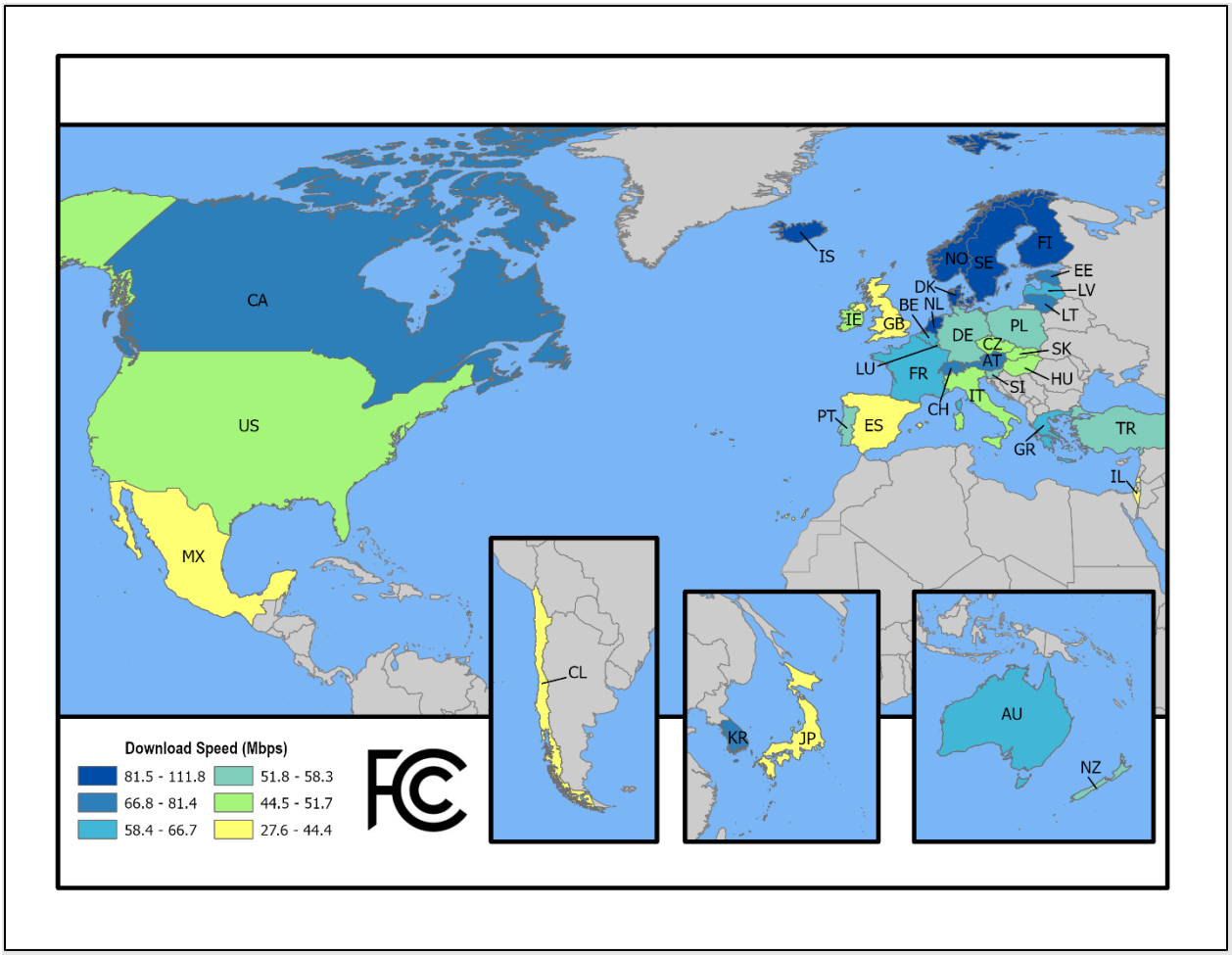
33. Figure III.B.2 presents a map of the mean 4G LTE download speeds by country in 2023.[53] The mean download speeds in North America ranged from 35.2 to 78.1 Mbps in 2023. The six countries with the highest mean download speeds in 2023 were Finland, Sweden, Iceland, the Netherlands, Denmark, and Norway, with download speeds ranging from 83.7 to 111.8 Mbps. The six countries with the lowest mean download speeds in 2023 were Chile, Mexico, the United Kingdom, Israel, Japan, and Spain, with download speeds ranging from 27.6 to 44.3 Mbps. All Nordic OECD countries were among the top ten countries in terms of download speeds in 2023.

[53] Each country's mean 4G LTE download speed values are reported in Figure III.B.1. *See supra* Fig. III.B.1.

Fig. III.B.2
Mobile Broadband – 4G LTE Mean Download Speed by Country (2023)



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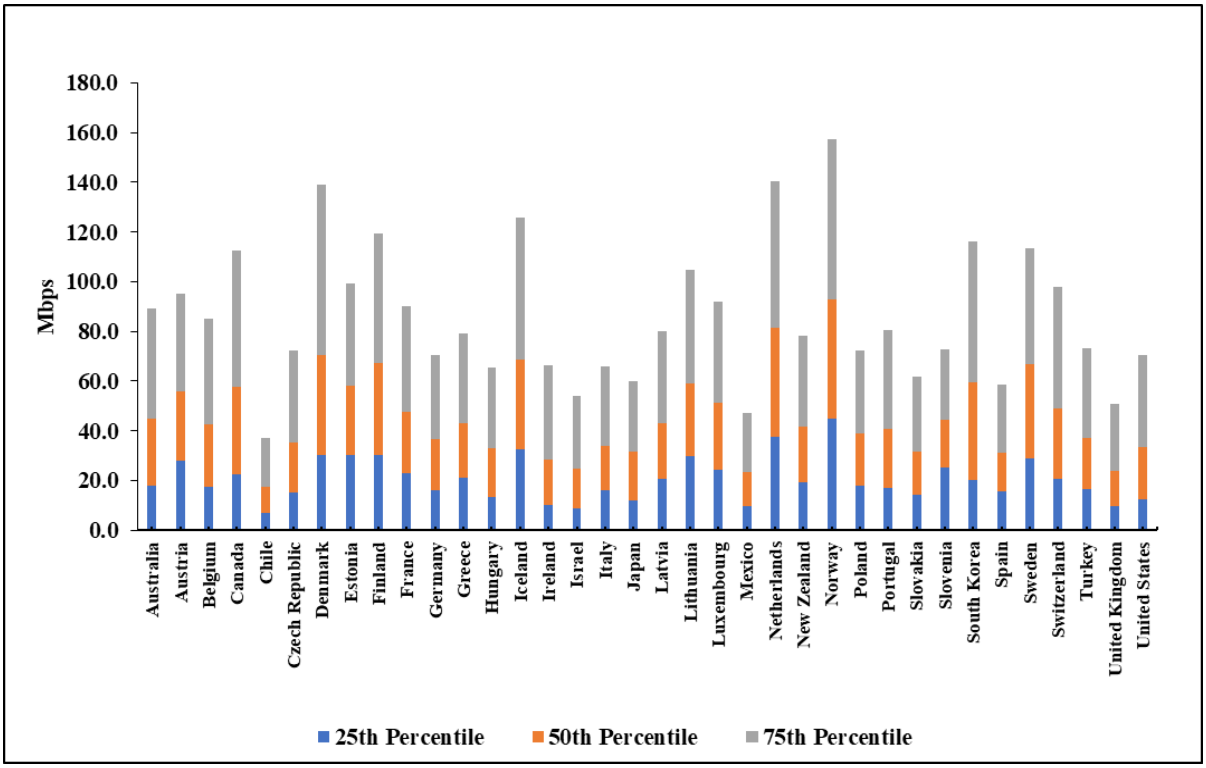
34. Figure III.B.3 shows the distribution of 4G LTE download speeds across cities for each country in 2023. The top of each color bar represents the corresponding 25th, 50th, and 75th download speed percentiles.[54] The 25th, 50th and 75th percentiles for download speeds in the United States in 2023 were 12.7 Mbps, 33.4 Mbps, and 70.5 Mbps, respectively.

[54] We calculate the country-level mean percentiles by taking the weighted average of the city-level percentiles using sample counts as weights.

Fig. III.B.3
Mobile Broadband – 4G LTE Download Speed Percentiles (2023)



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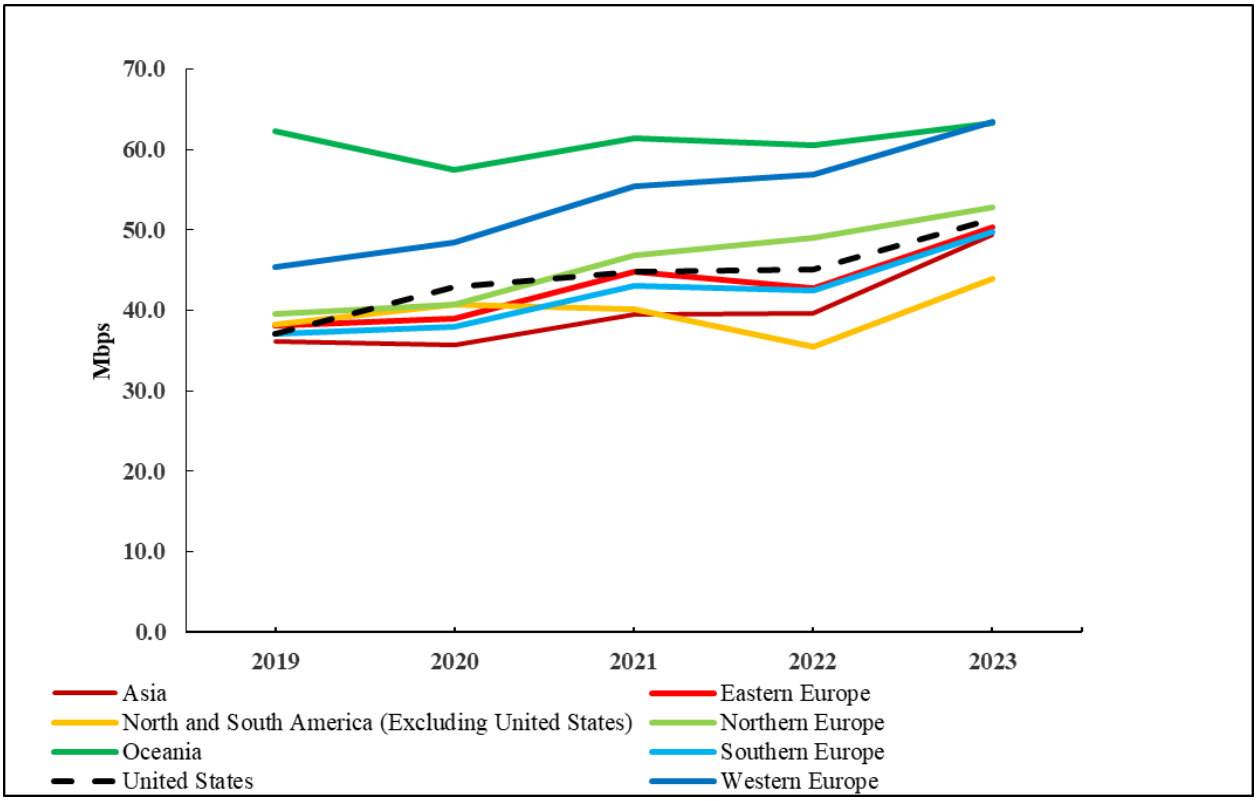
35. Figure III.B.4 shows that the mean 4G LTE download speed in the United States increased at a similar pace relative to the other regions, or groups of geographically close countries, during the past five years. Western Europe experienced the fastest growth in the mean download speed over the last five years, increasing from 45.4 Mbps in 2019 to 63.5 Mbps in 2023.

Fig. III.B.4
Mobile Broadband – 4G LTE Mean Download Speeds by Region vs. the United States (2019-2023)



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36. Figure III.B.5 compares the mean 4G LTE download speeds by country capital cities and U.S. state capital cities for the years 2019 to 2023. The mean download speed in Washington D.C. in 2023 was 57.3 Mbps, which ranked 35th among the 86 country and state capital cities. The highest ranked U.S state capital city in 2023 was Salt Lake City, Utah, which ranked 7th with a mean download speed of 82.2 Mbps. The only other U.S state capital city that was ranked among the top ten in 2023 was Pierre, South Dakota, which ranked 9th with a mean download speed of 81.0 Mbps.

Fig. III.B.5
Mobile Broadband – 4G LTE Mean Download Speed by Country Capital and U.S. State Capital Cities (2019-2023)

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Canberra, Australia	4	65.7	9	61.7	7	70.9	6	71.9	13	71.8
Vienna, Austria	29	44.0	28	49.6	31	51.6	29	53.0	20	66.2
Brussels, Belgium	14	49.7	11	57.6	12	63.4	27	54.1	26	61.2
Ottawa, Canada	3	65.9	3	70.7	5	73.0	13	61.7	21	65.4
Santiago, Chile	86	20.2	86	19.2	86	18.7	86	19.6	86	25.8
Prague, Czech Republic	9	55.6	15	54.5	24	54.5	30	52.3	30	59.8
Copenhagen, Denmark	11	51.3	16	54.2	8	67.1	3	84.8	2	105.8
Tallinn, Estonia	20	48.5	24	51.3	16	60.3	15	60.7	10	78.3
Helsinki, Finland	18	49.0	26	50.6	11	64.4	10	68.1	8	81.4
Paris, France	15	49.3	19	53.1	21	57.3	21	57.2	15	70.6
Berlin, Germany	26	44.9	31	46.5	25	54.3	20	57.7	29	59.8
Athens, Greece	30	42.6	64	38.2	33	50.9	28	53.3	39	56.0
Budapest, Hungary	23	46.5	39	44.8	50	44.8	51	44.6	57	51.2
Reykjavik, Iceland	1	82.2	2	79.9	2	86.9	2	85.6	6	84.7
Dublin, Ireland	65	31.8	76	33.0	68	39.8	67	39.9	64	48.3
Jerusalem, Israel	81	24.2	85	21.2	85	27.2	84	25.6	83	33.3
Rome, Italy	52	36.7	65	36.7	72	38.9	75	35.9	72	44.4
Tokyo, Japan	73	29.1	71	34.7	78	35.0	77	34.5	84	33.3
Riga, Latvia	60	35.0	68	35.6	66	40.2	55	43.4	33	58.0
Vilnius, Lithuania	17	49.2	18	53.4	17	59.4	19	58.1	12	75.9
Luxembourg City, Luxembourg	22	47.1	14	54.9	14	61.4	16	60.1	24	63.0
Mexico City, Mexico	78	27.3	80	31.9	81	33.4	81	31.7	82	35.0
Amsterdam, Netherlands	6	58.0	4	69.2	3	81.9	4	82.9	4	90.0
Wellington, New Zealand	13	50.2	17	53.7	32	51.4	23	56.4	17	69.6
Oslo, Norway	2	74.2	1	80.3	1	97.2	1	104.8	1	110.9
Warsaw, Poland	54	36.5	63	38.3	41	47.0	58	42.1	58	50.5
Lisbon, Portugal	31	42.1	40	44.8	26	54.1	17	59.3	22	64.3
Bratislava, Slovakia	34	42.1	32	46.4	30	52.1	38	48.8	47	53.4

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Ljubljana, Slovenia	43	38.2	62	38.6	60	43.0	44	46.8	36	56.7
Seoul, South Korea	5	63.3	5	67.5	6	71.6	8	68.9	5	86.2
Madrid, Spain	32	42.1	55	40.6	56	43.7	66	40.6	63	48.3
Stockholm, Sweden	7	57.7	8	62.3	4	78.9	5	76.8	3	94.5
Bern, Switzerland	10	52.8	12	55.8	10	64.9	12	62.1	11	78.3
Ankara, Turkey	50	37.1	67	35.9	62	42.7	53	44.0	52	53.0
London, United Kingdom	51	37.1	50	41.6	43	46.4	54	43.8	75	43.4
Albany, NY	61	34.6	51	41.6	48	45.4	61	41.1	53	52.9
Annapolis, MD	8	55.6	6	66.9	15	61.0	9	68.7	16	70.2
Atlanta, GA	21	48.4	29	49.0	36	49.7	33	51.0	48	53.4
Augusta, ME	79	26.1	83	29.7	71	39.2	72	37.6	54	52.7
Austin, TX	56	36.0	53	40.8	65	40.6	59	42.1	46	53.4
Baton Rouge, LA	57	35.8	38	45.1	51	44.6	50	45.1	56	51.5
Bismarck, ND	55	36.1	30	47.2	34	50.5	47	45.5	18	66.9
Boise, ID	41	38.7	47	42.8	46	45.9	46	45.9	50	53.2
Boston, MA	35	41.7	27	50.4	23	55.1	25	55.1	32	58.6
Carson City, NV	84	21.5	82	29.7	77	36.2	80	32.1	81	37.3
Charleston, WV	62	34.6	37	45.4	57	43.7	49	45.4	49	53.3
Cheyenne, WY	71	29.5	66	36.7	83	31.9	76	34.5	77	40.2
Columbia, SC	63	33.6	58	40.1	73	37.8	74	36.8	73	44.1
Columbus, OH	27	44.7	25	51.3	27	53.7	31	52.0	38	56.5
Concord, NH	83	23.3	75	33.5	75	36.7	71	38.8	19	66.6
Denver, CO	48	37.2	43	44.4	54	44.3	57	43.0	55	52.3
Des Moines, IA	74	29.1	74	33.8	64	40.6	70	38.8	43	54.7
Dover, DE	16	49.2	7	63.8	22	57.1	22	56.7	27	60.0
Frankfort, KY	38	40.2	41	44.6	42	46.9	41	47.7	14	71.3
Harrisburg, PA	28	44.6	10	58.4	9	65.7	26	54.9	34	58.0
Hartford, CT	53	36.6	46	43.9	35	49.7	37	49.3	60	49.9
Helena, MT	46	37.7	52	40.8	52	44.6	52	44.2	41	55.4
Honolulu, HI	67	31.4	60	39.4	67	40.2	62	41.0	67	47.4

City, Country/State	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Indianapolis, IN	36	40.9	44	44.4	39	48.4	32	51.4	31	59.0
Jackson, MS	80	24.6	84	27.6	84	29.2	83	28.7	80	37.8
Jefferson City, MO	68	30.9	78	32.9	80	33.6	64	40.6	61	49.9
Juneau, AK	85	21.2	69	34.9	76	36.6	85	24.1	85	28.4
Lansing, MI	39	39.0	33	46.3	29	52.9	34	50.9	25	61.5
Lincoln, NE	72	29.2	61	38.8	79	34.8	79	32.4	78	39.2
Little Rock, AR	33	42.1	36	45.9	37	48.6	43	47.1	40	55.4
Madison, WI	82	24.0	77	33.0	74	37.5	69	38.9	71	44.5
Montgomery, AL	64	31.9	57	40.4	70	39.6	73	36.9	28	59.9
Montpelier, VT	76	28.9	73	34.0	53	44.5	14	60.8	76	40.9
Nashville, TN	45	38.1	48	42.7	49	45.3	45	46.1	45	53.4
Oklahoma City, OK	77	27.4	79	32.6	63	41.4	63	40.7	62	49.2
Olympia, WA	69	30.4	59	39.6	69	39.7	60	41.6	74	43.9
Phoenix, AZ	42	38.7	35	46.0	44	46.4	42	47.4	37	56.7
Pierre, SD	58	35.8	81	30.8	28	53.0	7	69.7	9	81.0
Providence, RI	12	51.1	21	52.2	19	58.5	40	48.0	68	47.4
Raleigh, NC	47	37.4	45	44.0	38	48.4	39	48.2	44	53.6
Richmond, VA	40	38.9	49	42.5	47	45.5	65	40.6	65	47.7
Sacramento, CA	59	35.5	56	40.5	61	42.7	56	43.1	69	46.9
Saint Paul, MN	19	48.7	20	52.6	18	59.1	18	59.0	51	53.0
Salem, OR	37	40.9	42	44.5	55	44.0	36	49.4	42	55.0
Salt Lake City, UT	44	38.2	23	51.4	13	62.4	11	63.4	7	82.2
Santa Fe, NM	66	31.6	70	34.8	58	43.6	68	39.8	66	47.5
Springfield, IL	49	37.1	34	46.0	59	43.5	48	45.4	59	50.0
Tallahassee, FL	24	45.5	22	51.8	40	47.2	35	50.0	23	64.2
Topeka, KS	70	30.1	72	34.4	82	33.1	82	29.6	79	38.2
Trenton, NJ	75	29.0	54	40.7	45	46.3	78	34.3	70	45.6
Washington, DC	25	44.9	13	55.1	20	58.4	24	55.4	35	57.3

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37. Figure III.B.6 compares the mean 4G LTE upload speeds by country, for the years 2019 to 2023. For the mean upload speeds, the United States ranked 36th among the 36 countries in 2023 with the speed decreasing from 11.1 Mbps in 2019 to 8.8 Mbps in 2023. Norway had the fastest mean download speed in 2023 at 19.6 Mbps, slightly increasing from 18.6 Mbps in 2021.

Fig. III.B.6
Mobile Broadband – 4G LTE Mean Upload Speed by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	7	16.9	21	13.6	26	12.7	27	11.8	31	11.9
Austria	17	15.3	11	15.0	12	14.5	12	14.6	9	16.4
Belgium	8	16.6	9	15.3	11	14.8	15	14.1	20	13.5
Canada	15	15.9	19	13.7	25	12.8	25	12.2	24	13.4
Chile	25	13.8	20	13.6	22	13.4	17	13.4	15	13.9
Czech Republic	6	17.0	7	15.7	8	15.4	10	15.2	11	15.9
Denmark	3	19.9	4	18.1	4	17.1	5	17.6	5	18.4
Estonia	24	13.8	23	13.4	21	13.4	20	13.2	14	14.6
Finland	10	16.3	10	15.2	7	16.0	6	16.9	3	18.6
France	33	11.4	33	10.6	34	10.5	33	10.1	33	10.9
Germany	27	13.3	29	11.8	29	11.9	26	12.1	26	12.9
Greece	19	15.1	17	14.3	9	15.3	9	15.3	13	15.2
Hungary	14	16.1	12	14.6	16	14.1	14	14.4	12	15.7
Iceland	1	22.6	1	20.0	1	19.0	2	18.1	7	16.6
Ireland	28	13.3	26	12.5	19	13.6	21	13.1	23	13.4
Israel	9	16.3	22	13.5	23	13.0	29	11.8	32	11.7
Italy	22	14.4	27	12.5	27	12.6	24	12.2	25	12.9
Japan	36	9.8	32	11.1	33	10.7	34	9.6	34	10.0
Latvia	29	12.9	30	11.6	30	11.6	30	11.8	28	12.5
Lithuania	21	14.9	18	13.8	17	13.9	11	14.6	10	15.9
Luxembourg	12	16.1	16	14.3	15	14.2	13	14.4	18	13.7
Mexico	23	14.0	14	14.4	14	14.3	18	13.4	16	13.8
Netherlands	13	16.1	5	16.0	6	16.2	7	16.0	8	16.5
New Zealand	11	16.3	8	15.6	13	14.5	19	13.3	22	13.5
Norway	2	20.3	3	18.6	3	18.6	1	19.0	1	19.6
Poland	34	11.3	36	10.3	31	11.1	31	11.1	29	12.3
Portugal	26	13.5	25	12.6	20	13.5	16	13.7	19	13.6
Slovakia	31	12.5	31	11.6	32	10.9	32	10.8	27	12.9
Slovenia	30	12.8	28	11.9	28	12.1	28	11.8	30	12.1
South Korea	16	15.7	15	14.4	18	13.7	23	12.5	21	13.5
Spain	20	15.0	24	13.2	24	13.0	22	12.6	17	13.7
Sweden	18	15.1	13	14.6	10	15.2	8	15.3	6	18.0
Switzerland	4	19.5	2	19.1	2	18.6	3	17.9	4	18.4
Turkey	5	17.1	6	15.9	5	16.7	4	17.6	2	19.1
United Kingdom	32	12.2	35	10.3	35	9.9	35	9.3	35	9.0
United States	**35**	**11.1**	**34**	**10.5**	**36**	**9.9**	**36**	**8.9**	**36**	**8.8**

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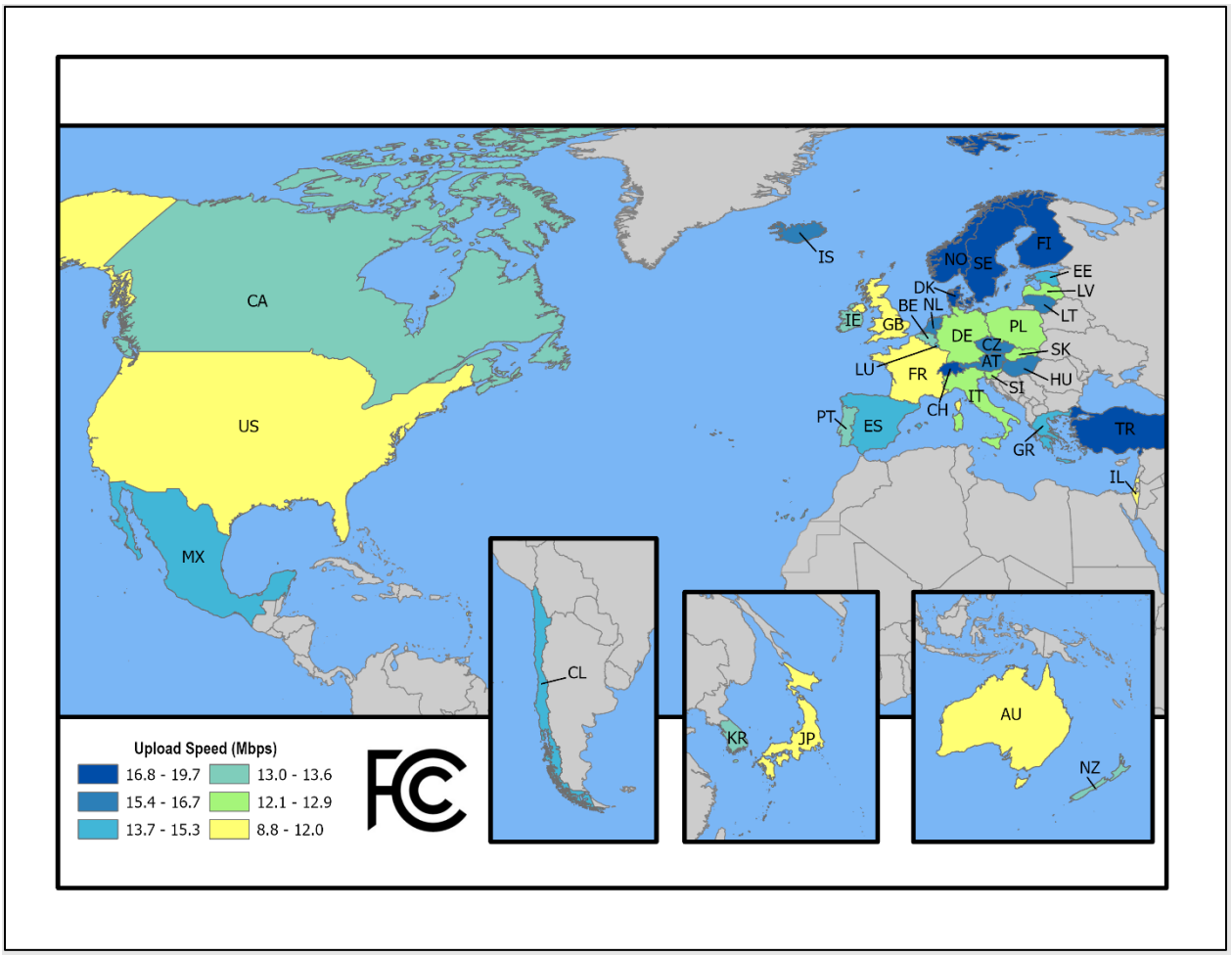
38. Figure III.B.7 presents a map of the mean 4G LTE upload speeds by country in 2023.[55] The mean upload speeds in 2023 in North America ranged from 8.8 to 13.8 Mbps. The six countries with the highest

mean upload speeds were Sweden, Denmark, Switzerland, Finland, Turkey, and Norway, with upload speeds ranging from 18.0 to 19.6 Mbps. The six countries with the lowest mean upload speeds were the United States, the United Kingdom, Japan, France, Israel, and Australia, with upload speeds ranging from 8.8 to 11.9 Mbps. All of the Nordic OECD countries were among the top ten countries in terms of upload speeds in 2023.

Fig. III.B.7
Mobile Broadband – 4G LTE Mean Upload Speed by Country (2023)



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39. Figure III.B.8 compares the mean 4G LTE latency by country for the years 2019 to 2023. For the mean latency, the United States ranking remained steady at 34th between 2021 and 2023 with a mean latency of 45.3 ms in 2023. Iceland ranked 1st from 2019 through 2023, with a mean latency of 22.3 ms in 2023.

[55] Each country's mean 4G LTE upload speed values are reported in Figure III.B.6. *See supra* Fig. III.B.6.

Fig. III.B.8
Mobile Broadband – 4G LTE Mean Latency by Country (2019-2023)

Country	2019		2020		2021		2022		2023	
	Rank	ms	Rank	Ms	Rank	ms	Rank	ms	Rank	ms
Australia	17	29.6	20	30.4	21	29.6	23	31.9	25	33.9
Austria	12	27.4	7	25.9	8	25.4	9	26.4	9	26.3
Belgium	18	29.7	13	27.5	16	29.1	22	31.5	23	33.1
Canada	23	34.1	24	32.7	24	31.7	25	34.1	22	32.7
Chile	22	33.9	26	35.6	26	32.7	26	34.3	26	35.8
Czech Republic	8	26.4	16	28.5	18	29.3	19	30.0	14	28.4
Denmark	10	27.1	11	26.7	7	24.7	5	25.5	5	25.2
Estonia	4	24.9	8	26.0	13	27.5	12	27.4	6	25.6
Finland	5	25.3	5	24.9	3	22.9	4	24.1	4	24.4
France	30	41.5	29	37.5	29	36.5	29	37.7	28	37.1
Germany	28	38.2	27	37.1	27	33.2	27	34.5	27	36.0
Greece	11	27.4	12	26.8	10	26.1	8	26.2	12	28.1
Hungary	6	25.3	4	24.7	6	24.1	7	25.5	11	28.0
Iceland	1	21.1	1	20.3	1	20.6	1	22.2	1	22.3
Ireland	24	34.3	23	31.5	19	29.3	17	29.6	18	30.6
Israel	15	29.1	21	30.5	15	28.0	18	29.9	21	31.3
Italy	33	45.3	31	40.9	33	40.5	31	39.9	32	39.0
Japan	36	54.0	36	45.6	35	42.9	35	45.8	35	46.6
Latvia	2	23.4	3	23.9	4	23.5	3	23.9	2	23.4
Lithuania	7	26.3	6	25.9	12	27.3	13	27.7	7	25.9
Luxembourg	9	26.5	10	26.1	9	26.0	11	27.2	15	28.8
Mexico	35	50.0	34	41.9	36	45.1	36	47.4	36	62.9
Netherlands	20	31.0	18	29.2	14	27.6	16	28.8	17	30.2
New Zealand	29	39.4	28	37.2	30	36.6	30	38.6	30	37.8
Norway	27	37.6	25	34.0	28	33.2	24	33.7	24	33.6
Poland	25	34.5	22	31.3	23	30.3	21	31.0	20	30.8
Portugal	16	29.5	17	29.2	20	29.5	15	28.8	19	30.8
Slovakia	21	31.1	9	26.0	5	23.6	6	25.5	8	26.0
Slovenia	3	24.5	2	23.5	2	22.2	2	22.7	3	23.5
South Korea	26	35.4	30	38.3	25	32.1	28	36.7	29	37.4
Spain	32	43.6	32	41.1	31	39.3	32	41.3	31	38.6
Sweden	19	30.9	19	30.2	17	29.1	20	31.0	16	29.6
Switzerland	13	28.9	14	27.6	11	26.8	10	27.2	10	27.7
Turkey	14	29.0	15	27.8	22	29.9	14	28.4	13	28.3
United Kingdom	31	42.0	33	41.6	32	40.4	33	42.2	33	41.1
United States	**34**	**46.7**	**35**	**44.1**	**34**	**41.5**	**34**	**42.7**	**34**	**45.3**

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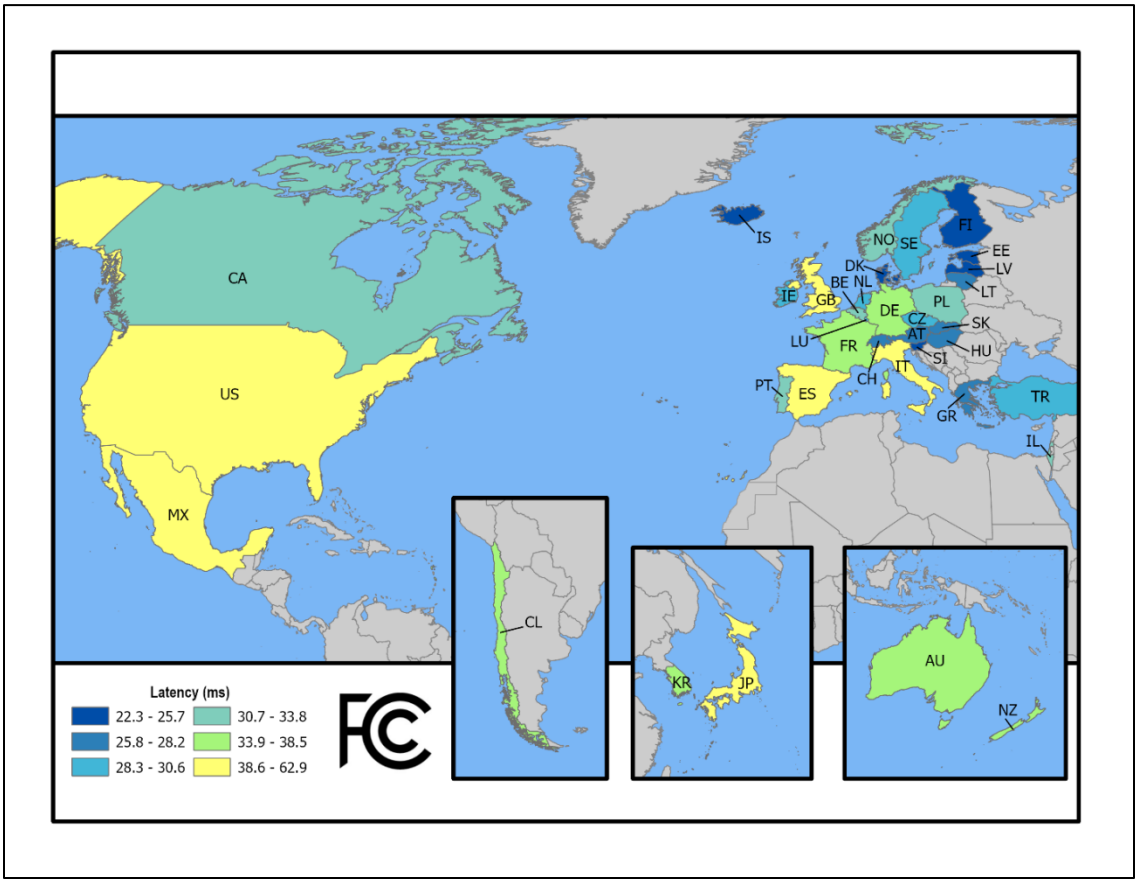
40. Figure III.B.9 presents a map of the mean 4G LTE latency by country in 2023.[56] The mean latency in 2023 was between 32.7 and 62.9 ms for North American countries. The lowest mean latency was concentrated in Eastern European countries, such as Estonia, Latvia, and Slovenia.

Fig. III.B.9
Mobile Broadband – 4G LTE Mean Latency by Country (2023)



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41. Figure III.B.10 presents the number of 4G LTE tests in the sample for each country and city for the years 2019 to 2023. Test counts in the United States, for example, decreased by 83% between 2019 and 2023. The number of U.S. cities with tests also decreased during that same period. These changes are most likely due to an increasing number of consumers testing on 5G networks instead of 4G LTE networks.[57] Year-to-year changes in download speeds, upload speeds, and latency may be not only due to changes in providers' networks over time but also due to changes in the composition of handset devices and geographic areas comprising the sample.[58]

[56] Each country's mean 4G LTE latency values are reported in Figure III.B.8. *See supra* Fig. III.B.8.

[57] In general, there has been a decline in the number of 4G LTE tests and number of cities with 4G LTE tests within the comparison countries, and there has been an increase in the number of 5G tests and number of cities with 5G tests. These patterns highlight that the comparison countries are at different stages of deploying 5G networks. *See infra* Fig. III.C.9.

[58] For instance, in an area where a provider offers both 5G and 4G LTE, the 4G LTE speed test results may be reported only by users who have not upgraded their device as a consumer with a 5G device is likely to get a 5G speed test result when they run the Ookla speed test. Furthermore, the mix of urban and rural areas contained in the reported 4G LTE speed tests may also change as the rollout of 5G networks continues.

Fig. III.B.10
Mobile Broadband – 4G LTE City Count and Test Count by Country (2019-2023)

Country	Test Count (1000s)					City Count				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
Australia	3,711	2,992	1,497	789	913	12,240	9,762	9,351	8,481	9,232
Austria	872	847	470	269	366	1,398	2,203	2,144	2,006	2,108
Belgium	214	196	135	75	135	610	600	604	579	580
Canada	1,255	837	537	272	433	2,628	2,741	2,613	2,414	2,657
Chile	1,245	1,246	961	654	581	245	1,338	1,762	1,682	1,799
Czech Republic	313	337	238	148	197	5,333	5,369	5,081	4,481	5,112
Denmark	559	563	297	130	119	615	629	625	612	609
Estonia	200	185	112	63	110	3,510	3,536	3,323	2,659	3,304
Finland	1,838	1,679	966	406	455	396	1,720	2,485	1,913	2,244
France	3,187	2,867	1,943	935	935	29,598	30,696	29,942	26,304	27,626
Germany	2,907	2,901	2,152	1,164	1,457	10,865	10,992	10,803	10,122	10,518
Greece	510	678	671	493	592	5,960	6,245	6,468	6,269	6,789
Hungary	618	630	413	269	359	2,923	2,921	2,805	2,665	2,847
Iceland	20	15	8	4	5	100	99	98	80	93
Ireland	339	371	203	115	133	143	148	144	133	247
Israel	651	640	420	260	349	1,023	1,036	1,040	989	1,023
Italy	9,563	9,039	5,808	3,191	3,533	34,517	35,959	34,322	30,288	31,876
Japan	1,802	2,117	1,957	925	1,132	1,826	1,765	1,760	1,744	1,759
Latvia	247	240	162	95	121	1,242	1,271	1,218	1,187	1,344
Lithuania	202	187	135	96	151	2,390	2,515	2,338	1,976	2,441
Luxembourg	28	25	15	7	9	361	371	232	102	102
Mexico	2,244	2,200	1,639	1,182	1,148	6,018	7,579	8,213	8,147	10,988
Netherlands	880	760	420	192	190	2,428	2,415	2,384	2,277	2,271

Country	Test Count (1000s)					City Count				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
New Zealand	159	139	88	50	73	1,574	1,599	1,536	1,362	1,520
Norway	209	203	122	64	76	1,619	2,055	1,884	2,451	3,018
Poland	2,013	1,842	1,178	754	953	7,913	12,833	11,641	9,866	11,335
Portugal	305	276	179	123	137	1,264	1,397	1,370	1,334	2,139
Slovakia	231	259	159	88	104	2,399	2,516	2,410	2,143	2,378
Slovenia	171	163	100	70	91	4,261	4,316	3,907	3,448	4,024
South Korea	387	172	122	59	153	162	162	162	162	164
Spain	727	766	509	317	317	9,639	10,729	9,668	8,014	8,925
Sweden	120	125	78	41	70	434	503	476	437	462
Switzerland	970	810	475	227	212	2,569	2,530	2,494	2,431	2,197
Turkey	1,702	1,736	1,164	789	855	3,428	7,042	6,754	6,140	6,934
United Kingdom	4,199	3,916	2,310	1,232	1,823	6,494	10,645	10,254	9,408	10,190
United States	**17,941**	**13,104**	**7,198**	**3,006**	**3,122**	**26,346**	**26,345**	**25,393**	**23,223**	**24,864**

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C. Mobile Broadband – 5G Speed and Latency Results

42. Figure III.C.1 compares the mean 5G download speeds by country for the years 2021 to 2023. For the mean download speeds, the United States' ranking rose to 16th among the 36 countries in 2023 with a mean download speed of 243.9 Mbps, up from 27th in 2021 with a mean download speed of 187.7 Mbps. In 2023, South Korea had the highest mean download speed at 537.3 Mbps, while Poland had the lowest mean download speed at 90.6 Mbps. There is considerable variation in mean download speed within some countries over time.

Fig. III.C.1
Mobile Broadband – 5G Mean Download Speed by Country (2021-2023)

Country	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	8	314.9	8	291.1	13	248.0
Austria	30	182.1	24	198.9	26	193.3
Belgium	26	191.0	20	206.5	15	244.2
Canada	32	176.8	32	167.7	25	195.5
Chile	21	212.8	27	190.0	28	186.3
Czech Republic	35	123.9	35	119.9	35	122.8
Denmark	25	198.3	9	271.5	8	297.6
Estonia	22	207.7	17	227.4	12	256.1
Finland	10	269.7	10	265.8	10	265.3
France	18	227.1	13	259.9	9	267.8
Germany	31	181.9	30	180.2	29	183.9
Greece	12	261.5	14	257.5	17	222.6
Hungary	13	257.1	12	260.8	27	191.5
Iceland	5	424.5	5	347.4	2	349.8
Ireland	15	253.1	16	232.2	19	212.6
Israel	28	187.7	19	209.7	21	210.7
Italy	33	173.2	31	175.9	24	195.9
Japan	19	219.9	26	196.5	31	172.8
Latvia	20	213.9	25	197.9	14	245.4
Lithuania	1	668.0	11	265.0	11	260.6
Luxembourg	14	255.7	21	206.2	32	172.6
Mexico	7	321.9	29	187.3	22	209.5
Netherlands	34	152.0	34	156.9	33	154.6
New Zealand	9	304.9	6	313.6	7	310.6
Norway	4	465.3	4	364.5	4	327.6
Poland	36	103.9	36	94.6	36	90.6
Portugal	11	268.5	7	310.5	5	325.8
Slovakia	29	184.9	33	159.5	34	140.8
Slovenia	17	234.2	23	199.0	23	206.7
South Korea	3	496.2	1	542.9	1	537.3
Spain	23	205.2	28	188.5	18	213.4

Country	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
Sweden	6	394.9	3	420.3	3	341.6
Switzerland	16	242.4	15	234.7	20	212.5
Turkey	2	562.6	2	505.7	6	311.3
United Kingdom	24	202.4	22	202.1	30	176.9
United States	**27**	**187.7**	**18**	**217.5**	**16**	**243.9**

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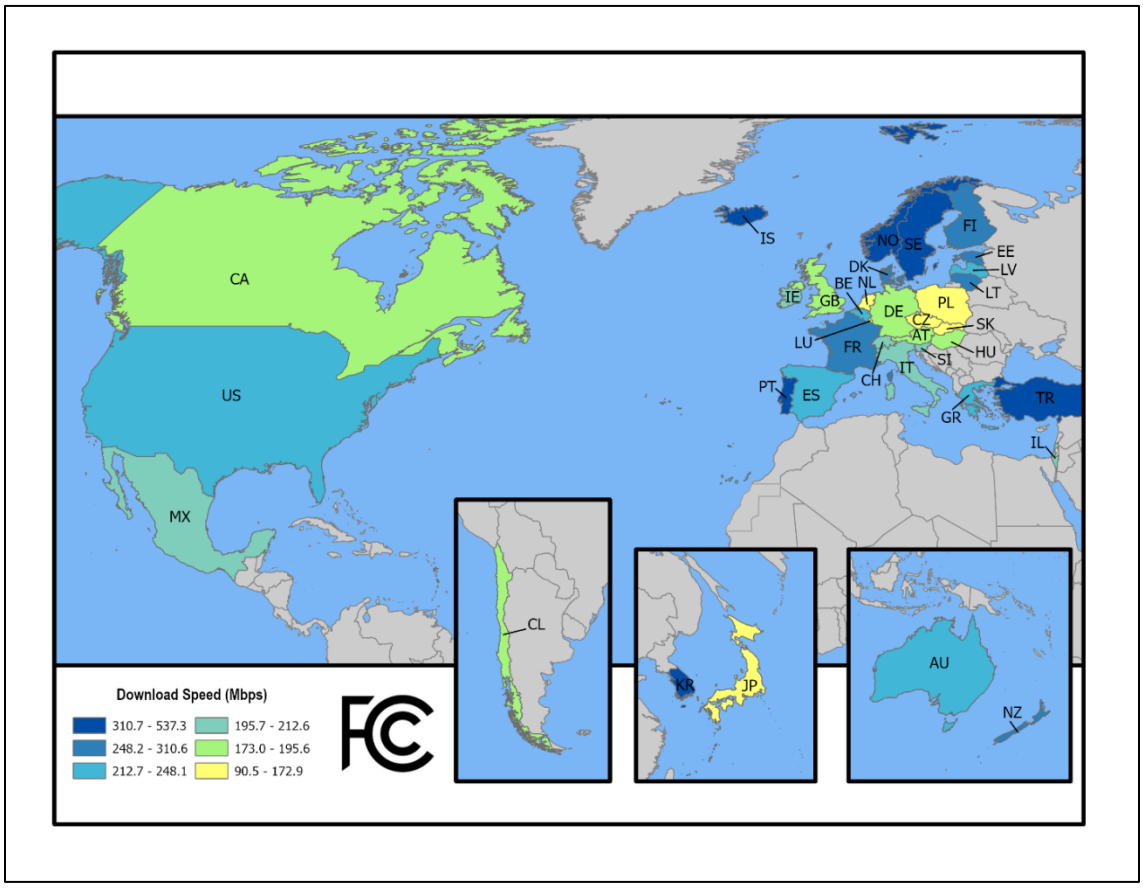
43. Figure III.C.2 presents a map of the mean 5G download speeds by country in 2023.[59] The mean download speeds in 2023 in North America ranged from 195.5 to 243.9 Mbps. The six countries with the highest mean download speeds were Turkey, Portugal, Norway, Sweden, Iceland, and South Korea, and they had a range of download speeds from 311.3 to 537.3 Mbps. The six countries with the lowest mean download speeds were Poland, the Czech Republic, Slovakia, the Netherlands, Luxembourg, and Japan, and they had a range of download speeds from 90.6 to 172.8 Mbps. All Nordic OECD countries were in the top ten countries in terms of download speeds in 2023.

[59] Each country's mean 5G download speed values are reported in Figure III.C.1. *See supra* Fig. III.C.1.

Fig. III.C.2
Mobile Broadband – 5G Mean Download Speed by Country (2023)



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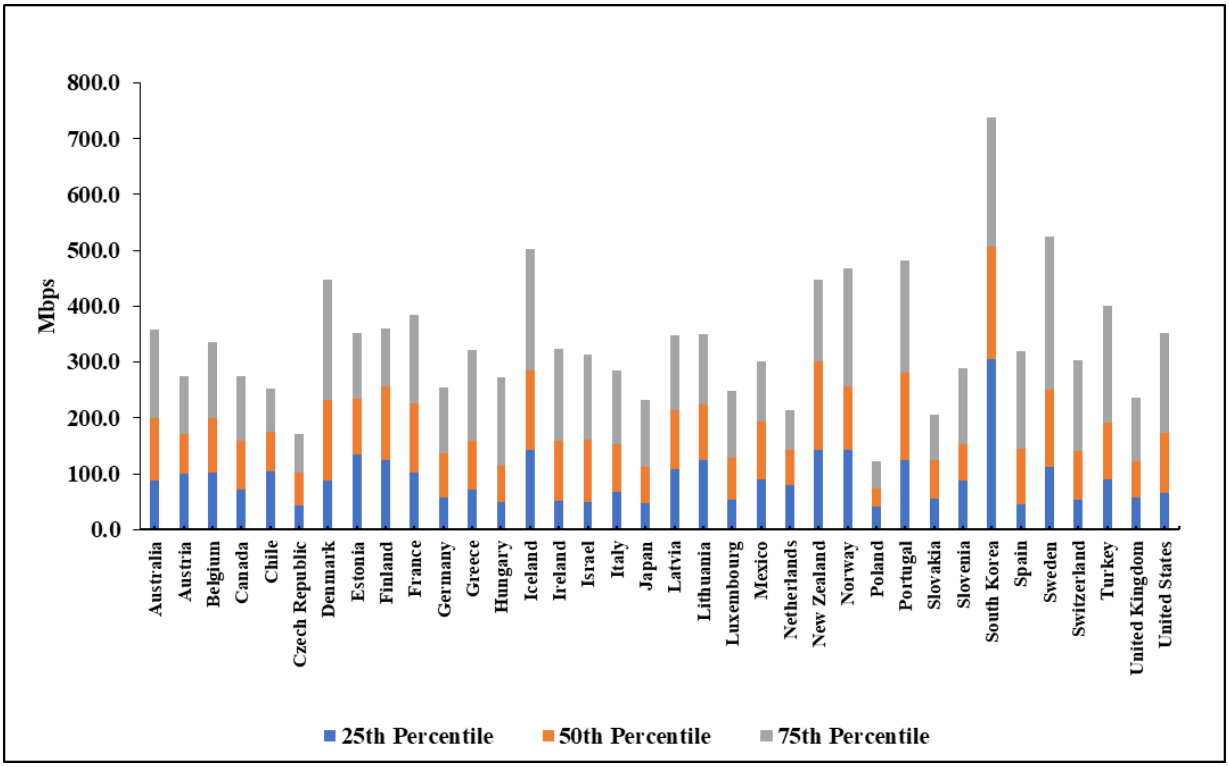
44. Figure III.C.3 shows the distribution of 5G download speeds across cities for each country in 2023. The top of each color bar represents the corresponding 25th, 50th, and 75th download speed percentiles.[60] The 25th, 50th and 75th percentiles for download speeds in the United States in 2023 were 65.1 Mbps, 174.0 Mbps, and 351.4 Mbps, respectively.

[60] We calculate the country-level mean percentiles by taking the weighted average of the city-level percentiles using sample counts as weights.

Fig. III.C.3
Mobile Broadband – 5G Download Speed Percentiles (2023)



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45. Figure III.C.4 compares the mean 5G download speeds by country capital cities and U.S. state capital cities for the years 2021 to 2023. The mean download speed in Washington D.C. in 2023 was 303.6 Mbps, which ranked 17th among the 86 country and state capital cities. The highest ranked U.S. state capital city in 2023 was Salt Lake City, Utah, which ranked 3rd with a mean download speed of 406.7 Mbps. Other U.S state capital cities that were ranked among the top ten in 2023 were Denver, Colorado, which ranked 4th with a mean download speed of 396.6 Mbps and Harrisburg, PA, which ranked 8th with a download speed of 368.2 Mbps.

Fig. III.C.4
Mobile Broadband – 5G Mean Download Speed by Country Capital and U.S. State Capital Cities (2021-2023)

City, Country/State	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
Canberra, Australia	24	299.3	26	294.2	42	247.9
Vienna, Austria	49	201.3	50	203.8	62	192.1
Brussels, Belgium	54	179.6	51	203.2	49	232.6
Ottawa, Canada	56	174.8	64	146.7	61	196.6
Santiago, Chile	42	218.5	54	192.8	64	186.4
Prague, Czech Republic	64	135.9	70	131.6	76	136.4
Copenhagen, Denmark	36	253.1	13	348.2	5	386.4
Tallinn, Estonia	38	250.2	24	299.0	18	303.3
Helsinki, Finland	29	278.0	31	274.2	35	268.1
Paris, France	32	270.6	27	291.8	19	302.9
Berlin, Germany	45	207.8	45	216.2	52	225.2
Athens, Greece	34	263.9	37	263.0	46	234.9
Budapest, Hungary	37	252.7	34	267.0	51	226.7
Reykjavik, Iceland	10	420.1	12	350.3	10	350.0
Dublin, Ireland	28	281.8	35	264.4	45	240.9
Jerusalem, Israel	55	175.7	56	188.8	57	204.6
Rome, Italy	50	200.8	53	194.9	53	217.7
Tokyo, Japan	46	207.2	61	177.9	69	178.9
Riga, Latvia	40	244.5	46	213.3	40	254.1
Vilnius, Lithuania	1	681.3	17	323.9	25	290.9
Luxembourg City, Luxembourg	31	272.6	42	238.2	59	198.2
Mexico City, Mexico	12	372.8	58	185.6	67	180.8
Amsterdam, Netherlands	60	148.9	63	153.3	74	148.5
Wellington, New Zealand	21	308.0	10	351.4	9	352.8
Oslo, Norway	7	502.0	7	414.7	6	378.7
Warsaw, Poland	69	94.8	80	90.6	85	88.9
Lisbon, Portugal	23	299.8	11	351.3	7	375.9
Bratislava, Slovakia	51	199.0	55	189.1	71	160.4
Ljubljana, Slovenia	27	282.9	43	218.1	47	234.7
Seoul, South Korea	4	522.1	1	565.6	1	576.9
Madrid, Spain	35	254.8	40	250.4	23	296.9
Stockholm, Sweden	8	493.0	3	509.5	2	406.8
Bern, Switzerland	39	246.2	38	257.0	41	254.1
Ankara, Turkey	5	514.4	16	338.7	70	172.9

City, Country/State	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
London, United Kingdom	48	202.0	57	187.7	73	155.8
Albany, NY	59	150.7	48	211.8	27	288.4
Annapolis, MD	58	156.9	18	320.5	29	281.2
Atlanta, GA	20	315.2	14	339.3	20	300.9
Augusta, ME	83	66.0	75	101.6	82	110.9
Austin, TX	57	160.7	52	200.0	38	257.1
Baton Rouge, LA	72	89.0	76	100.3	66	181.1
Bismarck, ND	71	91.7	82	86.8	43	247.5
Boise, ID	33	270.0	23	308.6	30	279.3
Boston, MA	19	319.9	21	316.0	15	308.6
Carson City, NV	86	55.3	85	66.8	77	133.2
Charleston, WV	82	73.1	77	95.2	81	115.2
Cheyenne, WY	80	75.2	84	78.0	83	99.3
Columbia, SC	15	354.8	8	390.6	12	324.7
Columbus, OH	25	293.0	28	286.2	31	278.7
Concord, NH	78	78.7	65	140.3	65	182.1
Denver, CO	17	332.6	2	517.3	4	396.6
Des Moines, IA	6	507.9	5	452.1	11	335.4
Dover, DE	66	126.2	59	183.4	54	212.8
Frankfort, KY	65	127.6	62	154.7	63	188.6
Harrisburg, PA	3	528.2	9	360.1	8	368.2
Hartford, CT	30	276.6	39	250.7	26	289.1
Helena, MT	67	98.1	83	78.8	79	120.4
Honolulu, HI	63	137.7	49	204.7	36	266.7
Indianapolis, IN	14	362.9	22	311.7	13	320.0
Jackson, MS	79	76.8	81	87.0	78	128.3
Jefferson City, MO	73	88.9	73	107.7	72	158.5
Juneau, AK	85	56.4	86	38.7	86	39.9
Lansing, MI	61	142.0	60	179.0	37	261.9
Lincoln, NE	74	85.5	66	139.1	55	205.6
Little Rock, AR	9	450.9	20	319.6	21	299.1
Madison, WI	76	83.7	68	136.6	56	204.9
Montgomery, AL	77	79.7	79	92.3	68	180.3
Montpelier, VT	70	93.7	69	133.0	84	90.2
Nashville, TN	22	305.1	33	271.8	22	297.7
Oklahoma City, OK	44	213.3	44	216.3	44	241.2
Olympia, WA	81	74.3	74	104.4	75	144.2

City, Country/State	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
Phoenix, AZ	47	204.4	47	212.8	34	273.2
Pierre, SD	62	138.3	67	138.8	50	229.6
Providence, RI	18	322.2	25	296.8	14	317.2
Raleigh, NC	16	334.6	19	320.0	16	304.8
Richmond, VA	11	413.7	6	440.6	24	291.4
Sacramento, CA	26	291.3	29	285.9	39	254.1
Saint Paul, MN	41	239.5	32	273.5	28	287.6
Salem, OR	53	182.1	41	247.6	33	273.6
Salt Lake City, UT	2	613.7	4	474.4	3	406.7
Santa Fe, NM	75	85.2	78	93.1	80	118.7
Springfield, IL	68	96.0	71	127.6	60	197.2
Tallahassee, FL	52	183.1	36	263.0	32	277.3
Topeka, KS	84	65.1	72	109.7	58	199.6
Trenton, NJ	43	214.0	30	277.9	48	233.3
Washington, DC	13	363.7	15	338.8	17	303.6

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46. Figure III.C.5 compares the mean 5G upload speeds by country for the years 2021 to 2023. For the mean upload speeds, the United States ranked 32nd among the 36 countries in 2023 with the mean upload speed slightly decreasing from 23.5 Mbps in 2021 to 22.6 Mbps in 2023. Turkey had the fastest mean upload speed in 2023 at 53.0 Mbps, slightly decreasing from 58.7 Mbps in 2021.

Fig. III.C.5
Mobile Broadband – 5G Mean Upload Speed by Country (2021-2023)

Country	2021		2022		2023	
	Rank	Mbps	Rank	Mbps	Rank	Mbps
Australia	25	28.2	27	25.6	30	23.0
Austria	26	27.4	20	28.8	18	30.4
Belgium	27	25.7	16	31.2	16	31.5
Canada	28	25.1	29	24.6	24	26.3
Chile	32	22.8	28	25.0	20	29.4
Czech Republic	14	34.9	10	35.3	10	34.4
Denmark	13	36.1	11	34.8	12	33.7
Estonia	15	33.7	19	29.7	19	29.6
Finland	22	30.9	17	30.4	15	31.6
France	35	20.4	34	20.8	34	21.4
Germany	21	31.4	21	28.6	21	28.2
Greece	17	32.2	15	32.4	17	30.5
Hungary	10	38.7	8	36.6	13	33.3
Iceland	8	41.4	7	36.9	8	35.2
Ireland	18	31.8	25	27.1	29	24.7
Israel	23	30.1	23	27.3	25	25.9
Italy	33	22.6	31	22.0	31	22.7
Japan	30	23.7	35	19.7	35	19.5
Latvia	29	23.9	33	21.6	28	24.7
Lithuania	1	62.9	5	42.1	9	35.0
Luxembourg	12	36.7	22	28.4	27	25.1
Mexico	3	57.9	12	34.7	5	37.9
Netherlands	11	38.6	9	35.8	11	34.1
New Zealand	19	31.6	14	33.7	14	32.0
Norway	5	51.2	2	46.2	3	45.3
Poland	34	22.1	32	21.8	33	22.1
Portugal	9	38.8	13	34.0	6	35.9
Slovakia	16	32.7	18	30.1	22	27.5
Slovenia	20	31.6	24	27.3	26	25.9
South Korea	6	48.1	4	45.5	2	46.1
Spain	24	28.9	26	26.5	23	27.2
Sweden	4	51.8	3	45.5	4	40.8
Switzerland	7	42.8	6	39.6	7	35.3
Turkey	2	58.7	1	56.7	1	53.0
United Kingdom	36	20.3	36	19.6	36	19.1
United States	**31**	**23.5**	**30**	**22.0**	**32**	**22.6**

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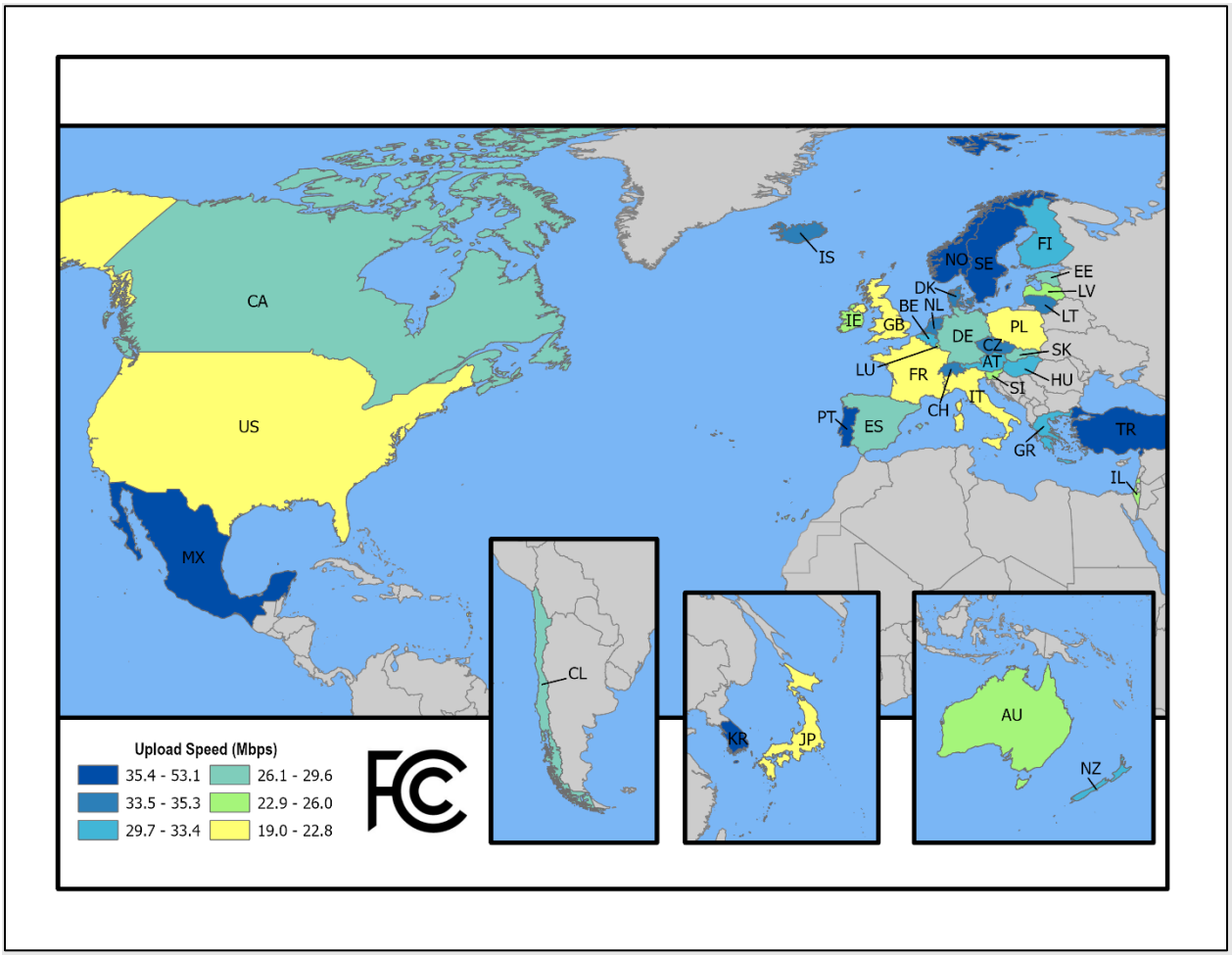
47. Figure III.C.6 presents a map of the mean 5G upload speeds by country in 2023.[61] The mean upload speeds in 2023 in North America ranged from 22.6 to 37.9 Mbps. The six countries with the highest mean upload speeds were Portugal, Mexico, Sweden, Norway, South Korea, and Turkey, and they had a range of upload speeds from 35.9 to 53.0 Mbps. The six countries with the lowest mean upload speeds were the United Kingdom, Japan, France, Poland, the United States, and Italy, and they had a range of upload speeds from 19.1 to 22.7 Mbps.

Fig. III.C.6
Mobile Broadband – 5G Mean Upload Speed by Country (2023)



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48. Figure III.C.7 compares the mean 5G latency by country for the years 2021 to 2023. For the mean latency, the United States ranked at 32nd among the 36 countries in 2023 at 32.6 ms. Latvia ranked 1st in 2023 with a mean latency of 18.1 ms.

[61] Each country's mean 5G upload speed values are reported in Figure III.C.5. *See supra* Fig. III.C.5.

Fig. III.C.7
Mobile Broadband – 5G Mean Latency by Country (2021-2023)

Country	2021		2022		2023	
	Rank	ms	Rank	ms	Rank	ms
Australia	21	22.5	21	24.2	22	25.0
Austria	24	23.8	20	23.9	13	22.9
Belgium	20	22.4	24	25.4	24	25.8
Canada	23	23.8	26	26.4	23	25.4
Chile	6	16.9	12	21.0	17	23.6
Czech Republic	22	23.0	23	25.2	16	23.2
Denmark	15	20.0	6	19.8	6	19.8
Estonia	5	16.6	5	19.7	4	19.5
Finland	10	19.0	9	20.5	7	20.7
France	32	31.3	31	31.7	31	31.4
Germany	27	26.7	29	28.5	29	29.5
Greece	11	19.0	15	21.7	20	23.8
Hungary	8	17.8	8	20.1	19	23.7
Iceland	1	14.4	1	17.0	5	19.6
Ireland	12	19.1	14	21.5	12	22.5
Israel	9	18.7	13	21.3	14	22.9
Italy	36	35.6	36	37.2	35	36.1
Japan	35	34.4	35	36.6	36	37.6
Latvia	4	16.2	2	17.4	1	18.1
Lithuania	7	17.0	3	18.2	3	19.2
Luxembourg	25	24.6	22	24.3	18	23.7
Mexico	30	30.1	18	22.9	25	27.0
Netherlands	18	21.4	17	22.9	15	23.1
New Zealand	28	28.1	30	29.1	30	29.8
Norway	19	21.7	19	23.5	21	24.4
Poland	26	25.6	27	26.9	27	27.9
Portugal	16	20.3	16	21.7	11	22.0
Slovakia	2	14.6	11	20.5	10	21.8
Slovenia	3	15.8	4	18.2	2	18.5
South Korea	17	21.2	28	27.5	26	27.5
Spain	31	30.2	33	34.2	33	33.3
Sweden	13	19.4	10	20.5	9	21.7
Switzerland	14	19.8	7	19.9	8	21.2
Turkey	29	29.6	25	25.8	28	28.4
United Kingdom	34	33.9	34	34.8	34	34.6
United States	**33**	**33.0**	**32**	**33.4**	**32**	**32.6**

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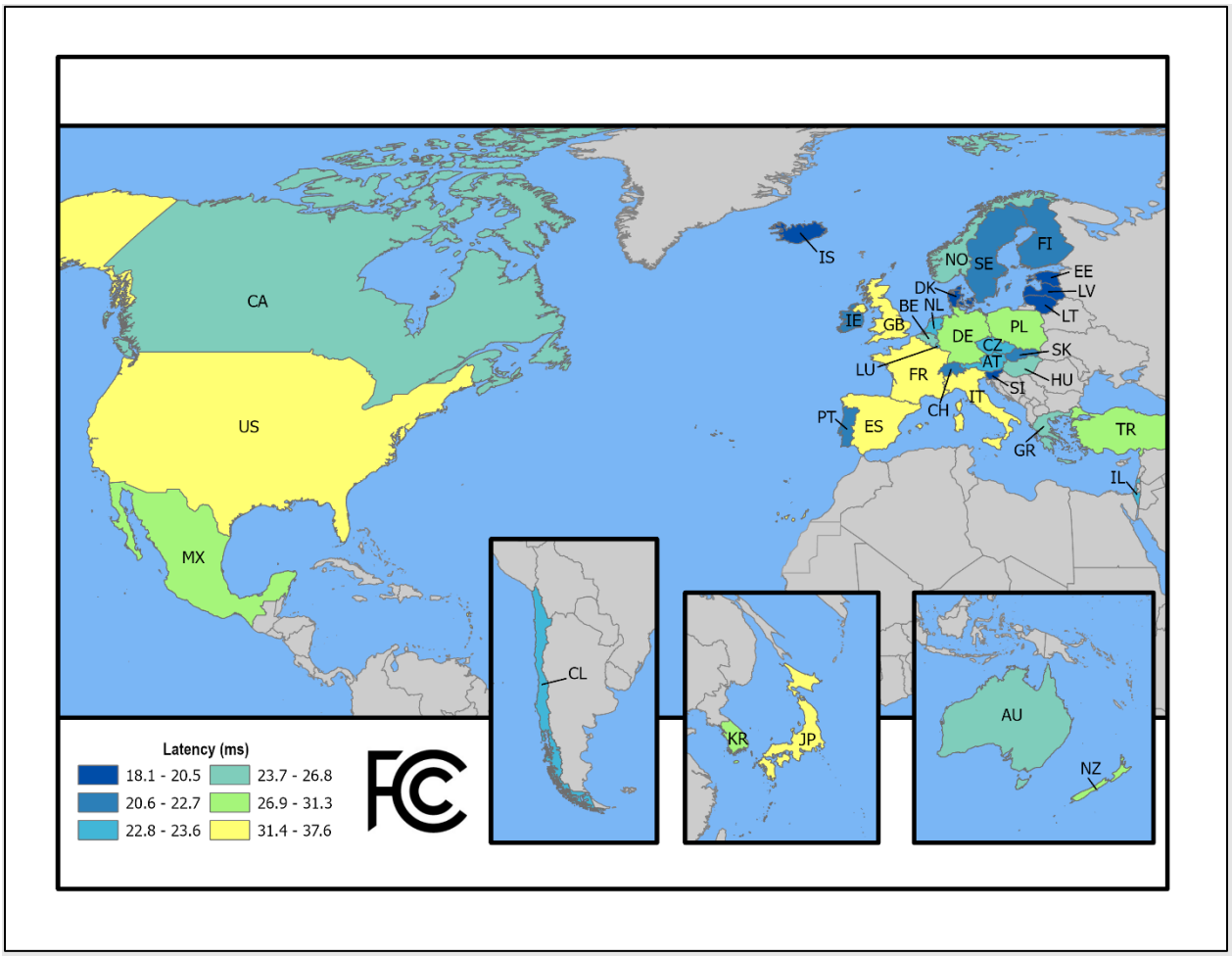
49. Figure III.C.8 presents a map of the mean 5G latency by country in 2023.[62] The mean latency in 2023 was between 25.4 to 32.6 ms for North American countries. The highest mean latency was concentrated in Southern and Western European countries: France, Italy, Spain, and the United Kingdom.

Fig. III.C.8
Mobile Broadband – 5G Mean Latency by Country (2023)



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50. Figure III.C.9 presents the number of tests in the sample for each country, as well as the number of cities with 5G tests in each country, for the years 2021 to 2023. Test counts in the United States increased by 80% from 8.5 million in 2021 to 15.4 million in 2023. The number of cities with tests in the United States increased by almost 3,000 during the same period. The increase in the number of tests and number of cities with tests is consistent with the continued deployment of 5G networks within countries in recent years.

[62] Each country's mean 5G latency values are reported in Figure III.C.7. *See supra* Fig. III.C.7.

Fig. III.C.9
Mobile Broadband – 5G City Count and Test Count by Country (2021-2023)

Country	Test Count (1000s)			City Count		
	2021	2021	2023	2021	2021	2023
Australia	703	939	1,004	2,619	3,610	4,732
Austria	92	171	409	962	1,334	1,650
Belgium	12	37	111	266	389	511
Canada	268	523	335	1,001	1,382	1,658
Chile	18	328	9	187	930	1,102
Czech Republic	52	104	181	953	2,022	3,454
Denmark	135	201	528	596	612	613
Estonia	6	16	3	219	807	2,062
Finland	303	299	117	651	1,283	1,741
France	389	645	1,704	9,582	14,422	17,587
Germany	591	1,098	4,403	7,485	9,007	9,707
Greece	155	311	107	1,416	3,643	5,599
Hungary	45	94	57	328	615	1,208
Iceland	4	7	6	18	50	63
Ireland	56	88	85	109	115	233
Israel	81	144	185	513	682	797
Italy	452	1,177	2,211	10,878	18,489	24,354
Japan	279	470	273	1,232	1,440	1,551
Latvia	4	36	6	73	271	671
Lithuania	1	22	6	22	636	1,724
Luxembourg	8	14	14	48	99	102
Mexico	4	181	43	36	354	693
Netherlands	234	247	1,434	2,101	2,232	2,314
New Zealand	19	36	26	89	269	432
Norway	68	113	37	394	1,772	2,413
Poland	138	271	237	1,818	3,054	5,445
Portugal	24	127	22	444	1,046	1,874
Slovakia	14	37	32	176	721	1,346
Slovenia	18	41	304	664	1,436	2,190
South Korea	102	98	130	150	152	163
Spain	103	168	626	2,109	3,470	5,155
Sweden	25	61	52	108	309	412
Switzerland	273	319	1,872	2,358	2,446	2,277
Turkey	1	1	9	8	13	46
United Kingdom	1,357	1,743	1,693	3,766	5,958	6,888
United States	**8,478**	**11,156**	**15,387**	**20,541**	**22,135**	**23,329**

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D. Data and Analysis

51. *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 broadband datasets are aggregated to the city-platform level, whereas the annual mobile broadband datasets are aggregated to the city-platform-technology level.[63] Prior to aggregating the data, Ookla applies a set of cleaning and filtering rules to ensure the quality of the data and to remove invalid test results. The Ookla Speed Test data are user-generated, meaning the users manually choose to run each speed test. Therefore, the results from these tests may represent nontypical situations (e.g., when users experienced congestion issues). Because the tests are not taken randomly, they may not represent consumers' typical broadband experience.

52. *Analysis*. In our analysis, we consistently aggregate the data to higher levels using sample counts as a weight. First, we aggregate over platforms for fixed broadband, mobile 4G LTE broadband, and mobile 5G broadband at the city level. Then, we aggregate data over cities to the state level or country level. Ideally, we would prefer having 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.

53. Our city-level and country-level results are not directly comparable to city-level and country-level results published by Ookla because Ookla applies its aggregation methodology to the given level of aggregation before calculating statistics, whereas we weigh the lower level of disaggregation by sample count to aggregate the data to higher levels. As a simplified example, if Ookla was calculating the average 5G download speed for the United States in 2023, they calculate each user's device's average 5G download speed across the United States in 2023 to create "samples"; then, Ookla calculates the average of the samples so that each user has an equal weight (i.e., a user with a disproportionate number of speed tests counts the same as a user with one speed test) for the given geography and time period. In our case, because we only have data aggregated to the city level, a user may have tests in multiple cities so when aggregating across cities to the national level, users with tests in a disproportionate number of cities will have a higher weight than they would in Ookla's methodology.

IV. BROADBAND PRICING COMPARISONS

54. Congress directed 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."[64] To meet this directive, we first collected a comprehensive sample of advertised prices and terms for over 1,500 fixed and mobile broadband plans from the largest broadband providers in the United States and 25 other countries. We then ranked the countries by fixed and mobile broadband prices from the least expensive (1st) to the 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 allowances.[65] These

[63] By platform, we refer to the testing platform such as the Android App, the iOS App, a web browser, or other Ookla testing platforms.

[64] 47 U.S.C. § 1303(b)(2); *see also* RAY BAUM'S Act of 2018.

[65] The data were collected between January and June of 2024. 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. We use download speeds as the primary differentiating product characteristic of fixed broadband plans because almost all fixed broadband plans have advertised download speeds; (continued….)

two weighted average prices are then used to calculate an overall average price, and countries are ranked by this measure.[66]

55. To better account for differences in the characteristics of the comparison communities and their broadband offerings, the second method constructs hedonic fixed and mobile broadband price indexes when regressing broadband prices on broadband product characteristics and country-level variables to control for differences in broadband market conditions.[67] The hedonic method seeks to better assess how U.S. broadband prices compare to prices in other countries after accounting for the types of country-level cost and demographic differences identified by Congress 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., download speeds and data allowances) and generates prices for a set of standardized broadband plans to facilitate pricing 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 provides a substantially different assessment of the competitiveness of the U.S. broadband marketplace.[68]

A. Overview and Data Highlights

56. 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 service is also frequently purchased as part of a discounted bundle of services, making it difficult to identify the price of the broadband service. Finally, differences across countries in the quality of networks deployed, cost factors (e.g., population density and topography), and demand factors (e.g., demographics), would be expected to affect pricing, all else equal. Our hedonic price index analysis accounts for these differences, with the intention of producing more meaningful price comparisons that potentially shed some light on which countries provide greatest consumer benefits.[69]

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for mobile broadband, we use data allowances as the primary differentiating product characteristic because most mobile broadband plans are advertised with varying data allowances.

[66] 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, are from each of the three download speed tiers and; and for mobile broadband, are from each of the three data usage tiers in the analyses.

[67] A hedonic regression indicates how pricing varies with the characteristics of a good (e.g., download speed). In this *Report*, the hedonic regression builds on the price index method by allowing for the 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.

[68] A 2021 study by Israel, Katz, and Keating reached similar conclusions regarding the importance of accounting for quality differences, bundling, as well as supply and demand factors in order to provide meaningful comparisons of broadband prices across countries. Mark Israel, Michael Katz, & Bryan Keating, International Broadband Price Comparisons Tell Us Little About Competition and Do Not Justify Broadband Regulation (May 2021), https://www.ncta.com/sites/default/files/2021-05/international-price-comparisons-paper-11-may-2021.pdf. The same logic they apply led us to implement our current price comparison approach which was first introduced in the *Sixth International Broadband Data Report*.

[69] 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

(continued….)

1. Fixed Broadband Pricing Results

57. *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 8th out of the 26 countries in our broadband price index, not adjusting for cost, quality, and demand factor differences across countries.[70]
- For broadband service purchased in a bundle with video service, we find that the United States ranks 9th out of the 26 countries, not adjusting for cost, quality, and demand factor differences across countries.
- Overall, we find that the United States ranks 8th out of the 26 countries, not accounting for cost, quality, and demand differences across countries.

58. *Hedonic Price Index Results*. The hedonic price index adjusts broadband prices for differences in broadband demand factors (e.g., demographics) and network 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 pricing comparisons. Based on the predicted prices for these standardized plans, we then calculate a hedonic price index to serve as our pricing comparison measure across countries. This index estimates what the average U.S. consumer would expect to pay for service in each country if those countries had similar demand characteristics, network cost structures, and broadband offerings as the United States.[71]

- 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 11th out of the 26 countries.[72]
- The U.S. ranking remains unchanged at 11th after adjusting for our measure of fixed broadband network quality.

2. Mobile Broadband Pricing Results

59. Our mobile broadband pricing comparison methodology is the same as our fixed broadband pricing comparison methodology with two exceptions. First, because most mobile broadband plans are differentiated by data usage allowance rather than speed, we classify mobile broadband products by data usage allowances rather than by download speeds.[73] Second, we account for bundling in this

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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.

[70] *See infra* Fig. IV.D.1.

[71] The country rankings would not change if, instead of using the United States as our base country, we predicted prices at the values of the country-level variables (e.g., population density, income per capita) 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. If we changed the values of the plan characteristics (e.g., download speeds, data allowance) of any of the six predicted plans, the country rankings would potentially change due to the varying provider-level random coefficients in the hedonic model.

[72] *See infra* Fig. IV.D.3.

[73] In some countries, providers have begun to differentiate plans based on maximum download speeds, especially for various tiers of unlimited data plans, in addition to differentiating plans based on data usage allowances. However, (continued….)

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.

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

- The United States ranks 25th in single-line plan pricing and 24th in multi-line pricing out of the 26 countries, not adjusting for cost, quality, and demand factor differences across countries.[74]
- Overall, we find that the United States ranks 25th out of the 26 countries in our mobile broadband price index, not adjusting for cost and demand factor differences across countries.

61. *Hedonic Price Index Results.* 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 similar demand characteristics, network cost structure, and broadband plan characteristics as the United States.

- After adjusting for differences in the cost and demographic factors, as well as differences in mobile broadband plan characteristics across countries, our hedonic price index estimates that the United States ranks 19th out of the 26 countries.[75]
- Adjusting for mobile network quality measures, the United States ranks 19th out of 26 countries.

3. Combining Fixed and Mobile Hedonic Price Index Rankings

62. Typical consumers in the United States subscribe to both fixed and mobile broadband services, so we also measure overall broadband price by calculating the average monthly cost that U.S. consumers would pay to subscribe to both services in each country based on the fixed broadband and mobile broadband hedonic price indexes.[76] After accounting for differences in costs, demographics, and broadband plan characteristics, we find that the United States ranks 16th overall by this measure, at $103.33 per month for an average mobile and fixed broadband connection.[77] Adjusting for network quality measures, the United States ranking remains at 16th.[78]

B. Data

63. For our fixed broadband data analysis, we collected fixed residential broadband plan prices and terms from 87 providers in 26 countries, including the United States, between April and June 2024. 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 September 2023 and such that the sample represented at least 75% of the national market share for each

we do not have information on subscription rates by download speed tiers or a proxy (e.g., data usage as a proxy for data allowance) as we do for fixed broadband.

[74] *See infra* Fig. IV.E.1.

[75] *See infra* Fig. IV.E.3.

[76] We do not account for discounts for bundling of fixed broadband and mobile broadband services that are offered by some providers. *See infra* Fig. IV.F.2.

[77] *Id*.

[78] *Id*.

country.[79] This threshold was chosen to balance data collection costs against the desire to obtain a representative sample of broadband pricing for each country.[80] For each provider, we collected plans from 10 randomly selected addresses in the country's capital city.[81] These addresses were then entered into providers' websites to determine the product offerings at each address. For the first time, we recorded terrestrial fixed wireless and satellite fixed broadband plans, in addition to wired broadband plans (e.g., copper, cable, FTTP), if available at any of the 10 addresses. 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.[82] Where we could not collect address level plan data, we collected "promotional splash page" plans (i.e., we assume the plan is available for at least one address in the city).[83]

64. We also collected mobile broadband plan prices and terms from 84 providers across 26 countries, including the United States, between January and March of 2024. We restrict the sample to providers with national broadband market shares of at least 10% as of September 2023 and such that the sample represented at least 75% of the national market share for each country.[84] Given the wide scope of offerings by mobile providers, we limited the collection of 4G LTE and 5G postpaid smartphone plans that included voice calling for up to four lines (when adding lines provided a discount).[85] Therefore, all recorded plans have both voice and data components in their provision.

C. Methodology

65. *Fixed and Mobile Broadband Price Index Calculations.* 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. Consumer Price Index (CPI), calculated by the Bureau of Labor Statistics of the U.S. Department of Labor.[86] 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.

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[79] TeleGeography, *TeleGeography GlobalComms Database*, http://www.telegeography.com (last accessed Jan. 29, 2024) (navigate to *Company Statistics*, then choose *Fixed Broadband* within the *GlobalComms Database*). *TeleGeography GlobalComms Database* is subscription-only. We obtained these data as of January 2024.

[80] The lowest total sum of market shares is about 76% while 16 countries have over 90% total national market shares accounted for in our sample.

[81] In some cases, a provider did not offer service in the capital city which required collecting some providers' plans from another major city. We only considered the provider as serving the city if wired broadband plans (e.g., copper, FTTP, cable) were available at least in one of the city addresses.

[82] If we were able to collect address-level plans, we only recorded plans that were available for at least one address in the city. 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 sampled addresses.

[83] 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.

[84] *See* TeleGeography, *TeleGeography GlobalComms Database*, http://www.telegeography.com (last accessed Dec. 4, 2023) (navigate to *Company Statistics*, then choose *Mobile* within the *GlobalComms Database*).

[85] 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.

[86] U.S. Bureau of Labor Statistics, *Consumer Price Index: Frequently Asked Questions*, https://www.bls.gov/cpi/questions-and-answers.htm (last visited July 29, 2024).

66. Both our broadband price index and hedonic price index are Laspeyres broadband price indexes.[87] In the Laspeyres index calculation shown below, $p_{j,t}$ 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.[88]

$$\text{Laspeyres Index} = \frac{\sum_{j=1} p_{j,t} q_{j,0}}{\sum_{j=1} p_{j,0} q_{j,0}}$$

67. 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, but 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 for our mobile and fixed price indexes. For fixed broadband, we classify products by download speed tier ranges for which we have information on the share of U.S. fixed broadband households that subscribe to the speed tier.[89] We define three standalone fixed broadband products classified by the following download speed tiers: less than 100 Mbps; at least 100 Mbps but less than 250 Mbps; and at least 250 Mbps. We also define three additional products when these speed tiers are purchased in a bundle with video service.[90]

68. For mobile broadband, we classify products by data allowance rather than download speed[91] and define the three bundled products as multi-line data plans (i.e., "family plans"), rather than by bundles of telecommunications services as we do for fixed broadband.[92] Relative to purchasing multiple

[87] 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 PC's*, 93 American Economic Review 1578 (2003) (Pakes, 2003).

[88] 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.

[89] Aggregating products in this manner is common in the differentiated products demand model literature. *See* Steven Berry, James Levinsohn, & Ariel Pakes, *Automobile Prices in Market Equilibrium*, 63 Econometrica 841 (1995); Aviv Nevo, *Measuring Market Power in the Ready-to-Eat Cereal Industry*, 69 Econometrica 307 (2001); Austan Goolsbee & Amil Petrin, *The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV*, 72 Econometrica 351 (2004).

[90] For video service, we limit the scope to traditional linear TV plans and do not consider over-the-top (OTT) streaming services from the provider or from a third-party (e.g., Netflix bundled with broadband service).

[91] With the introductions of 5G plans, many providers are differentiating their plans primarily on download speeds in addition to differentiating on data allowance. However, we continue to define products based on the number of lines and data allowance because we do not have information on subscription rates by download speeds.

[92] In some countries, providers offer mobile broadband bundled with fixed broadband. We do not consider this type of bundling in our analysis.

single line plans, bundled plans are offered at greatly discounted rates and need to be properly accounted for to reflect the prices that consumers actually pay for their mobile services. We therefore define three standalone mobile broadband products (i.e., single line plans), which are classified by the following monthly data allowances: less than or equal to 10 GB per line; greater than 10 GB but less than or equal to 25 GB per line; and greater than 25 GB per line. We also define three bundled (i.e., more than one line plans) mobile broadband products, which are classified by the following monthly data allowances: less than or equal to 10 GB per line; greater than 10 GB but less than or equal to 25 GB per line; and greater than 25 GB per line.[93]

1. Fixed and Mobile Product Shares

69. *Fixed Product Shares.* We use the United States as the base country. To calculate the U.S. quantity weights for each of the six products in our fixed broadband price indexes, we use the FCC Form 477 data[94] to estimate the share of U.S. households that subscribe to each of the three download speed tiers and an estimate from S&P Global that about 58% of all U.S. broadband households purchase their service in a bundle.[95] The resulting broadband products and their estimated U.S. market shares are shown in Figure IV.C.1 below.

Fig. IV.C.1
Fixed Broadband Product Shares

Product	Download Speed Tier	Bundle Share	Speed Tier Share	Product Share	Plans
1	**Standalone: 0 < Mbps < 100**	41.6%	34.57%	14.38%	102
2	**Standalone: 100 ≤ Mbps < 250**	41.6%	41.73%	17.36%	111
3	**Standalone: 250 ≤ Mbps**	41.6%	23.70%	9.86%	254
4	**Bundle: 0 < Mbps < 100**	58.4%	34.57%	20.19%	117
5	**Bundle: 100 ≤ Mbps < 250**	58.4%	41.73%	24.37%	129
6	**Bundle: 250 ≤ Mbps**	58.4%	23.70%	13.84%	314

Sources: S&P Global (Bundle Shares); December 2023 FCC Form 477 data (Speed Tier Shares).
Note: Plan counts include "synthetic" plans.[96]

70. *Mobile Product Shares.* To construct our mobile broadband price indexes, we need to estimate the percentage of U.S. consumers who subscribe to each of the six mobile products defined by data usage allowance and number of lines. We follow the same approach first adopted in the *2020 International Broadband Data Report* of estimating product shares based on the estimated distribution of

[93] These multi-line products include any plans with two to four lines.

[94] FCC, *Form 477 Resources*, https://www.fcc.gov/economics-analytics/industry-analysis-division/form-477-resources (last visited July 31, 2024). All FCC Form 477 data used in this *Report* have been certified as accurate by the filers. We used December 2023 FCC Form 477 subscription data for these calculations. We further note that the analysis in this *Report* 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 July 29, 2024) (describing quality and consistency checks performed on providers' submitted data and explaining any adjustments made to the FCC Form 477 data as filed).

[95] S&P Global, *Estimated Broadband-Only Homes As a Percentage of US Occupied Homes, Q1 2019-Q3 2022* (last accessed July 19, 2024). We do not provide URLs for S&P Global articles and data throughout this section because it is a paid subscription service that cannot be publicly accessed.

[96] *See infra* para. 95.

mobile data usage in the United States,[97] but, similar to the approach used in the *2022 International Broadband Data Report*, we adjust for the continued growth in mobile broadband data usage.[98] The U.S. Census finds that 29% of U.S. households were one-person households in 2022 which we use as a proxy for the percentage of mobile subscribers who purchase single-line plans.[99] In Figure IV.C.2 below, we calculate the product shares for each of the six standardized mobile broadband products.[100] The column "Data Usage (Per Line) Share" provides the estimated percentage of all subscribers that consume an amount of data within the corresponding ranges of data usage and number of lines on the plan. For example, 40% of all single-line plans in the United States are estimated to consume between 0 and 10 GB of data per line (product 1), while 52% of multi-line plans would be expected to consume this amount of data per line (product 4).[101] We then multiply these estimated single-line and multi-line data usage shares by the percentage of all U.S. plans that are single versus multi-line to arrive at the final mobile product shares.

Fig. IV.C.2
Mobile Broadband Product Shares

Product	Lines	Data Allowance Tier (Per Line)	Bundling Share	Data Usage Share (Per Line)	Product Share	Plans
1	**1**	**0 < GB ≤ 10**	29%	40%	11.6%	143
2	**1**	**10 < GB ≤ 25**	29%	31%	9.0%	82
3	**1**	**GB > 25**	29%	29%	8.4%	290
4	**2-4**	**0 < GB ≤ 10**	71%	52%	36.9%	495
5	**2-4**	**10 < GB ≤ 25**	71%	28%	19.9%	265
6	**2-4**	**GB > 25**	71%	20%	14.2%	909

Source: Cisco, *Annual Internet Report (2018-2023) White Paper* (Mar. 9, 2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html; Ericsson, *Ericsson Mobility Visualizer*, https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer?f=11&ft=1&r=4&t=8&s=1&u=5&y=2017,2029&c=2 (last visited July 30, 2024); U.S. Census, *Census Bureau Releases New Estimates on America's Families and Living* Arrangements (Nov. 17, 2022), https://www.census.gov/newsroom/press-releases/2022/americas-families-and-living-arrangements.html#:~:text=Households%3A,only%2013%25%20of%20all%20households.
Note: Plan counts include "synthetic" plans.[102]

2. Product Price Calculations

71. Calculating comparable prices for each of the six broadband products for each country is more difficult. To calculate such prices using the Laspeyres index formula as set out above, we follow

[97] *See 2020 Communications Marketplace Report*, 36 FCC Rcd at 3797, Appx. G-3: International Broadband Data Report, para. 23.

[98] *See 2022 Communications Marketplace Report*, 37 FCC Rcd at 16399, Appx. G-4: International Broadband Data Report, para. 70.

[99] U.S. Census, *Census Bureau Releases New Estimates on America's Families and Living* Arrangements (Nov. 17, 2022), https://www.census.gov/newsroom/press-releases/2022/americas-families-and-living-arrangements.html#:~:text=Households%3A,only%2013%25%20of%20all%20households.

[100] *See infra* Fig. IV.F.1 (estimating log-normal parameters and distribution).

[101] 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, whereas 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.

[102] *See infra* paras. 107-108.

two common approaches in the price index literature. The first approach estimates 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. The second approach estimates a hedonic regression model and then uses this model to predict the prices for each of the six fixed and mobile broadband products.

72. *Broadband Price Index Prices.* In our broadband price index calculations, 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.[103] Finally, we calculate an average broadband price for each country by weighting these six product level prices by the estimated percentage of consumers in the United States, the base country, that subscribe to each product category. The prices we calculate using this methodology for our fixed broadband price index are shown in Figure IV.D.1, and the mobile price index prices are shown in Figure IV.E.1 below.

73. *Hedonic Price Index Prices.* Many studies compare advertised prices for "similar" telecommunications services, as we have done in our broadband price index calculations.[104] While such price comparisons are appropriate for descriptive assessments of price levels, they are less useful for identifying which countries may be producing the highest broadband consumer benefits.[105] 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 (i.e., how well a country is doing relative to others) 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. Rankings that account for these factors are necessary to inform government competition and regulatory policy because the exogenous determinants of price that are outside the scope of competition policy (e.g., terrain and population density) may differ across countries and distort comparisons.[106]

74. A hedonic regression indicates 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 such as the CPI.[107] Our

[103] 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 in the country offer the highest standalone (bundled) product, we assign the next highest available standalone (bundled) product price to the highest missing product price(s). *See infra* paras. 135-140.

[104] *See, e.g.,* Carol Corrado & Olga Ukhaneva, Hedonic Prices for Fixed Broadband Services: Estimation across OECD Countries (Oct. 2016), https://www.oecd-ilibrary.org/docserver/5jlpl4sgc9hj-en.pdf?expires=1603997556&id=id&accname=guest&checksum=1D0A776B692D8F368F8A696A24A0E702.

[105] 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 are 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, our results should still be interpreted with caution when comparing country rankings.

[106] The *Sixth 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. *See Sixth International Broadband Data Report*, 33 FCC Rcd at 980-81, paras. 5-6; *see also id.* at 1023-27, paras. 7-13.

[107] U.S. Bureau of Labor Statistics, *Quality Adjustment in the CPI*, https://www.bls.gov/cpi/quality-adjustment/home.htm (last visited July 30, 2024).

approach extends the standard hedonic framework by also controlling for country-level cost and demand factor differences, instead of only controlling for product characteristics (e.g., download speed).[108] We estimate four hedonic regression models and then use the predicted prices from these models to construct hedonic price indexes. While the details of the hedonic modeling are contained in section IV.F.2, we summarize the basic approach here. For both fixed and mobile broadband price estimates, 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 adds country-level variables that likely affect broadband deployment costs (e.g., population density) and broadband demand (e.g., income per capita). The third model adds a control for network quality and investment. The final model adds a proxy measure for availability and quality of content that is complementary to broadband and would be expected to raise broadband demand (e.g., websites and video content availability).

75. 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 product characteristics and country-level variables at typical U.S. values and use the estimated provider-specific coefficients on product characteristics to predict prices for each provider in each country. This procedure effectively estimates what each provider's price would be for each of the six standardized broadband products in each country if broadband demand, cost, and network quality, were at the levels observed in the United States.[109] We then aggregate these provider-specific price predictions for each of the six products by using U.S. product share weights and the 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, quality, and demand conditions.

[108] 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, 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.

[109] Fixed broadband product prices are predicted at the following download speeds for both standalone and bundled plans: 100 Mbps, 250 Mbps, and 1 Gbps. All other fixed broadband 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 fixed voice service, wired broadband technology (i.e., copper, cable, FTTP), symmetric upload and download speeds, and an unlimited data usage allowance. The mobile broadband products are predicted at the following data allowances for both single-line and multi-line plans: 10 GB, 25 GB, and unlimited data per line. For the multi-line products, the 10 GB and 25 GB plans have two lines each and the unlimited data plan has three lines. For both single-line and multi-line 10 GB plans, we set the download speed to 3 Mbps; for the other four products, we set to unrestricted download speeds. The other plan features for the price predictions are as follows: month-to-month contract duration, 5G technology, unlimited minutes, and unlimited texts.

D. Fixed Broadband Pricing Analysis and Results

76. *Fixed Broadband Price Index.* In Figure IV.D.1 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).[110] The United States ranks 8th out of 26 countries in standalone broadband pricing and ranks 9th for broadband bundled with video service.[111] Combining standalone and bundled pricing, the overall ranking of the United States is 8th out of 26 countries. On a price per GB of data consumed basis, the United States ranks 3rd out of the 22 countries for which we have usage data.[112]

[110] All reported prices for the broadband index are adjusted using a measure of Purchasing Power Parity (PPP) to make the results comparable to the income-adjusted hedonic index results. Figure IV.D.1 presents the weighted average prices in each country for the indicated products. The Laspeyres index for each country is calculated by dividing the given country's weighted price by the U.S. weighted price. *See infra* Fig. IV.D.1.

[111] To calculate the price of broadband for each bundled 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 Figure IV.D.1 because the plans that are included in each calculation may be different. *See infra* Fig. IV.D.1. For this reason, the bundle price in a country may be higher than the standalone price. *See infra* Fig. IV.F.5.

[112] Dividing monthly price by data usage may not be appropriate because data usage affects broadband pricing and broadband pricing also likely affects data usage. In other words, data usage is endogenous. However, we provide this commonly reported metric for comparison with other similar analyses. *See, e.g., 2022 Communications Marketplace Report*, 37 FCC Rcd at 16402, Appx. G-4: International Broadband Data Report, para. 76 & n.113.

Fig. IV.D.1
Fixed Broadband Price Indexes (Purchasing Power Parity (PPP) Adjusted)

Country	Standalone		Bundled		Overall		$/GB	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Australia	73.11	25	73.11	24	73.11	25	0.18	15
Austria	35.01	2	35.01	2	35.01	2	0.17	12
Belgium	54.36	17	58.44	20	56.74	19	0.21	17
Canada	65.80	22	65.80	21	65.80	21	0.16	9
Czech Republic	37.65	3	38.45	3	38.12	3	0.13	5
Denmark	44.04	6	44.04	7	44.04	6	0.12	4
Estonia	56.82	19	56.82	18	56.82	20		
Finland	50.09	12	50.09	11	50.09	11	0.22	18
France	47.93	9	58.18	19	53.91	15	0.17	10
Germany	49.16	11	49.30	10	49.24	10	0.18	14
Greece	57.30	20	54.55	16	55.69	17	0.26	21
Iceland	69.39	23	69.39	22	69.39	22	0.15	7
Ireland	48.80	10	47.15	8	47.84	9	0.18	16
Italy	42.86	5	42.86	6	42.86	5	0.18	13
Latvia	24.21	1	22.31	1	23.10	1	0.06	1
Luxembourg	70.47	24	70.47	23	70.47	24		
Mexico	53.18	15	54.19	14	53.77	14	0.15	6
Netherlands	50.93	13	50.93	12	50.93	12		
New Zealand	56.24	18	56.24	17	56.24	18	0.16	8
Norway	89.21	26	87.99	26	88.50	26		
Portugal	61.17	21	76.01	25	69.84	23	0.26	20
Spain	52.52	14	52.56	13	52.55	13	0.17	11
Sweden	42.62	4	40.76	4	41.53	4	0.22	19
Switzerland	54.35	16	54.35	15	54.35	16	0.31	22
United Kingdom	47.46	7	41.69	5	44.09	7	0.09	2
United States	**47.92**	**8**	**47.50**	**9**	**47.68**	**8**	**0.09**	**3**

Source: TeleGeography, *GlobalComms Database*, http://www.telegeography.com (last accessed July 30, 2024); Ofcom, *International Broadband Scorecard 2023: Interactive Data* (Dec. 19, 2023), https://www.ofcom.org.uk/phones-and-broadband/coverage-and-speeds/international-broadband-scorecard-2023-interactive-data/; International Telecommunication Union, *Fixed-Broadband Internet Traffic*, https://datahub.itu.int/data/?i=13067&v=chart&u= (last visited July 18, 2024).
Note: To make the results comparable to the income-adjusted hedonic analysis, prices are reported in PPP-adjusted U.S. dollars.

77. *Fixed Broadband Hedonic Price Index.* The estimated coefficients for the four fixed broadband hedonic models are shown in Figure IV.D.2 below.[113] Before reviewing the estimates, we first note that the estimated coefficients in our models are 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 on product characteristics coefficients.

78. The model estimates that higher download speed plans cost more, and the rate of increase in price (i.e., slope) is higher for plans at a higher speed tier.[114] Bundling broadband with other services is estimated to lower the price of the broadband service by approximately 3.1% on average across all countries.[115] Symmetric download and upload speeds are expected to be associated with higher prices because upload speeds are significantly lower than download speeds for most broadband technologies except for FTTP plans, which often offer symmetric download and upload speeds. As expected, symmetric download and upload speeds are estimated to increase price by about 2.2% in all models. We include a wired broadband technology dummy variable that indicates whether the plan is provided via copper, cable, or FTTP technologies (i.e., not terrestrial fixed wireless or satellite) as well as an interaction between this wired dummy variable and the unlimited data dummy variable because non-wired broadband plans are usually offered with a data allowance. The interaction term has the expected negative coefficient and is statistically significant at around 5% across the four models.[116]

79. In general, our control variables are not statistically significant. For the country-level control variables, we find that the per capita income in a country has a positive but statistically insignificant coefficient . As expected, population density has a negative coefficient but is not statistically significant, while educational attainment has a positive coefficient but is also not statistically significant. In Model 3, we add a proxy for network quality which has a positive but statistically insignificant coefficient.

[113] The estimated random coefficient variances are provided in Figure IV.F.7. *See infra* Fig. IV.F.7.

[114] 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 for the range of download speeds across cutoffs. For example, our estimated coefficients imply that the price of fixed broadband increases more steeply for plans with download speeds above 250 Mbps compared to those below 100 Mbps.

[115] When a dependent variable is measured in logarithmic form, the percentage change in the dependent variable for a change in a dummy variable from 0 to 1, or a logarithmic 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).

[116] We expect a negative term because while we would expect plans with higher data allowances to have higher prices, we expect the price for more data to be higher for non-wired broadband plans relative to wired broadband plans.

Fig. IV.D.2
Fixed Broadband Hedonic Regressions

Log Average Monthly Price (USD)	Model 1			Model 2			Model 3		
	Coef.	SE	p	Coef.	SE	p	Coef.	SE	p
Spline: 0 < Log(Download (Mbps)) < 100	0.108	0.016	0.000	0.107	0.016	0.000	0.106	0.016	0.000
Spline: 100 ≤ Log(Download (Mbps)) < 250	0.095	0.030	0.002	0.092	0.030	0.002	0.092	0.030	0.002
Spline: 250 ≤ Log(Download (Mbps))	0.201	0.020	0.000	0.201	0.020	0.000	0.201	0.020	0.000
Symmetric Speeds Dummy	0.021	0.020	0.290	0.020	0.020	0.318	0.020	0.020	0.319
Bundle Dummy	-0.031	0.010	0.001	-0.031	0.010	0.001	-0.031	0.010	0.001
Fixed Voice Dummy	0.080	0.051	0.117	0.102	0.051	0.045	0.102	0.051	0.045
Wired Broadband Technology Dummy	0.154	0.082	0.060	0.171	0.080	0.032	0.171	0.080	0.032
Unlimited Data Dummy	0.372	0.052	0.000	0.372	0.052	0.000	0.372	0.052	0.000
Wired Broadband & Unlimited Data Interaction	-0.244	0.074	0.001	-0.245	0.074	0.001	-0.245	0.074	0.001
Log GNI Per Capita				0.386	0.138	0.005	0.381	0.169	0.024
Log Non-Rural Population Density				-0.036	0.057	0.525	-0.036	0.057	0.523
Educational Attainment				0.963	0.766	0.209	0.969	0.773	0.210
Log Terrain Ruggedness Weighted by Population				0.059	0.069	0.392	0.059	0.069	0.392
Coverage (% Households with > 100 Mbps)							0.027	0.521	0.958
Constant	2.840	0.111	0.000	-1.463	1.264	0.247	-1.432	1.398	0.306
Number of Observations	1027			1027			1027		
Log Likelihood	214.8			224.2			224.2		
Likelihood Ratio Test vs. Linear Model									
P-Value	0.000			0.000			0.000		

Note: The estimated random coefficient variances and measures of goodness of fit are provided in Figure IV.F.6.

80. The resulting country rankings under each model are shown in Figure IV.D.3 below. This figure reports the overall rankings that aggregate over the three standalone and three bundled products in each country. In Model 1, after controlling for broadband plan characteristics that vary by country, we find that the United States ranks 18th out of the 26 countries in our sample, with an average broadband price of $51.87. Countries with lower average incomes, like Latvia and Mexico, rank near the top under Model 1 before we correct the price levels for per capita income in the subsequent models. In Model 2, after we correct price levels for differences in income and education (as factors affecting demand for broadband) and terrain and population density (as factors affecting the costs of providing broadband), we find that the United States ranks 11th. The change in ranking from the first model is largely due to the United States having relatively high income (measured by logarithmic of gross national income (GNI) per capita).[117] Because higher income is associated with higher demand for broadband, the prices would have been higher in other countries if their consumers have a similar income level and demand. Therefore, the US price ranking improves when these factors are taken into account. Model 3 includes the variables in Model 2 and adds our network quality proxy variable (the percentage of households with access to at least 100 Mbps download speed) and the ranking of the United States remains at 11th.

[117] *See infra* Fig. IV.F.13.

Fig. IV.D.3
Fixed Broadband Hedonic Price Indexes

Country	Model 1		Model 2		Model 3	
	Price	Rank	Price	Rank	Price	Rank
Australia	78.67	24	84.54	24	84.91	24
Austria	33.39	6	40.74	3	40.78	3
Belgium	57.83	20	72.56	22	72.42	22
Canada	66.82	23	65.18	18	65.06	18
Czech Republic	25.83	2	46.36	6	46.20	6
Denmark	44.85	13	51.60	10	51.56	9
Estonia	46.74	17	73.86	23	73.64	23
Finland	42.16	11	51.59	9	51.72	10
France	31.25	5	40.25	2	40.28	2
Germany	41.33	10	55.10	12	55.07	12
Greece	36.09	7	60.86	16	61.08	16
Iceland	85.11	26	86.54	25	86.70	25
Ireland	46.67	16	47.72	7	47.78	7
Italy	27.74	3	45.38	5	45.38	5
Latvia	12.73	1	23.37	1	23.42	1
Luxembourg	62.08	21	56.06	14	56.07	14
Mexico	36.29	8	92.45	26	93.07	26
Netherlands	46.09	15	62.63	17	62.50	17
New Zealand	55.41	19	65.65	19	65.61	19
Norway	85.06	25	68.19	20	68.21	20
Portugal	41.11	9	70.51	21	70.18	21
Spain	30.16	4	42.61	4	42.43	4
Sweden	45.13	14	48.75	8	48.76	8
Switzerland	64.49	22	56.51	15	56.53	15
United Kingdom	43.95	12	55.43	13	55.56	13
United States	**51.87**	**18**	**51.95**	**11**	**51.94**	**11**

E. Mobile Broadband Pricing Analysis and Results

81. *Mobile Broadband Price Index*. In Figure IV.E.1 below, we present the country rankings, including an index for single-line plans, another for multi-line plans, and an overall index that is a weighted average of the single-line and multi-line plan indexes.[118] The United States ranks 25th out of the 26 countries in single-line plan pricing at $69.10, and ranks 24th for multi-line pricing at $50.90 per line. Spain ranks 1st in single-line plan pricing and 1st in multi-line pricing, at $19.88 per line per month and $14.14 per line per month, respectively. Combining single-line and multi-line data plan pricing, the

[118] The product prices by country that were used in the mobile broadband price index calculations are presented in Fig. IV.F.10 adjusted using a measure of PPP. The overall single line and overall multi-line prices are averaged weighting by the bundling share. *See supra* Fig. IV.C.2.

overall ranking of the United States is 25th. Finally, on a dollar per GB basis, the ranking of the United States is 24th.[119]

Fig. IV.E.1
Mobile Broadband Price Indexes (PPP Adjusted)

Country	Single Line		Multi-Line		Overall		$/GB	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Australia	46.17	23	45.17	23	45.46	23	3.94	18
Austria	37.65	17	37.65	20	37.65	20	1.24	6
Belgium	22.64	5	20.91	4	21.41	4	3.62	16
Canada	72.79	26	68.58	26	69.80	26	11.92	26
Czech Republic	37.68	18	35.24	19	35.95	19	4.91	22
Denmark	21.20	2	21.64	5	21.52	5	1.13	5
Estonia	22.61	4	18.14	2	19.44	2	0.88	2
Finland	42.02	20	41.75	21	41.83	21	1.04	3
France	24.46	7	22.68	6	23.20	6	1.61	10
Germany	42.66	21	30.13	14	33.76	17	4.59	21
Greece	32.38	12	29.23	12	30.14	12	4.34	20
Iceland	29.15	10	25.63	9	26.65	9	1.13	4
Ireland	45.29	22	45.16	22	45.20	22	2.37	11
Italy	24.12	6	24.12	8	24.12	8	1.46	7
Latvia	22.60	3	19.82	3	20.63	3	0.49	1
Luxembourg	33.73	13	29.45	13	30.69	13	2.93	13
Mexico	37.93	19	33.33	18	34.66	18	6.00	25
Netherlands	24.92	8	23.11	7	23.63	7	3.82	17
New Zealand	37.25	16	31.09	16	32.88	16	5.69	23
Norway	34.80	15	31.91	17	32.75	15	2.91	12
Portugal	34.37	14	30.60	15	31.69	14	4.12	19
Spain	19.88	1	14.14	1	15.80	1	1.55	9
Sweden	31.84	11	26.32	10	27.92	11	1.48	8
Switzerland	58.58	24	54.45	25	55.65	24	3.13	14
United Kingdom	28.33	9	27.01	11	27.39	10	3.29	15
United States	**69.10**	**25**	**50.90**	**24**	**56.18**	**25**	**5.89**	**24**

Source: OECD, *Broadband and Telecom Databases*, https://data-explorer.oecd.org/vis?df[ds]=DisseminateFinalDMZ&df[id]=DSD_BB_DATABASE%40DF_BB_TEL_DATABASE&df[ag]=OECD.STI.DEP&dq=.Q..DATA.&lom=LASTNPERIODS&lo=5&to[TIME_PERIOD]=false&ly[cl]=TIME_PERIOD&ly[rw]=REF_AREA&vw=ov (last visited July 10, 2024).
Note: To make the results comparable to the income-adjusted hedonic analysis, prices are reported in PPP-adjusted U.S. dollars.

82. *Mobile Hedonic Price Index.* The estimated coefficients for the four mobile broadband hedonic models are shown in Figure IV.E.2 below.[120] The four models presented in this section mirror the

[119] The same caveat regarding the potential problems with dividing price by data usage also applies to mobile broadband. However, the plans are now sold by data allowances. Thus, the endogeneity problem may be exacerbated. Again, we provide this commonly reported metric for comparison with other similar analyses.

[120] The estimated random coefficient variances and measures of goodness of fit are provided in Fig. IV.F.11.

models in our fixed pricing analysis with the exception that the network quality variable now includes measures of both provider level 4G and 5G network availability and download and upload speeds. Increasing the number of lines from one to two is expected to decrease the expected price per line by approximately 4.7%. As expected, the inclusion of unlimited minutes is associated with higher prices and is statistically significant; and longer contract durations are associated with lower prices and the coefficient is also statistically significant.

83. For mobile broadband, the estimated coefficients of the country-level variables on broadband prices only slightly differ from the patterns we observed in our fixed hedonic analysis. In general, we associated higher income and education level with higher demand for broadband, and thus expect higher income and education levels to be associated with higher prices. As expected, the estimated coefficient on income (i.e., logarithmic of GNI per capita) is positive, but this result is not statistically significant in any specification. Also, educational attainment, a measure closely related to income, is found to increase expected mobile broadband prices but is not statistically significant in any model. Population density has an expected negative but statistically insignificant coefficient, while terrain variation in a country has an unexpected negative coefficient estimate for Models 2 and 3. The estimated coefficient on Network Quality is negative in Model 3and is statistically insignificant.

Fig. IV.E.2
Mobile Broadband Hedonic Regressions

Log Average Monthly Price Per Line (USD)	Model 1			Model 2			Model 3		
	Coef.	SE	p	Coef.	SE	p	Coef.	SE	p
Number of Lines	-0.015	0.005	0.003	-0.015	0.005	0.003	-0.015	0.005	0.003
Family Plan Dummy	-0.016	0.027	0.541	-0.017	0.027	0.531	-0.017	0.027	0.531
Log Data Allowance	0.231	0.026	0.000	0.228	0.026	0.000	0.228	0.026	0.000
Unlimited Data Allowance Dummy	-0.296	0.084	0.000	-0.295	0.084	0.000	-0.295	0.084	0.000
5G Technology Dummy	-0.362	0.191	0.058	-0.338	0.189	0.074	-0.339	0.190	0.074
Log Download Speed	0.038	0.040	0.340	0.044	0.039	0.269	0.043	0.039	0.270
5G Technology & Log Download Speed Interaction	0.069	0.027	0.011	0.066	0.027	0.014	0.066	0.027	0.015
Unrestricted Download Speed Dummy	-0.056	0.033	0.090	-0.055	0.033	0.097	-0.055	0.033	0.097
Unlimited Minutes Dummy	0.172	0.036	0.000	0.173	0.036	0.000	0.173	0.036	0.000
Unlimited Text Messages Dummy	-0.093	0.040	0.020	-0.095	0.040	0.018	-0.095	0.040	0.018
Contract Length	-0.007	0.001	0.000	-0.007	0.001	0.000	-0.007	0.001	0.000
Log GNI Per Capita				0.219	0.547	0.689	0.231	0.654	0.724
Educational Attainment				3.294	3.064	0.282	3.254	3.310	0.326
Log Country Population Density				-0.078	0.154	0.612	-0.080	0.169	0.635
Log Terrain Ruggedness Weighted by Population				-0.306	0.245	0.212	-0.309	0.259	0.233
Network Quality (1st Principal Component) (Standardized)							-0.009	0.277	0.974
Constant	2.363	0.280	0.000	-1.273	5.089	0.803	-1.370	5.922	0.817
Number of Observations	2184			2184			2184		
Log Likelihood	415.9			419.6			419.6		
Likelihood Ratio Test vs. Linear Model									
P-Value	0.000			0.000			0.000		

Note: The estimated random coefficient variances and measures of goodness of fit are provided in Fig. IV.F.11.

84. Our hedonic price indexes based on the four estimated hedonic regressions are provided in Figure IV.E.3. For mobile broadband service, adjusting for cost and demographic factors has a sizeable impact on the ranking of the United States 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 23rd among the 26 countries in mobile broadband pricing. Correcting for these factors in Model 2 improves the U.S. ranking to 19th. Adding the network performance measures in Model 3 maintains the U.S. ranking at 19th.

Fig. IV.E.3
Mobile Broadband Hedonic Price Indexes

Country	Model 1		Model 2		Model 3	
	Price	Rank	Price	Rank	Price	Rank
Australia	37.11	16	25.54	4	25.24	4
Austria	70.73	25	166.45	25	164.85	25
Belgium	28.90	8	36.67	11	36.30	11
Canada	68.99	24	37.23	12	37.06	12
Czech Republic	37.93	18	119.03	23	118.33	23
Denmark	21.04	5	23.45	3	23.37	3
Estonia	20.72	4	26.25	5	26.07	5
Finland	26.91	7	31.83	9	31.68	9
France	29.21	9	46.30	16	45.93	16
Germany	40.67	19	83.50	20	82.57	20
Greece	30.07	11	85.76	21	85.41	21
Iceland	30.94	13	33.92	10	33.58	10
Ireland	52.11	21	39.99	14	38.89	14
Italy	13.50	1	52.27	17	51.50	17
Latvia	18.21	3	22.82	2	22.67	2
Luxembourg	34.12	15	38.32	13	38.16	13
Mexico	94.13	26	432.58	26	428.10	26
Netherlands	25.45	6	18.80	1	18.80	1
New Zealand	29.81	10	42.37	15	41.70	15
Norway	43.42	20	53.02	18	52.89	18
Portugal	37.12	17	122.82	24	122.14	24
Spain	15.48	2	31.27	8	31.07	8
Sweden	31.30	14	29.36	6	29.05	6
Switzerland	52.39	22	91.19	22	90.71	22
United Kingdom	30.56	12	30.65	7	30.27	7
United States	**55.72**	**23**	**56.32**	**19**	**56.31**	**19**

F. Data and Methods Technical Details

85. This section provides the technical details of how the pricing data were collected and constructed and how other data sources and analysis variables were constructed, along with the mathematical formulas for the empirical estimation of the hedonic broadband price index.

1. Data Collection and Variable Construction

a. Fixed Broadband Pricing Data Collection

86. For each fixed broadband provider, we recorded the least expensive combination of download speed, upload speed, data usage allowance, and broadband technology (the core broadband

product characteristics)[121] that is offered by the provider at each address as well as whether fixed voice service is included, contract duration, and whether the customer can bring their own equipment (e.g., modem/router) vs. must rent or purchase equipment from the provider (non-core product characteristics).[122] For example, if a provider offers (1) a copper-based plan with 100 Mbps download, 100 Mbps upload, and no data cap; (2) a copper-based plan with 100 Mbps download, 50 Mbps upload, and no data cap; and (3) a cable-based plan with 100 Mbps download, 100 Mbps upload, and no data cap, we record three separate plans.

87. We collected both standalone broadband plans as well as double play packages of broadband bundled with multichannel video services.[123] 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 fixed voice service, and doing so would have greatly increased the data collection burden.[124] In cases where a provider only offered Internet service to customers who also subscribe to fixed voice services (or if the plan with fixed voice service is less expensive than without it), we collected Internet bundled with fixed voice service plans and any relevant bundled plans of Internet, fixed voice service, and television.[125] In such cases, we collected triple play bundles from the provider that included the particular fixed voice plan to isolate the bundled broadband price using the methodology described below. Finally, if the provider did not offer video service, bundle discounts, and standalone TV plans, we did not collect bundled plans for the particular download speed, upload speed, data usage allowance, and broadband technology combinations for the provider except if that combination of core product characteristics was only offered bundled with video service.

88. Given the large number of countries, providers, and plan offerings, we limited the scope of the collection along several dimensions. First, we assumed customers were new to fixed broadband service (i.e., neither switching from another provider nor a current customer of the given 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 core product characteristics that resulted in the lowest price for a given plan at each address.[126] For example, we did not include optional add-on features (e.g., fixed voice service, streaming services, security software, etc.), always chose the lowest priced equipment required for the plan, and selected the contract duration option associated with the least

[121] We classified all plans into one of the FCC BDC broadband technology categories: cable, copper, FTTP, satellite, terrestrial fixed wireless, or other. When a provider did not report an associated broadband technology with a plan and we could not make an educated guess based on other information, we reported the technology as unknown. We considered terrestrial fixed wireless and satellite plans for the first time.

[122] Generally, providers offer the same pricing for a given set of product characteristics at different addresses in the city, but in some cases, providers have different pricing at different addresses for the same set of product characteristics in which case, we record each set of prices as separate plans.

[123] By multichannel video services, we mean linear television packages usually offered using cable, satellite, or Internet with regularly scheduled programs. OTT services, which stream programs to specific users through bundled broadband plans, are not considered in our analysis and thus are unobserved product characteristics if such services are included in any plans.

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

[125] 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.

[126] Essentially, if a provider offered multiple plans that would have appeared identical within our data framework, we recorded the lowest priced plan.

expensive price (i.e., generally the longest contract).[127]

89. 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 the currency used for the collected prices. For pricing data, we collected all pricing information available on the provider's website including promotions, equipment fees, installation fees, and rebates to calculate the total cost of the broadband service plan over a two-year time horizon (regardless of the contract period). Non-pricing data includes information such as download and upload speeds, data usage allowances, number of channels (if applicable), and contract duration. A unique plan for an address is defined by countries, providers, broadband technologies, download speeds, upload speeds, data allowance, and the number of channels (if applicable).

- *Data Review and Cleaning Process.* Upon completion of the data collection, we reviewed the data for accuracy and completeness. First, we made several provider- or plan-specific assumptions when core product characteristics (broadband technology, download speed, upload speed, and data allowance) were not reported. For example, Czech Republic's Vodafone, we assume three asymmetric plans with unknown broadband technology (a core product characteristic) use wired broadband technology.
- For Greece's Vodafone's "Vodafone 24" plan, we assume the associated download speed is 24 Mbps because Vodafone generally uses the download speed in their plans' names (e.g., Vodafone 50 explicitly has a 50 Mbps download speed).
- For all four of Iceland providers' 5G terrestrial fixed wireless plans that have no advertised download and upload speeds, we set these values to the 2023 average 5G download and upload speeds for Iceland (across all providers) according to Ookla.[128] Therefore, all providers' have the same download and upload speeds.
- For Iceland's Siminn's FTTP plan with a data allowance of 100 GB but no reported download speeds, we set this value to 1000 Mbps because the provider's least expensive plan without a data allowance has a download speed of 1000 Mbps.
- For Latvia's Balticom's plans, we assume all plans are wired broadband technology because all the plans have symmetric download and upload speeds which typically indicates FTTP.
- For Luxembourg's Post, we assume one explicitly non-FTTP plan is wired broadband technology.
- For New Zealand's 2degrees' 4G terrestrial fixed wireless plan with no reported download and upload speeds, we set the values to the 2023 average 4G download and upload speeds for New Zealand (across all providers) according to Ookla.[129] For 2degrees's 5G terrestrial fixed

[127] More generally, if a provider offered the same plan with different contract length options with discounts for longer contracts, we chose the least expensive contract duration option available (generally the longest duration).

[128] *See supra* Fig. III.C.1; *supra* Fig. III.C.5. We use country level Ookla speed test data because Opensignal does not publish any speed test data for Iceland.

[129] *See supra* Fig. III.B.1; *supra* Fig. III.B.6. For 2degrees's 4G plans, we rely on country-level 4G download and upload speeds based on Ookla 2023 data because Opensignal has not published 4G download and upload speeds for 2degrees or New Zealand overall in recent years. In general, we use provider-level Opensignal data over country-level Ookla data when the more granular Opensignal data are available.

wireless plan with no reported download and upload speeds, we set the values to the provider's October 2023 average 5G download and upload speeds according to Opensignal.[130]

- For Sweden's Telenor's 5G terrestrial fixed wireless plans with no reported download and upload speeds, we set the values to the provider's December 2023 average 5G download and upload speeds according to Opensignal.[131]

90. After imposing provider or plan specific assumptions, if any variables essential for the analysis were missing, we made the following assumptions to impute the missing data:

- If fixed voice service was not explicitly included in the plan, we assume the service is not included.
- If upload speeds were not advertised, we assumed that the upload and download speeds were asymmetric for all technologies except for FTTP in which case, we assumed symmetric download and upload speeds.[132]
- If the provider's website did not list a data allowance, we assumed that the plan offered an unlimited data allowance.[133]
- If the regular monthly price was not found, we assumed that the last available promotional price stayed in effect for the remainder of the 24-month period.
- If equipment prices were not available, we assumed the relevant equipment was included.[134]
- 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 the average tax rate to the total pre-tax prices.[135] For all other countries, we assumed taxes were included.[136]

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[130] For 2degrees's 5G plans, we rely on Opensignal 5G download and upload speeds specifically for 2degrees as October 2023. Sam Fenwick, Opensignal, *New Zealand – Mobile Network Experience Report* (Oct. 2023), https://www.opensignal.com/reports/2023/10/newzealand/mobile-network-experience.

[131] Rupert Bapty, Opensignal, *Sweden – Mobile Network Experience Report* (Dec. 2023), https://www.opensignal.com/reports/2023/12/sweden/mobile-network-experience.

[132] For plans with known download and upload speeds, we consider plans with upload speeds that are at least 80% of their download speeds as being effectively symmetric when defining the symmetric speeds dummy variable for the hedonic analysis.

[133] We top coded monthly data allowances to 2000 GB so that any plans with at least 2000 GB per month were considered unlimited.

[134] Equipment refers to a modem/router for broadband service and a set top box for television service, if applicable. For terrestrial fixed wireless plans and satellite plans, equipment may also include an outdoor antenna.

[135] International Telecommunication Union, *World Telecommunications/ICT Indicators Database 2022 (26th Edition/July 2022)* (last accessed Sept. 16, 2022). Since 2022, the International Telecommunications Union (ITU) has made its data publicly available; however, tax rates are not included in the dataset and we therefore rely on the prior values.

[136] With the exception of the United States and Canada, most providers in other countries note that list prices included taxes such as value added taxes (VAT). Providers in the United States and Canada generally displayed 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 did not apply a percentage of the pre-tax total price to estimate the tax).

91. *Fixed 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.

$$\text{Total}_{24,h} = \left(\text{Promo Price}_1 * \text{Promo Months}_1\right) + \left(\text{Promo Price}_2 * \text{Promo Months}_2\right) + \left(24 - \text{Promo Months}_1 - \text{Promo Months}_2\right) * \text{Regular Price} + 24 * \left(\text{Taxes \& Fees}_h + \text{Other Fees}_h + \text{Equipment Fees}_h * \text{Equipment Rental}_h\right) + \left(\text{One-time Fees} + \text{One-time Taxes \& Fees} - \text{One-time Discounts} + \text{Equipment Purchase}_h\right)$$

92. We then divided this price by 24 months to calculate the average monthly price. We converted all currencies to U.S. dollars using PPP for the broadband price index and Currency Exchange Rate conversion factors for the hedonic price index.[137]

93. As noted above, U.S. consumers often purchase fixed broadband and video service in a bundle at discounted rates. Furthermore, 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 not of great interest 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 in which more of the characteristic is always better there is no standardized video product that would be comparable across countries by holding consumer utility fixed. Given that many studies attempt to control for video quality differences based on observable product characteristics (e.g., number of channels) and because we do not believe the observable measures adequately capture quality differences across countries, we therefore calculate a bundle discount and allocate this across the standalone component pricing to isolate the price of broadband when purchased in a bundle.

94. To calculate this bundled discount, we matched all bundled plans with their corresponding standalone Internet and standalone video component plans to calculate a bundle discount percentage.[138] 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 many bundled plans, we were able to collect the exact corresponding standalone Internet and video component plans.

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

95. 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.[139] 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

[137] OECD, *OECD Data Explorer*, https://data-explorer.oecd.org/ (last visited August 1, 2024) (navigate to Economy – National accounts – GDP and non-financial accounts – GDP components – Annual Purchasing Power Parities and exchange rates). The hedonic index already corrects for income and price-level differences across countries through the inclusion of a country income variable in the regression and does not need further adjustments for PPPs.

[138] Matching of bundle plans with their corresponding standalone broadband and standalone TV plans is performed at the address level because in some cases, providers offer different pricing for the bundle or one of the standalone components at different addresses. However, we aggregate over addresses with the same plans so the plan price is equal to the average price across the addresses where the plan is available.

[139] 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.

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. However, 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 may represent bundled plans that are available without a bundle discount (i.e., add-on pricing).

96. In Figure IV.F.3, we present 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. Then, we aggregate over providers, weighted 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 product bundling is important in order to accurately reflect the prices actually paid by consumers for broadband services in each country.

b. Mobile Broadband Pricing Data Collection

97. For each mobile broadband provider, we recorded the least expensive combination of the number of lines, number of minutes, number of text messages, contract duration, broadband technology (i.e., 4G or 5G), data allowance, and download speed (the core product characteristics) that are offered by the provider as well as whether the data allowance is shared or separate (for multiple lines) and hotspot data allowance (non-core product characteristics).[140]

98. We considered bundles of multiple lines, up to four, when the provider offered a clear discount for purchasing multiple lines together. These bundles generally took two forms: (1) lines with separate data allowances and (2) lines with a shared data allowance. In the first case, each line would have the same product characteristics but the price per line would be decreasing with each additional line. In the second case, the total data allowance would be equally shared across the number of lines (i.e., data allowance per line decreases as the number of lines increase in the plan), usually with a small increase in additional price for each line.

99. Given the large number of countries, providers, and plan offerings, we limited the scope of the collection along several dimensions. First, we assumed customers were new to mobile broadband service (i.e., neither switching from another provider nor a current customer of the given provider) and did not receive any special discounts that were not available to all new customers. Second, we only consider plans that include minutes to all numbers outside of the provider's networks (i.e., minutes that can be used to call other providers' customers' landline or mobile numbers) and a monthly data

[140] Additionally, we record a "premium" data allowance which applies only to U.S. providers and a video streaming quality restriction which applies only to U.S. providers and one Canadian provider. The former product characteristic is a threshold beyond which customers are subject to de-prioritization during periods of congestion (i.e., the customer's speeds are reduced in a limited geographic area and/or limited period of time but returns to normal). We distinguish this type of data allowance from a traditional data allowance where beyond the threshold, the customer's service is restricted for the remainder of the billing period (e.g., 3G speeds, data overage fees, cessation of broadband service). Similarly, some plans offered by U.S. providers and Bell Canada have restrictions on the video streaming quality which we treat as a "close substitute" product characteristic to a maximum download speed because video streaming consumes more data than other activities (e.g., browsing the web, messaging services, etc.) even if general data usage does not have any maximum speed restrictions associated with the plan.

allowance.[141] Third, we only recorded information for the combination of core product characteristics that resulted in the lowest price for a given plan. We sought to collect pricing information excluding the cost of handsets due to both the complexity that handsets introduce in measuring price and the fact that 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 to keep prices comparable across countries.

100. We collected mobile plan information in three broad categories: (1) general information including the 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 and the number of minutes and text messages.[142] A unique plan is defined by the country, provider, contract duration, technology, data allowance per line, advertised download speed,[143] number of lines, number of minutes, and number of text messages.[144]

101. One of the most important price factors for mobile broadband service is the data usage allowance.[145] We recorded the monthly data allowance for each plan.[146] In general, providers set a data allowance per month beyond which the provider imposes a consequence for exceeding the usage allowance, such as decreasing mobile broadband speeds for the remainder of the billing period, charging overage fees (i.e., a consumer pays for additional data use), or stopping service entirely for the remainder of the billing period (i.e., a "hard" data limit).[147] The structure of the data allowance policies varies by provider and can be quite complex.[148]

102. Although many providers continue to offer plans that are generally differentiated by data allowances, some providers offer plans differentiated by download speeds, video streaming quality

[141] This rule excludes plans with only in-network minutes, data only (e.g., smartwatch and tablet data plans), non-data mobile voice plans.

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

[143] Some providers do not advertise any download speed associated with their plans in which case we assume in the hedonic analysis that the customer will receive the highest possible speed at the given moment and location for the customer (i.e., unrestricted download speed). For one Canadian provider and the U.S. providers, we use video streaming quality restrictions as a proxy for the advertised download speed.

[144] 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 two services and recorded the exchange rate among the services (e.g., 1 unit = 1 minute = 1 text).

[145] We only consider data that can be used within the customer's country. In some cases, particularly the plans offered by providers in Europe, customers can use the primary data allowance in several countries and/or have a separate international data allowance included in the base plan. To simplify our analysis, international data allowances are not considered in our analysis because each provider has different policies regarding international data usage.

[146] In rare circumstances, the monthly data allowance of a plan changes over the 24-month time horizon such as an initial bonus data allowance (i.e., a decrease after a period of time) or a loyalty bonus in the form of increased data allowance for staying with the provider. We recorded the data allowance as the average monthly data allowance over the initial 24-month period.

[147] In our analysis, an "unlimited" data plan is reserved for plans that have at least 500 GB per line per month before the provider imposes a consequence that significantly degrades the quality of service for the remainder of the billing period.

[148] 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.

restrictions, streaming service provisions, or other product characteristics. Also, with the introduction of 5G networks in many countries, some providers differentiate plans by restricting access to 5G to more expensive plans. Similarly, more providers are differentiating plans by restricting download speeds, for both limited data plans and unlimited data plans. To address these trends, we collected the technology (e.g., 4G or 5G) associated with the plan, the advertised download speed (if any), and the video streaming quality limit.

103. *Data Review and Cleaning Process.* After completing the data collection, we reviewed the data for any issues. First, we made several provider- or plan-specific assumptions when core product characteristics were not reported.

- For Austria's Hutchison Drei's least expensive plan (with the lowest advertised download speed and only limited data allowance plan) which has no advertised technology, we assume this plan is restricted to 4G only because the provider's two more expensive (with higher download speed and unlimited data) plans are explicitly 5G plans.
- For Belgium's Orange's two plans without an advertised download speed, we set the maximum advertised download speed to 1000 Mbps because the provider's higher data allowance (and more expensive) plans advertise 1000 Mbps.
- For Belgium's Proximus's 4G plan without a reported download speed, we set this value to an unrestricted speed (i.e., customer achieves the fastest available download speed / is not restricted by the plan). The provider offers 5G plans with download speeds starting from 200 Mbps so we assume that the lack of download speed for the 4G plan implies there is no such restriction.
- For Canada Bell's plans that have video streaming quality restrictions at either Standard Definition or High Definition, we set the download speed to 3 Mbps and 8 Mbps, respectively.[149] Note that these plans generally have high (250 Mbps) or unrestricted download speeds for general data usage.
- For Estonia's Tele2's and Telia's plans with no reported technology, we set these values to 4G because the providers explicitly offer other 5G plans.
- For Iceland's Nova's and Vodafone's plans, we set all plans to 5G because these providers have 5G networks deployed but do not advertise that some plans are restricted to their 4G networks.
- For Latvia's LMT's and Tele2's, we set all plans to 5G because these providers have 5G networks deployed but do not advertise that some plans are restricted to their 4G networks.
- For Luxembourg's Post's 5G plan with no advertised download speed, we set this value to 225 Mbps because its more expensive plans have download speed restrictions with the lowest download speed restriction of 225 Mbps. Therefore, we assume this less expensive plan (with less minutes/texts units and lower data allowance) also has this download speed restriction.
- For New Zealand's Spark's plans, we set all plans' technology to 5G because the provider does not explicitly advertise a technology associated with the plans but does have a 5G network deployed.

[149] Generally, if a provider restricts video streaming quality, we use the quality restriction as a proxy for the download speed restriction because video streaming requires high download speeds and data usage, whereas other common use cases, such as browsing or messaging, do not require high download speeds to function normally. We choose a download speed of 3 Mbps for plans with Standard Definition (480p) and 8 Mbps for High Definition (720p) because these are typical recommended download speeds for these video streaming quality levels. *See, e.g.,* VdoCipher, *What is Video Bandwidth? 720p, 1080p, GB Transfer Explained* (Aug. 19, 2021), https://www.vdocipher.com/blog/video-bandwidth-explanation.

- For Norway's Ice's plans, we set all plans' technology to 5G because the provider does not explicitly advertise a technology associated with the plans but does have a 5G network deployed.
- For the United Kingdom's EE's plans, we set all plans' technology to 5G because the provider does not explicitly advertise a technology associated with the plans but does have a 5G network deployed.
- For the United States' AT&T, we set plans with a video streaming quality restriction of Standard Definition to 3 Mbps download speed.
- For the United States' T-Mobile and Verizon, we set plans with video streaming quality restrictions at either 480p (Standard Definition) or 720p (High Definition) to have download speeds of 3 Mbps and 8 Mbps, respectively.

104. After imposing the provider- or plan-specific assumptions, if any variables essential for the analysis were missing, we made the following assumptions to complete the analysis:

- If a contract duration was unknown, we assumed that the plan was month-to-month (i.e., 1 month).
- If no download speed restriction is advertised, we assumed that the plan has unrestricted download speeds (while under the plan's data allowance threshold).
- If the regular monthly price was not found, we assumed that the last available promotional price stayed in effect for the remaining 24-month 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 the average tax rate to the total pre-tax prices.[150] For all other countries, we assumed taxes were included.[151]

105. *Mobile 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:

$$\text{Total}_{24\text{-mo}} = \left(\text{Promo Price}_1 * \text{Promo Duration}_1\right) + \left(\text{Promo Price}_2 * \text{Promo Duration}_2\right) + \left(24 - \text{Promo Duration}_1 - \text{Promo Duration}_2\right) * \left(\text{Regular Price} + 24 * \left(\text{Activation Fee} - \text{Activation Fee Rebate}\right) + \text{Access Fee} + \text{Other Recurring Fees} - \text{Other Recurring Fee Rebate}\right) + \text{Other Non-Recurring Fees}$$

106. 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

[150] International Telecommunication Union, *World Telecommunications/ICT Indicators Database 2022 (26th Edition/July 2022)* (last accessed Sept. 16, 2022).

[151] In many countries, providers explicitly stated that taxes (e.g., VAT) were included in prices.

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.[152]

107. Similar to our fixed broadband analysis, we also created mobile broadband synthetic plans from collected plans when a provider did not offer a particular plan at a discounted price for bundling additional lines, up to four lines.[153] 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 least expensive of (a) the per line price of the 2-line plan (i.e., the total price of purchasing two 2-line plans divided by four), (b) the per line price of the weighted average of twice the 1-line plan and the 2-line plan (i.e., the total price of purchasing 2 1-line plans and 1 2-line plan divided by four), or (c) the per line price of 1-line price (i.e., the total price of purchasing 4 1-line plans divided by four). We made other similar synthetic plan calculations for plans that are not available with explicit 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.[154]

108. For a typical shared data plan where multiple lines share a pool of data, we treat these as separate plans because the per line data allowance is not constant with the different number of lines. For example, consider a 12 GB shared data plan which is offered for $20 for the first line and $10 for each additional line; the 1-line plan would have a data allowance of 12 GB per line for $20, the 2-line plan would have a data allowance of 6 GB per line for $30, the 3-line plan would have a data allowance of 4 GB per line for $40, and the 4-line plan would have a data allowance of 3 GB per line for $50. Each of these four plans would be treated separately when creating synthetic plans.

109. In Figure IV.F.8, we present country-level average mobile broadband bundle discounts (relative to single-line plans).[155] 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, weighted by their market shares. Finally, we aggregated over country-level products using the

[152] OECD, *OECD Data Explorer*, https://data-explorer.oecd.org/ (last visited August 1, 2024) (navigate to Economy – National accounts – GDP and non-financial accounts – GDP components – Annual Purchasing Power Parities and exchange rates). The hedonic index already corrects for income and price-level differences across countries through the inclusion of a country income variable in the regression and does not need further adjustments for PPPs.

[153] To count as the same plan (ignoring the number of lines), the provider must clearly indicate that each line on the plan receives the same services on a per line basis. If a plan includes shared minutes, text, or data, then the plan would be counted as a different plan since the per line minutes, text, or data decrease per line with additional lines. Less common plans where per line data increase or decrease with more lines (e.g., bonus data for bundling lines) count as different plans.

[154] In some cases where a provider does not offer a single-line plan, we cannot calculate some combinations of the 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.

[155] In some cases, a plan may change data usage tiers (and thus product definition) as the number of lines increases. For example, if a provider offers a 12 GB single-line plan that allows a customer to add lines to the plan and share the data allowance, we classify the single-line plan with 12 GB in the 10 to 25 GB data usage (per line) tier and the 2-line plan with 6 GB per line in the 0 to 10 GB data usage (per line) tier.

bundled data usage product shares. We again find that bundle discounts vary widely across countries and must be accounted for to properly measure the prices that 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.

c. Variable Construction

110. *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 subscriber 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 58% of all U.S. broadband subscribers purchase their service in a bundle.[156] The resulting broadband products and their estimated U.S. market shares are shown in Figure IV.C.1 above.

111. *Mobile Product Shares.* In the *2020 International Broadband Data Report*, we used the *Cisco White Paper*[157] to estimate the mobile product shares by assuming that data usage follows a log-normal distribution and using Cisco's estimates of data usage per line for single line and multi-line plans.[158] Because Cisco has not released more recent data, in order to update the mobile product shares, we assume that the shape (standard deviation) of the log-normal distribution has not changed but that the distribution has shifted to the right due to an increase in average data usage over time. To estimate how far the distribution has shifted, we use the *Ericsson Mobility Visualizer* data usage estimates for North America to calculate the percentage change in mobile data usage between 2019 and 2023.[159] We then apply this percentage change to the previous Cisco estimates of data usage per line on single-line and shared data plans to recalculate the mean of the log-normal distribution using our previous methodology.[160]

112. The log-normal distribution has been shown to approximate consumer usage over nearly every communications network, including broadband.[161] This simplifies the estimation of the distribution of data usage because a log-normal distribution is entirely determined by only two parameters: a location parameter that pins down the mean and a scale parameter that determines the shape of the usage

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[156] S&P Global, *Estimated Broadband-Only Homes As a Percentage of US Occupied Households, Q1 2019-Q3 2022* (last accessed July 19, 2024). We use FCC Form 477 subscriber data as of December 2023 for these calculations.

[157] Cisco, *Annual Internet Report (2018-2023) White Paper* (Mar. 9, 2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html (*Cisco White Paper*).

[158] *2020 Communications Marketplace Report*, 36 FCC Rcd at 3814-15, Appx. G-3: International Broadband Data Report, paras. 69-70, Fig. G-31.

[159] Specifically, Ericsson reports an increase of North American smartphone monthly data usage from 10.18 GB in 2019 to 19.14 GB in 2023, a 88% increase. *See* Ericsson, *Ericsson Mobility Visualizer*, https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer?f=11&ft=1&r=4&t=8&s=1&u=5&y=2017,2029&c=2 (last visited July 30, 2024) (to view the specific data, choose mobile data traffic per device per month for North America for smartphones only).

[160] Cisco reports that the overall North American Tier 1 operators' average monthly mobile data usage in May 2019 was 12.25 GB (this value is calculated as the weighted average of the monthly data consumption for two types of plans: tiered/data caps and unlimited), the single-line average mobile data usage was about 14 GB, and for 2-line, 3-line, and 4-line plans, the average monthly data usage was about 10 GB. *Cisco White Paper* (navigate to Figures 18-19). Based on the 88% increase between 2019 and 2023 reported by the Ericsson data, we estimated that the overall mobile data usage is 23.0 GB, 26.3 GB for single-line plans, and 18.8 GB for multi-line plans.

[161] Ioannis Antoniou et al., *On the Log-Normal Distribution of Network Traffic*, 167 Physica D: Nonlinear Phenomena 72 (2002).

distribution.[162] Another important property of the distribution is that percentiles are preserved if the mean of the distribution is shifted up or down.[163] 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 parameter estimates of this approach are summarized in Figure IV.F.1 below.

Fig. IV.F.1
Mobile Broadband Data Usage Shares Parameter Estimates

Distribution Parameters			
Plan Type	**Mean (GB)**	**Mu**	**Standard Deviation**
Overall	23.02	2.48	1.15
Individual	26.31	2.61	1.15
Shared	18.79	2.27	1.15

Note: *Mu* is the expected value of the variable's natural logarithm: $Mu = \ln(Mean) - 0.5 * StandardDeviation^2$.

113. *Purchasing Power Parity (PPP).* To convert pricing data collected in local currencies to U.S. dollars, we use the OECD's 2023 PPPs for household final consumption expenditure which are the rates of currency conversion that try to equalize the purchasing power of different currencies, by eliminating the differences in price levels between countries.[164]

114. *Exchange Rates.* To convert pricing data collected in local currencies to U.S. dollars, we also use the OECD's 2023 average exchange rates which are defined as "the price of one [country's] currency in relation to another country's currency."[165]

115. *Gross National Income (GNI) Per Capita.* The GNI per capita data for 2023 are used as a demographic control variable in the hedonic regression models and are from the World Bank.[166] The World Bank defines GNI as the "sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad" and converts it to U.S. dollars using a special Atlas method of conversion.[167]

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[162] *See* George S. Ford, *Approximating the Distribution of Broadband Usage from Publicly-Available Data*, 12-03 Phoenix Center Policy Perspective 1 (2012). A random variable is log-normally distributed if the logarithm of the variable is normally distributed.

[163] *Id.*

[164] OECD, *OECD Data Explorer*, https://data-explorer.oecd.org/ (last visited August 1, 2024) (navigate to Economy – National accounts – GDP and non-financial accounts – GDP components – Annual Purchasing Power Parities and exchange rates).

[165] *Id*.

[166] The World Bank, *GNI Per Capita, Atlas Method (Current US$)*, https://data.worldbank.org/indicator/NY.GNP.PCAP.CD (last visited July 1, 2024).

[167] The Atlas method applies a conversion factor that averages the exchange rate for a given year and the two preceding years, adjusted for differences in rates of inflation between the country and countries in the Euro area, Japan, the United Kingdom, and the United States. The World Bank, *GNI Per Capita, Atlas Method (Current US$)*, https://data.worldbank.org/indicator/NY.GNP.PCAP.CD (last visited July 1, 2024). The World Bank uses this method to account for exceptionally large margins from the official exchange rate and the rate actually applied in international transactions. *Id*.

116. *Educational Attainment.* These data are used as a demographic control variable in the hedonic regression models and are from the OECD.[168] We used the most recently available percentage of 25 to 64-year-olds with tertiary education to account for educational attainment. For most countries, we used the 2023 values, but for Canada and Mexico, we used 2022 values; for Australia, the United Kingdom, and the United States, we used 2021 values; and for New Zealand, we used 2020 values.

117. *Non-Rural Population Density.* For the fixed broadband hedonic analysis, we construct a measure of non-rural population density by using four OECD datasets: (1) National Population Distribution (NPD),[169] (2) National Area Distribution (NAD),[170] (3) land area, and (4) population. The NPD is the percentage of the population living in three categories of population density: urban, intermediate, and rural areas. The NAD is the percentage of the area in three categories: urban, intermediate, and rural. The NPD and NAD data are from 2014;[171] therefore, we multiply the percentages by the 2014 population and 2014 land area, respectively, to obtain the total population and total land area in each category. Then, we divide the total population in the three population density categories by the total land area in that category. Non-rural population density is the sum of urban and intermediate population divided by the sum of urban and intermediate land area.

118. *Population Density.* For the mobile broadband hedonic analysis, we used the OECD's overall national population density data for 2022, which is the most recent year that data are available for all 26 countries.[172]

119. *Fixed Coverage.* For the fixed broadband hedonic analysis, we include a variable measuring the percentage of households with access to broadband with download speeds of greater than 100 Mbps in each country. For the 21 European comparison countries, we use data presented in the 2023 Broadband Coverage in Europe Report on the percentage of households in areas where broadband with a download speed of greater than 100 Mbps was deployed as of June 2023.[173] For the United States, we rely on the BDC data for the same measure, as of June 2023.[174] For Canada, we use the percentage of households with fixed broadband service of at least 100 Mbps available as of 2022.[175]

120. For the remaining three countries of the 26 under study, we relied on proxy measures of coverage. For Australia, the Australian government reports that almost 75% of premises were able to access fixed broadband services with download speeds greater than or equal to 100 Mbps in 2021.[176] For

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[168] OECD, *OECD Data Explorer*, https://data-explorer.oecd.org/ (last visited August 1, 2024) (navigate to Education and skills – Subnational education indicators and Regional, rural and urban development – Regions – Regional education).

[169] OECD, *National Population Distribution*, https://data.oecd.org/popregion/national-population-distribution.htm#indicator-chart (last visited Oct. 17, 2024).

[170] OECD, *National Area Distribution*, https://data.oecd.org/popregion/national-area-distribution.htm#indicator-chart (last visited Oct. 17, 2024).

[171] We use the most recently available data.

[172] OECD, *OECD Data Explorer*, https://data-explorer.oecd.org/ (last visited Aug. 1, 2024) (navigate to Regional, rural and urban development – Regions – Regional society).

[173] *See generally* 2023 Broadband Coverage in Europe Report; *see also supra* Fig. II.A.1.

[174] BDC Data as of June 30, 2023; *see also infra* Fig. IV.F.13.

[175] Canadian Radio-television and Telecommunications Commission, *Current Trends – High-Speed Broadband*, https://crtc.gc.ca/eng/publications/reports/PolicyMonitoring/ban.htm (last visited Aug. 1, 2024).

[176] Australian Government, Department of Infrastructure, Transport, Regional Development and Communications & Bureau of Communications, Arts and Regional Research, Australia's Broadband Performance – Update 2021 at 1 (2021), https://www.infrastructure.gov.au/sites/default/files/documents/bcarr--australias-broadband-performance--march2022.pdf.

New Zealand, we rely on data from the country's Ministry of Business, Innovation, and Employment related to their Ultra-Fast Broadband (UFB) initiative.[177] In particular, we use the percentage of the population in New Zealand with access to at least 100 Mbps download and 50 Mbps upload speeds for the second quarter of 2021.[178]

121. For Mexico, we use 2023 data from Instituto Federal de Telecomunicaciones' Anuario Estadistico to calculate a proxy coverage measure based on the percentage of households with fiber or cable broadband technologies.[179] First, we calculate the number of residential accesses with either cable or fiber by multiplying the percentage of residential accesses via cable (13.1%) or fiber (42.8%) with the total number of residential accesses (approximately 22.5 million). Then, we divide the total number of accesses via cable or fiber by the total number of households (approximately 37.6 million) to get about 40.8% fixed coverage. Note that this number does not represent the percentage of households that can receive broadband via cable or fiber, nor does it represent the percentage of households which could receive at least 100 Mbps download.[180]

122. *Mobile Network Quality Variable.* To construct the mobile network quality measure used in our hedonic regressions, we perform a principal component analysis of four network quality proxy variables (download speed, upload speed, 4G availability, and 5G availability), using the national provider-level data from Opensignal. We keep only the first principal component which summarizes and reduces the four network quality proxy variables into a single variable measure and explains about 45% of the variation in the four network quality measures.[181] We then standardize the first principal component so that the mean value is zero and the standard deviation is one across the 84 provider-level values.

123. *Mobile Download and Upload Speeds.* For the mobile broadband hedonic analysis, we use most recently available provider-level overall download speeds based on Opensignal reports.[182] Because Opensignal does not report data for Iceland or Luxembourg and has not released updated data for Estonia, Latvia, and Lithuania since 2022, we impute values for the providers in these countries by running a simple regression of Opensignal's overall download speed at a country level (weighting provider-level download speeds by market share) on Ookla's 2023 country-level overall download speeds for all available OECD countries and predicting country-level download speeds for these five countries.[183] We perform the same analysis to predict upload speeds for the five countries.

124. *Mobile 4G Availability and 5G Availability.* For the mobile broadband hedonic analysis, we use OpenSignal's provider-level measure of 4G availability which is defined as "the proportion of

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[177] Crown Infrastructure Partners, Quarterly Connectivity Update Q2: to 30 June 2022 at 5 (2022), https://www.mbie.govt.nz/dmsdocument/25797-quarterly-connectivity-update-q2-to-30-june-2022-pdf.

[178] UFB NZ, *Glossary*, https://ufb.org.nz/terms/ (last visited July 25, 2024).

[179] Instituto Federal de Telecomunicaciones, Anuario Estadistico 2023 at 24, Fig. 25 (Dec. 2023), https://www.ift.org.mx/sites/default/files/contenidogeneral/estadisticas/anuarioestadistico2023.pdf.

[180] We acknowledge that our proxy value is likely an underestimate of the percentage of households where broadband is available with at least 100 Mbps download speeds because not all households which could receive such speeds will subscribe to broadband plans with download speeds of at least 100 Mbps. However, cable or fiber access does not necessarily guarantee download speeds of at least 100 Mbps, but we expect most cable or fiber plans to support download speeds of at least 100 Mbps.

[181] Principal component 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.

[182] Opensignal, *Market Insights*, https://www.opensignal.com/market-insights (last visited July 11, 2024).

[183] The imputed download and upload speeds for these countries are constant across providers for these countries because we do not have a reasonable way to predict provider-level download and upload speeds for the providers in these countries. The country-level Ookla download speed data are the same data used in Section III, but the overall country-level download speeds and upload speeds include all technologies.

time Opensignal users with a 4G device and a 4G subscription – but have never connected to 5G - had a 4G connection."[184] 5G availability is similarly defined as "the proportion of time Opensignal users with a 5G device and a 5G subscription had an active 5G connection."[185] For each country, we use the most recent Market Insight reports available,[186] except for Iceland and Luxembourg for which Opensignal does not report data, and for Estonia, Latvia, and Lithuania for which Opensignal has not released updated data since 2022. We impute country-level 4G availability and 5G availability values for these five countries by, again, relying upon country-level Ookla Speedtest data.[187] Specifically, we calculate the 2023 percentage of all speed tests on 4G LTE technology. Then, we calculate the country-level 4G availability by weighting the provider-level values by market shares and regressing Opensignal 4G availability on the percentage of tests on 4G LTE networks to predict values for the five countries. We follow the same approach to impute the 5G availability values for these five countries.

125. *Fixed Data Usage.* For the fixed broadband calculation of average monthly data usage, we rely on three different sources: (1) the TeleGeography GlobalComms Database, (2) the International Telecommunications Union (ITU) Datahub, and (3) Ofcom International Broadband Scorecard 2023.[188] The TeleGeography GlobalComms Database's Fixed Data Traffic Volume dataset has a monthly average representing a period of several months between 2022 and 2024.[189] We divide monthly averages from the TeleGeography dataset by the total number of fixed broadband subscribers as of June 2023 from OECD data to obtain the monthly fixed broadband data usage per subscriber.[190] The ITU DataHub reports the total annual data usage (in exabytes) by country, and we divided it by the OECD's number of fixed broadband subscribers as of June 2023 to obtain monthly fixed broadband data usage per subscriber.[191] We rely on Ofcom data for fixed broadband data consumption per capita.[192] We multiply these values by OECD population and then divide them by the total number of fixed broadband subscribers from OECD in order to get the monthly fixed broadband data usage per subscriber.

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[184] Opensignal, *Understanding Mobile Network Experience: What Do Opensignal's Metrics Mean?* (Mar. 24, 2022), https://www.opensignal.com/2022/03/24/understanding-mobile-network-experience-what-do-opensignals-metrics-mean.

[185] *Id*.

[186] Opensignal, *Market Insights*, https://www.opensignal.com/market-insights (last visited July 11, 2024).

[187] The imputed 4G availability and 5G availability values for these five countries are constant across providers in these countries because we do not have a reasonable way to predict provider-level values for the providers in these countries. Also, in the simple regressions for imputing country-level 4G availability and 5G availability values for these five countries, we use the other 31 comparison countries presented in Section III.

[188] For a given country, if we have values from multiple sources, we take the average of these values.

[189] TeleGeography, *TeleGeography GlobalComms Database*, http://www.telegeography.com (last accessed July 18, 2024) (navigate to *Data Traffic* within the *GlobalComms Database*). 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 traffic wherever possible.

[190] OECD, *Broadband Statistics*, https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html (last visited July 20, 2024).

[191] International Telecommunication Union, *Fixed-Broadband Internet Traffic*, https://datahub.itu.int/data/?i=13067&v=chart&u= (last visited July 18, 2024).

[192] Ofcom, *International Broadband Scorecard 2023: Interactive Data* (Dec. 19, 2023), https://www.ofcom.org.uk/phones-and-broadband/coverage-and-speeds/international-broadband-scorecard-2023-interactive-data/.

126. *Mobile Data Usage.* For the mobile broadband analysis, we use average monthly data usage reported by the OECD as of the fourth quarter of 2022.[193]

127. *Terrain Roughness (Weighted by Population).* Our measure of terrain roughness, a proxy for broadband network deployment costs, is a population weighted terrain ruggedness index.[194] 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. The terrain roughness index (TRI) calculates the sum squared elevation change of the cell relative to adjacent cells:

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

128. 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.[195]

d. Price Index Construction

129. We use the same general methodology to calculate the fixed broadband and mobile broadband price indexes in Figure IV.D.1 and Figure IV.E.1, respectively. The supplementary figures of broadband prices by product referenced here are available in section IV.G below.

130. *Step 1.* We calculate the unweighted average price of all plans for each provider within each product category.[196] Therefore, each provider has up to six product prices.

131. *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, it carries zero weight; and, the weights of remaining providers are proportional to only those providers that do offer a product in the given product category.[197] Figure IV.F.5 and Figure IV.F.10 display the country-level product prices for fixed broadband and mobile broadband, respectively.

132. *Step 3.* There are cases in which no provider in a country offers plans in a product category, thus 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).[198] Next, if the highest tiered product(s) is not offered, we set the missing product price(s) to the next available product price. For example, if no providers in the country offer product 1, then we set its value equal to the price of product 2. If both products 1 and 2 are not offered,

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[193] OECD, *Broadband and Telecom Databases*, https://data-explorer.oecd.org/vis?df[ds]=DisseminateFinalDMZ&df[id]=DSD_BB_DATABASE%40DF_BB_TEL_DATABASE&df[ag]=OECD.STI.DEP&dq=.Q..DATA.&lom=LASTNPERIODS&lo=5&to[TIME_PERIOD]=false&ly[cl]=TIME_PERIOD&ly[rw]=REF_AREA&vw=ov (last visited July 10, 2024).

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

[195] Nathan Nunn & Diego Puga, *Data and Replication Files for 'Ruggedness: The Blessing of Bad Geography in Africa'*, https://diegopuga.org/data/rugged/ (last visited Oct. 17, 2024).

[196] This calculation includes "synthetic plans."

[197] 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.

[198] Specifically, we set the price of product 4 to the price of product 1, the price of product 5 to the price of product 2, and the price of product 6 to the price of product 3.

then we set both product values to the price of product 3. Finally, for any remaining missing product prices, we set these to the next highest available product price.[199] For example, if providers in a country only offer products 1 and 3, then the price of product 2 is set to the price of product 3.

133. *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 IV.C.1 for fixed broadband and Figure IV.C.2 for mobile broadband.[200] For fixed broadband, we calculate the overall standalone price and overall bundled price by using the download speed shares in Figure IV.D.1. For mobile broadband, we calculate the overall single-line price and overall multi-line price by using the data usage shares in Figure IV.E.1. To calculate the overall broadband price, we use the bundle shares to weight the overall standalone price and overall bundle price.

134. *Step 5.* To produce price per GB rankings, we divide the overall broadband price calculated in Step 4 by the average monthly data usage in each country.

2. Hedonic Regression Model

135. The classic hedonic framework involves adjusting for changing product quality over time, and 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.[201]

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

136. 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.[202] 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.

137. 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.[203] 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

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[199] 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.

[200] *See supra* para. 66 (price index formula).

[201] *See* Zvi Griliches, *Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change*, The Price Statistics of the Federal Government 173 (1st ed. 1961).

[202] *See* W. Erwin Diewert, Saeed Heravi, & Mick Silver, *Hedonic Imputation versus Time Dummy Hedonic Indexes*, Price Index Concepts and Measurement 161 (1st ed. 2009).

[203] *See* Carol Corrado & Olga Ukhaneva, Hedonic Prices for Fixed Broadband Services: Estimation across OECD Countries (Oct. 2016), https://www.oecd-ilibrary.org/docserver/5jlpl4sgc9hj-en.pdf?expires=1603997556&id=id&accname=guest&checksum=1D0A776B692D8F368F8A696A24A0E702. These models are also called "random effects models," "hierarchical linear models," and "mixed models."

estimating separate parameters for each provider and product characteristic, the model assumes normally distributed zero-mean random coefficients on some product characteristics at the country- or 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.

138. 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 including them in the price predictions as they would in a fixed effect specification.

139. Our base multilevel hedonic pricing equation is as follows:

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

- P_{ijk} is the price for plan *i*, offered by provider *j,* in country *k*;
- X_i is a vector of plan characteristic variables;[204]
- 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 $Var[\tilde{\beta}] = G$;[205]

[204] 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 variable for whether fixed voice is included, a dummy variable for whether download and upload speeds are symmetric, a dummy for whether the plan is a wired broadband plan, a dummy variable for whether more than 2000 GB of data is included (i.e., unlimited data), and an interaction term between the wired broadband dummy and the unlimited data dummy. For mobile broadband, the plan characteristics include the number of lines, a family plan dummy indicating whether more than one line is included, contract duration, the logarithm of the data allowance per line, a dummy variable for whether the data allowance per line is at least 1000 GB (i.e., unlimited data), a dummy variable for whether the plan includes at least 1000 minutes (i.e., unlimited minutes), a dummy variable for whether the plan includes at least 1000 text messages (i.e., unlimited text message), the logarithm of the download speed, a dummy variable for whether the plan has at least 2Gbps download speed (i.e., unrestricted download speed), a dummy if the plan allows access to a provider's 5G network, and an interaction of the logarithm of download speed and 5G technology dummy. 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 as key product characteristics that likely had the greatest impact on consumer choices.

[205] 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 (continued….)

- 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.

140. The multilevel model is estimated by maximum likelihood estimation (MLE). In the matrix form, the model can be written as:[206]

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

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

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

142. Let $u = \tilde{X}\tilde{\beta} + \varepsilon$ be the combined error term, and $\ln(p)$ is normally distributed multivariate with mean $X\beta + Z\gamma$ and the following variance-covariance matrix:

$$V = \tilde{X}G\tilde{X}' + \sigma_\varepsilon^2 I_n.$$

143. Let θ be a vector of the unknown variance components of G and use the following likelihood function to find the unique vectors β, θ, and σ_ε^2 that maximize this likelihood of observing our data sample:[207]

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

144. 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:

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

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

$$\ln\left(\hat{P}_{ijk}\right) = X_i\hat{\beta} + Z_k\hat{\gamma} + \tilde{X}_i\hat{b}_j + \hat{\mu}_j + \hat{\upsilon}_k.$$

146. 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

assumed to be zero. When predicting prices for each provider, we use the best linear unbiased predictors of the random coefficients based on the estimated variance components.

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

[207] 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 (2013), https://www.stata.com/manuals13/me.pdf.

coefficient β.[208] In our fixed broadband hedonic models, the product characteristics with provider random coefficients are three download speed splines and a constant; the wired broadband technology indicator variable also has a country random effect in addition to a constant.[209] In our mobile broadband hedonic models, there are country random coefficients on a family plan dummy, a logarithm of data allowance per line, an unlimited data allowance dummy, and the logarithm of download speed; there is also a constant provider random effect.

147. 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.[210] 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 structures.[211] As such, in imperfectly competitive markets, hedonic coefficients should only be considered as a reduced-form 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.[212] 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 by predicting prices for all countries at the U.S. values of Z_k.

3. Supplementary Figures

148. Following are our supplementary figures that provide additional data and information.

[208] *See infra* Fig. IV.F.6; *infra* Fig. IV.F.11 (fixed and mobile broadband, respectively, estimated variances of the random coefficients).

[209] We control for download speeds 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 fixed broadband products (i.e., knots at 100 and 250 Mbps).

[210] *See* Sherwin Rosen, *Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition*, 82 Journal of Political Economy 34 (1974).

[211] *See generally* Pakes (2003); Robert C. Feenstra & Gordon H. Hanson, Foreign Investment, Outsourcing and Relative Wages (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 (2001). 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.

[212] *See generally* Pakes (2003).

Fig. IV.F.2
Fixed Broadband and Mobile Broadband Combined Hedonic Price Indexes

Country	Model 1		Model 2		Model 3	
	Price	Rank	Price	Rank	Price	Rank
Australia	110.04	25	105.60	17	105.88	17
Austria	71.94	11	133.86	22	133.60	22
Belgium	79.78	17	100.15	14	99.92	14
Canada	108.71	22	87.28	12	87.12	12
Czech Republic	57.20	5	144.37	24	144.02	24
Denmark	62.61	7	71.78	3	71.71	3
Estonia	64.04	9	95.01	13	94.75	13
Finland	63.61	8	76.82	7	76.92	7
France	51.83	4	72.36	4	72.31	4
Germany	74.66	15	124.93	20	124.66	20
Greece	61.42	6	127.61	21	127.74	21
Iceland	109.41	23	113.64	19	113.71	19
Ireland	94.97	20	84.06	10	83.79	10
Italy	35.53	2	76.45	6	76.30	6
Latvia	29.19	1	42.74	1	42.75	1
Luxembourg	87.53	19	84.70	11	84.67	11
Mexico	77.98	16	258.11	26	258.19	26
Netherlands	68.63	10	79.08	8	78.96	8
New Zealand	80.27	18	100.46	15	100.25	15
Norway	120.93	26	112.46	18	112.45	18
Portugal	72.07	12	171.60	25	171.09	25
Spain	42.00	3	65.71	2	65.48	2
Sweden	74.28	14	75.38	5	75.30	5
Switzerland	109.67	24	136.97	23	136.85	23
United Kingdom	72.18	13	82.67	9	82.69	9
United States	**102.73**	**21**	**103.33**	**16**	**103.33**	**16**

Note: The values in this table are the sum of the predicted prices from each of the four fixed broadband models and mobile broadband models (e.g., Fixed Broadband Model 1 + Mobile Broadband Model 1).

Fig. IV.F.3
Fixed Broadband Average Bundle Discounts and Discount Rates (PPP Adjusted)

Country	Discount ($)	Discount Rate
Australia		
Austria		
Belgium		
Canada		
Czech Republic		
Denmark		
Estonia		
Finland		
France		
Germany		
Greece	12.17	16.7%
Iceland		
Ireland	6.29	6.9%
Italy		
Latvia	7.91	18.2%
Luxembourg		
Mexico		
Netherlands		
New Zealand		
Norway	23.79	13.1%
Portugal		
Spain		
Sweden	15.91	17.0%
Switzerland		
United Kingdom	49.83	62.0%
United States	**10.89**	**7.6%**

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

Fig. IV.F.4
Fixed Broadband Unweighted Average Prices by Product (PPP Adjusted)

Country	Standalone						Bundled					
	0 < Mbps < 100		100 ≤ Mbps < 250		Mbps ≥ 250		0 < Mbps < 100		100 ≤ Mbps < 250		Mbps ≥ 250	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia	57.47	19	67.98	7	95.87	4	57.47	19	67.98	7	95.87	4
Austria	27.26	5	32.54	8	49.83	11	27.26	5	32.54	8	49.83	11
Belgium	39.34	1	54.89	4	79.82	3	39.34	1	54.89	4	94.93	7
Canada	48.35	6	63.37	4	89.38	12	48.35	6	63.37	4	89.38	12
Czech Republic	32.73	6	42.82	5	37.57	11	35.91	10	40.44	9	38.31	13
Denmark			41.78	5	51.21	9			41.78	5	51.21	9
Estonia	39.60	11	51.80	7	84.61	9	39.60	11	51.80	7	84.61	9
Finland			47.77	7	58.67	15			47.77	7	58.67	15
France					47.77	3					57.03	15
Germany	41.56	6	47.36	5	50.55	6	42.34	7	47.97	6	51.18	7
Greece	45.90	5	59.49	7	61.90	8	41.47	9	53.27	11	59.30	12
Iceland			65.33	1	73.54	20			65.33	1	73.54	20
Ireland	52.61	2	42.50	2	55.95	12	48.08	2	42.50	2	55.58	12
Italy			41.16	4	40.93	7			41.16	4	40.93	7
Latvia	20.55	2	27.00	2	26.69	5	18.32	6	20.04	5	21.67	10
Luxembourg			55.41	3	91.94	6			55.41	3	91.94	6
Mexico	41.27	4	50.82	5	79.84	9	43.98	5	50.82	5	79.84	9
Netherlands	41.86	1	50.15	6	69.12	7	41.86	1	50.15	6	69.12	7
New Zealand	40.15	11			66.83	11	40.15	11			66.83	11
Norway	72.14	3	85.47	4	113.77	11	72.14	3	83.87	5	112.03	15
Portugal			50.27	2	96.28	3	87.35	1	59.49	4	80.77	8
Spain			51.37	1	55.29	8			51.37	1	55.65	10
Sweden	22.77	1	45.55	8	60.08	29	22.77	1	43.29	11	58.63	35
Switzerland			51.41	5	62.88	7			51.41	5	62.88	7
United Kingdom	45.08	17	43.41	7	58.51	10	40.30	17	31.54	7	52.32	10
United States	**42.66**	**2**	**44.18**	**2**	**88.36**	**18**	**42.66**	**2**	**44.18**	**2**	**81.76**	**33**
Total		102		111		254		117		129		314

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

Fig. IV.F.5.
Fixed Broadband Weighted Average Prices by Product (PPP Adjusted)

Country	Standalone						Bundled					
	0 < Mbps < 100		100 ≤ Mbps < 250		Mbps ≥ 250		0 < Mbps < 100		100 ≤ Mbps < 250		Mbps ≥ 250	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia	62.88	19	69.06	7	95.15	4	62.88	19	69.06	7	95.15	4
Austria	28.22	5	33.09	8	48.30	11	28.22	5	33.09	8	48.30	11
Belgium	39.34	1	54.34	4	76.34	3	39.34	1	54.34	4	93.53	7
Canada	48.55	6	66.59	4	89.60	12	48.55	6	66.59	4	89.60	12
Czech Republic	33.29	6	41.34	5	37.51	11	36.12	10	39.86	9	39.37	13
Denmark			41.42	5	52.51	9			41.42	5	52.51	9
Estonia	40.58	11	52.24	7	88.57	9	40.58	11	52.24	7	88.57	9
Finland			47.43	7	58.66	15			47.43	7	58.66	15
France					47.93	3					58.18	15
Germany	43.91	6	50.08	5	55.22	6	44.18	7	50.20	6	55.19	7
Greece	47.31	5	60.45	7	66.31	8	44.41	9	57.05	11	64.96	12
Iceland			65.33	1	82.47	20			65.33	1	82.47	20
Ireland	52.61	2	42.89	2	53.65	12	48.08	2	42.89	2	53.27	12
Italy			42.99	4	42.46	7			42.99	4	42.46	7
Latvia	20.55	2	28.79	2	21.49	5	18.32	6	27.51	5	19.00	10
Luxembourg			61.84	3	98.28	6			61.84	3	98.28	6
Mexico	39.21	4	48.74	5	81.39	9	42.11	5	48.74	5	81.39	9
Netherlands	41.86	1	50.74	6	64.52	7	41.86	1	50.74	6	64.52	7
New Zealand	40.15	11			64.74	11	40.15	11			64.74	11
Norway	80.91	3	85.16	4	108.44	11	80.91	3	83.25	5	106.66	15
Portugal			50.27	2	96.28	3	87.35	1	64.70	4	79.36	8
Spain			51.37	1	56.22	8			51.37	1	56.42	10
Sweden	22.77	1	47.27	8	63.41	29	22.77	1	44.33	11	60.71	35
Switzerland			51.59	5	63.24	7			51.59	5	63.24	7
United Kingdom	45.42	17	43.34	7	57.71	10	42.10	17	36.56	7	50.13	10
United States	**34.96**	**2**	**40.28**	**2**	**80.28**	**18**	**34.96**	**2**	**40.28**	**2**	**78.52**	**33**
Total		102		111		254		117		129		314

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

Fig. IV.F.6
Fixed Broadband Estimated Variances of Random Coefficients and Likelihood Ratio Tests

Random Effect Parameters	Model 1		Model 2		Model 3	
	Estimate	SE	Estimate	SE	Estimate	SE
Country: Variance(Wired Broadband Technology)	0.028	0.011	0.024	0.009	0.024	0.009
Country: Variance(Constant)	0.104	0.035	0.040	0.017	0.040	0.017
Provider: Variance(0 < Mbps < 100)	0.001	0.001	0.001	0.001	0.001	0.001
Provider: Variance(100 ≤ Mbps < 250)	0.035	0.009	0.035	0.009	0.035	0.009
Provider: Variance(250 ≤ Mbps)	0.023	0.005	0.023	0.005	0.023	0.005
Provider: Variance(Constant)	0.017	0.009	0.018	0.009	0.018	0.009
Variance(Residual)	0.022	0.001	0.022	0.001	0.022	0.001
Likelihood Ratio Tests			**1 vs. 2**		**2 vs. 3**	
P-Value			0.001		0.958	

Fig. IV.F.7
Fixed Broadband Country Random Coefficients

Country	Model 1	Model 2	Model 3
Australia	0.272	0.121	0.124
Austria	-0.373	-0.319	-0.318
Belgium	0.137	0.092	0.091
Canada	0.414	0.157	0.156
Czech Republic	-0.384	-0.052	-0.054
Denmark	0.059	-0.009	-0.010
Estonia	-0.061	0.118	0.115
Finland	0.127	0.086	0.087
France	-0.277	-0.199	-0.198
Germany	0.011	0.040	0.040
Greece	-0.200	0.004	0.005
Iceland	0.357	0.149	0.150
Ireland	0.131	-0.022	-0.021
Italy	-0.265	-0.049	-0.049
Latvia	-0.721	-0.335	-0.333
Luxembourg	0.230	-0.005	-0.005
Mexico	-0.257	0.187	0.191
Netherlands	0.071	0.085	0.084
New Zealand	0.102	0.042	0.041
Norway	0.563	0.139	0.139
Portugal	0.089	0.249	0.246
Spain	-0.260	-0.133	-0.136
Sweden	-0.331	-0.400	-0.400
Switzerland	0.303	0.014	0.014
United Kingdom	0.111	0.072	0.073
United States	**0.154**	**-0.031**	**-0.031**
Overall	0.000	0.000	0.000

Fig. IV.F.8
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	-0.33	-0.8%	-0.65	-1.6%	-0.98	-2.4%
Austria						
Belgium						
Canada	-3.44	-3.8%	-4.59	-5.1%	-5.89	-6.6%
Czech Republic						
Denmark	-0.20	-0.5%	-0.27	-0.7%	-0.30	-0.8%
Estonia	-1.82	-4.5%	-1.85	-4.2%	-2.62	-5.9%
Finland	-0.30	-1.1%	-0.30	-1.1%	-0.30	-1.1%
France						
Germany	-7.92	-13.0%	-10.75	-17.3%	-13.03	-21.4%
Greece	-0.52	-1.3%	-0.69	-1.8%	-0.78	-2.0%
Iceland						
Ireland						
Italy						
Latvia	-1.91	-3.9%	-2.55	-5.1%	-2.87	-5.8%
Luxembourg						
Mexico	-0.01	0.0%	-0.01	0.0%	-0.01	0.0%
Netherlands	-0.16	-0.4%	-0.11	-0.3%	-0.16	-0.4%
New Zealand	-2.47	-6.3%	-3.71	-9.4%	-4.33	-11.0%
Norway	-1.20	-2.6%	-1.60	-3.4%	-1.80	-3.8%
Portugal	-0.69	-0.9%	-0.92	-1.2%	-1.04	-1.3%
Spain	-5.64	-18.3%	-7.55	-24.4%	-8.51	-27.5%
Sweden	-2.28	-4.1%	-3.14	-5.6%	-4.28	-9.0%
Switzerland						
United Kingdom						
United States	**-7.07**	**-10.9%**	**-14.75**	**-22.8%**	**-17.26**	**-26.1%**

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

Fig. IV.F.9
Mobile Broadband Unweighted Prices by Product (PPP Adjusted)

Country	Single Line Plans						Multi-Line Plans					
	0.2 < GB ≤ 10		10 < GB ≤ 25		25 < GB		0.2 < GB ≤ 10		10 < GB ≤ 25		25 < GB	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia					46.45	11					44.84	34
Austria					52.44	21					52.44	63
Belgium	19.90	4	23.82	1	39.78	5	19.90	12	23.82	3	39.78	15
Canada					80.30	9					75.42	27
Czech Republic	42.95	8	58.51	2	75.70	9	42.95	24	58.51	6	75.70	27
Denmark	12.50	4	19.58	4	31.48	11	15.25	23	20.27	19	28.54	46
Estonia	22.42	4	28.25	5	48.83	5	20.68	21	26.42	16	45.13	15
Finland					44.45	14					44.03	42
France	22.63	1	26.64	1	48.07	17	22.63	3	26.64	3	48.07	51
Germany	40.27	8	56.79	3	75.77	15	31.01	24	38.82	9	48.85	66
Greece	38.31	8	52.90	2	60.87	3	37.63	38	52.90	6	55.51	12
Iceland	14.45	3	20.86	3	47.01	7	14.45	9	20.86	9	47.01	21
Ireland			43.67	1	44.91	10			43.67	3	44.91	30
Italy					32.80	11					32.80	33
Latvia	27.82	3	36.40	1	45.59	6	27.82	9	36.40	3	40.30	18
Luxembourg	16.25	6	30.31	3	62.23	5	16.25	18	30.31	9	62.23	15
Mexico	33.24	8	52.46	11	106.33	7	33.24	24	52.37	33	106.33	21
Netherlands	21.80	16	26.45	14	41.83	30	21.80	48	26.41	44	41.10	92
New Zealand	25.65	5	42.32	3	53.17	3	24.66	15	38.02	9	47.64	9
Norway	29.14	7	31.22	1	49.04	7	28.56	21	31.22	3	44.27	21
Portugal	34.03	21	61.90	3	70.81	10	34.18	75	61.90	9	67.78	30
Spain	27.24	1	18.00	2	43.62	9	17.95	3	16.46	6	33.88	27
Sweden	26.77	6	39.07	4	50.79	11	25.61	38	35.55	21	38.49	33
Switzerland	29.25	4			54.53	7	29.25	12			54.53	21
United Kingdom	24.73	25	30.10	18	37.77	39	24.73	75	30.10	54	37.77	117
United States	**56.03**	**1**			**77.81**	**8**	**46.95**	**3**			**54.63**	**23**
Total		143		82		290		495		265		909

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

Fig. IV.F.10
Mobile Broadband Weighted Prices by Product (PPP Adjusted)

Country	Single Line Plans						Multi-Line Plans					
	0.2 < GB ≤ 10		10 < GB ≤ 25		25 < GB		0.2 < GB ≤ 10		10 < GB ≤ 25		25 < GB	
	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
Australia					47.91	11					46.88	34
Austria					46.54	21					46.54	63
Belgium	19.43	4	23.82	1	41.00	5	19.43	12	23.82	3	41.00	15
Canada					80.28	9					75.64	27
Czech Republic	42.63	8	59.10	2	79.04	9	42.63	24	59.10	6	79.04	27
Denmark	12.64	4	19.95	4	31.57	11	17.56	23	21.04	19	28.97	46
Estonia	20.31	4	31.95	5	47.68	5	17.63	21	27.21	16	43.86	15
Finland					46.58	14					46.28	42
France	22.63	1	26.64	1	46.01	17	22.63	3	26.64	3	46.01	51
Germany	37.62	8	52.82	3	76.75	15	31.36	24	40.23	9	51.71	66
Greece	39.29	8	55.62	2	62.90	3	37.56	38	55.62	6	55.55	12
Iceland	14.41	3	20.63	3	46.97	7	14.41	9	20.63	9	46.97	21
Ireland			43.67	1	45.07	10			43.67	3	45.07	30
Italy					33.60	11					33.60	33
Latvia	27.65	3	36.40	1	46.40	6	27.65	9	36.40	3	34.18	18
Luxembourg	16.82	6	33.85	3	59.95	5	16.82	18	33.85	9	59.95	15
Mexico	32.42	8	58.88	11	107.61	7	32.42	24	58.83	33	107.61	21
Netherlands	22.05	16	26.43	14	41.77	30	22.05	48	26.38	44	40.75	92
New Zealand	26.13	5	43.03	3	54.18	3	25.07	15	37.53	9	47.11	9
Norway	33.57	7	31.22	1	52.67	7	32.84	21	31.22	3	46.93	21
Portugal	35.52	21	61.37	3	72.17	10	33.64	75	61.37	9	67.76	30
Spain	27.24	1	18.41	2	44.62	9	17.95	3	16.77	6	34.92	27
Sweden	26.66	6	39.93	4	53.79	11	25.79	38	38.50	21	38.81	33
Switzerland	30.05	4			57.31	7	30.05	12			57.31	21
United Kingdom	24.34	25	31.73	18	37.65	39	24.34	75	31.73	54	37.65	117
United States	**56.03**	**1**			**77.82**	**8**	**46.95**	**3**			**55.18**	**23**
Total		143		82		290		495		265		909

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

Fig. IV.F.11
Mobile Broadband Estimated Variances of Random Coefficients and Likelihood Ratio Tests

Random Effect Parameters	Model 1		Model 2		Model 3	
	Estimate	SE	Estimate	SE	Estimate	SE
Country: Variance(Family Plan)	0.013	0.005	0.013	0.005	0.013	0.005
Country: Variance(Log Data Allowance)	0.015	0.005	0.015	0.005	0.015	0.005
Country: Variance(Unlimited Data Allowance Dummy)	0.141	0.049	0.141	0.049	0.141	0.049
Country: Variance(Log Download Speed)	0.021	0.007	0.020	0.006	0.020	0.006
Country: Variance(Constant)	0.981	0.319	0.684	0.233	0.684	0.233
Provider: Variance(Constant)	0.061	0.012	0.061	0.012	0.061	0.012
Variance(Residual)	0.029	0.001	0.029	0.001	0.029	0.001
Likelihood Ratio Tests			**1 vs. 2**		**2 vs. 3**	
P-Value			0.116		0.974	

Fig. IV.F.12
Mobile Broadband Country Random Coefficients

Country	Model 1	Model 2	Model 3
Australia	0.760	0.104	0.101
Austria	-3.097	-2.523	-2.524
Belgium	-0.256	-0.359	-0.361
Canada	0.184	-0.605	-0.602
Czech Republic	0.240	0.975	0.977
Denmark	-0.034	-0.147	-0.144
Estonia	-0.222	-0.250	-0.250
Finland	-0.379	-0.419	-0.417
France	-0.439	-0.333	-0.333
Germany	0.340	0.671	0.668
Greece	0.058	0.328	0.329
Iceland	-0.074	-0.183	-0.184
Ireland	1.284	0.684	0.666
Italy	-1.668	-0.730	-0.736
Latvia	0.100	-0.031	-0.029
Luxembourg	-0.036	-0.253	-0.249
Mexico	-0.488	0.037	0.036
Netherlands	0.234	-0.412	-0.404
New Zealand	0.083	0.057	0.054
Norway	0.570	0.400	0.406
Portugal	0.214	1.002	1.005
Spain	-0.802	-0.474	-0.472
Sweden	0.888	0.465	0.463
Switzerland	0.421	0.585	0.587
United Kingdom	0.701	0.340	0.336
United States	**1.418**	**1.071**	**1.079**
Overall	0.000	0.000	0.000

Fig. IV.F.13
Summary Statistics for Independent Variables

Country	PPP	Exchange Rate	Fixed Usage	Mobile Usage	GNI/Capita	Non-Rural Pop. Density	Pop. Density	Educational Attainment	TRI (Weighted by Population)	Fixed Coverage
Australia	1.45	1.51	400	11.5	63,140	155	9	48.7%	0.18	73.0%
Austria	0.75	0.92	200	30.3	55,070	686	282	36.6%	1.15	87.5%
Belgium	0.77	0.92	267	5.9	54,530	1,093	988	44.8%	0.26	96.9%
Canada	1.22	1.35	403	5.9	53,930	190	11	63.0%	0.37	90.1%
Czech Republic	14.35	22.20	289	7.3	27,110	368	353	27.0%	0.58	91.1%
Denmark	7.16	6.89	381	19.0	73,360	751	362	42.9%	0.19	98.0%
Estonia	0.66	0.92		22.1	27,240	89	80	41.6%	0.19	84.4%
Finland	0.83	0.92	231	40.1	53,390	232	47	42.6%	0.27	78.0%
France	0.74	0.92	319	14.4	45,070	440	277	42.4%	0.50	82.1%
Germany	0.73	0.92	270	7.3	53,970	822	610	33.3%	0.41	92.9%
Greece	0.58	0.92	216	6.9	22,580	464	208	34.3%	1.29	60.7%
Iceland	155.98	137.94	459	23.7	79,840	540	9	44.0%	0.56	89.3%
Ireland	0.95	0.92	259	19.0	80,390	3,695	191	54.5%	0.28	91.6%
Italy	0.66	0.92	236	16.5	38,200	655	513	21.6%	0.75	87.1%
Latvia	0.58	0.92	403	41.8	21,970	168	77	39.2%	0.14	63.6%
Luxembourg	0.90	0.92		10.5	88,370	560	646	51.9%	0.58	95.4%
Mexico	10.79	17.76	364	5.8	12,100	607	169	20.8%	0.82	40.8%
Netherlands	0.79	0.92		6.2	60,670	1,297	1,333	44.3%	0.04	98.7%
New Zealand	1.54	1.63	354	5.8	48,610	44	50	40.1%	0.45	86.3%
Norway	9.58	10.56		11.2	102,460	122	39	48.7%	1.25	96.6%
Portugal	0.59	0.92	272	7.7	26,270	775	295	29.9%	0.97	95.7%
Spain	0.62	0.92	308	10.2	32,180	382	244	41.4%	0.81	95.7%
Sweden	8.74	10.61	187	18.8	61,650	319	66	49.4%	0.34	89.0%
Switzerland	1.13	0.90	175	17.8	95,160	800	568	46.2%	1.45	98.6%
United Kingdom	0.75	0.80	496	8.3	47,800	893	721	50.1%	0.21	77.1%
United States	1.00	1.00	510	9.5	80,300	252	94	46.2%	0.33	94.6%
Analysis	Both	Both	Fixed	Mobile	Both	Fixed	Mobile	Both	Both	Fixed
Source	OECD	OECD	Various	OECD	World Bank	OECD	OECD	OECD	Nunn & Puga	Various
Year	2023	2023	Most Recent	2022	2023	2014	2022	Most Recent	2000/2001	Most Recent
Unit	LCU/USD	LCU/USD	GB/Month/Subscriber	GB/Month/Subscriber	Current USD (Atlas)	People/Mile2	People/Mile2	Percentage	100s Meters	Percentage

Note: *See supra* section IV.F.1. Data and Methods Technical Details for discussion of data sources, variable construction, and details of data issues.

Fig. IV.F.14
Mobile Network Quality Variables

Country	First Principal Component	Download Speed	Upload Speed	4G Availability	5G Availability
Australia	0.63	59.3	8.1	94.4%	21.6%
Austria	-0.18	52.2	12.89	89.8%	12.6%
Belgium	-0.47	46.5	11.6	91.7%	5.4%
Canada	0.33	71.7	11.5	93.6%	9.1%
Czech Republic	-0.08	40.1	15.8	93.0%	14.2%
Denmark	1.17	98.2	18.3	93.7%	14.2%
Estonia	-0.11	53.3	11.8	91.5%	10.8%
Finland	1.09	75.5	16.2	93.7%	23.8%
France	-0.24	54.4	7.5	86.8%	16.9%
Germany	-0.10	48.4	11.0	92.5%	12.0%
Greece	-0.49	41.7	9.9	88.1%	13.9%
Iceland	0.97	94.3	16.1	90.8%	17.1%
Ireland	-2.08	36.2	10.0	70.2%	10.7%
Italy	-0.59	32.5	9.3	88.9%	14.8%
Latvia	-0.15	52.7	10.6	89.9%	13.5%
Luxembourg	0.38	54.2	12.8	93.3%	18.9%
Mexico	-1.29	24.8	8.2	86.3%	6.8%
Netherlands	1.23	82.1	15.6	96.9%	18.5%
New Zealand	-0.60	41.6	31.3	87.5%	6.7%
Norway	1.40	103.1	18.9	97.3%	10.7%
Portugal	-0.32	47.3	12.2	87.9%	15.1%
Spain	-0.56	35.9	11.0	88.4%	14.2%
Sweden	0.03	59.7	13.8	93.4%	7.3%
Switzerland	0.36	61.7	16.1	93.4%	13.4%
United Kingdom	-1.04	29.6	7.0	86.6%	10.2%
United States	1.62	78.4	9.8	97.6%	29.9%
Analysis	Mobile	Mobile	Mobile	Mobile	Mobile
Source		Opensignal	Opensignal	Opensignal	Opensignal
Year		Most Recent	Most Recent	Most Recent	Most Recent
Unit	Standardized	Mbps	Mbps	Percentage	Percentage
Loading Factor		0.6497	0.186	0.5542	0.4859