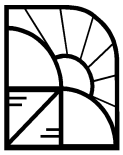

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PHOENIX CENTER POLICY BULLETIN NO. 49

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May 2020

COVID-19 AND BROADBAND SPEEDS: A MULTI-COUNTRY ANALYSIS

Abstract: COVID-19 has forced the residents of many nations to shelter-in-place, either by choice or by mandate. As a result, Internet use has skyrocketed, putting stress on both fixed and mobile broadband networks. In this BULLETIN, I take an early look at the performance of broadband networks with respect to download speeds. Using weekly speed data for fixed and mobile networks for months preceding and following March-2020, I find sizable reductions in speed for several countries, but also some increases in speed. Larger negative effects appear more often for lower-income countries and those with slower networks, with a few exceptions including France. Significantly, fixed networks in the United States were resilient to the traffic surges; there were no statistically-significant changes in download speeds. Mobile networks in the United States, alternately, were found to have a statistically-significant increase in download speeds.

I. Background

Deadly to both people and economies, the COVID-19 pandemic has wreaked havoc across the globe.[1] With much of the world forced to shelter-in-place, Internet use skyrocketed as

[1] *See*, *e.g.*, R. Berman, *The Economic Devastation is Going to be Worse than You Think*, THE ATLANTIC (March 21, 2020) (available at: https://www.theatlantic.com/politics/archive/2020/03/covid-19s-devastating-effects-jobs-and-businesses/608461); N. Paumgarten, The Price of the Coronavirus Epidemic, The New Yorker (April 20, 2020) (available at: https://www.newyorker.com/magazine/2020/04/20/the-price-of-the-coronavirus-pandemic).

people turned to the Internet for work and entertainment.[2] The sharp and unexpected increase in traffic has stressed some Internet networks, causing shutdowns and slower download speeds. In the United States, for instance, traffic is up about 40%, while in Italy, an early hotbed of the virus, traffic has more than doubled.[3]

In this BULLETIN, I use data from Ookla, a popular Internet speed test tool, to quantify the effect of COVID-19 on download speeds for fixed and mobile connections. Changes in average download are calculated for the periods before-and-after the initiation of shelter-in-place policies, most of which were implemented in March-2020.[4] Peer group analysis, where countries are grouped by average speeds, is also performed. Statistically significant changes in speeds are found for many countries in the sample, though not all are reductions in speed. Speed reductions are found more frequently in lower-income countries and countries with slower average download speeds, but I demonstrate that speed and income are highly correlated. Significantly, fixed networks in the United States were resilient to the traffic surges; there were no statistically-significant changes in download speeds. Mobile networks in the United States, alternately, were found to have a statistically-significant increase in download speeds.

II. Data

Weekly data on average download speeds for fixed and mobile connections covering 116 countries for the weeks beginning December 16, 2019 through May 11, 2020 are obtained from Ookla.[5] Data on per-capita Gross Domestic Product ("GDP", constant US$) for each country are obtained from the World Bank Development Indicators database.[6] Syria is dropped from the

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[2] D. Holtz-Eakin, *Who Needs Net Neutrality? Internet Providers are Handling Coronavirus Demand Just Fine*, USA TODAY (May 11, 2020) (available at: https://www.usatoday.com/story/opinion/2020/05/11/coronavirus-streaming-demand-light-regulation-works-column/3105366001); R. Bennett, *The Internet Works Fine for Those Who Have It*, HighTech Forum (May 11, 2020) (available at: https://hightechforum.org/the-internet-works-fine-for-those-who-have-it); S. Flemming, *Will the Coronavirus Break the Internet*, World Economic Forum (March 23, 2020) (available at: https://www.weforum.org/agenda/2020/03/will-coronavirus-break-the-internet); M. Beech, *COVID-19 Pushes Up Internet Use 70% and Streaming More than 12%, First Figures Reveal*, FORBES (March 25, 2020) (available at: https://www.forbes.com/sites/markbeech/2020/03/25/covid-19-pushes-up-internet-use-70-streaming-more-than-12-first-figures-reveal/#5e56e97c3104); E. Koeze and N. Popper, *The Virus Changed the Way We Internet,* NEW YORK TIMES (April 7, 2020) (available at: https://nyti.ms/2XePBWp).

[3] *See*, *e.g.*, A. Bergman and J. Iyengar, *How COVID-19 is Affecting Internet Performance*, FASTLY.COM (April 8, 2020) (available at: https://www.fastly.com/blog/how-covid-19-is-affecting-internet-performance).

[4] https://en.wikipedia.org/wiki/COVID-19_pandemic_lockdowns.

[5] Data is obtained from: https://ookla.d.pr/FtITnM.

[6] Data is obtained from: http://wdi.worldbank.org/tables.

sample due to a lack of recent GDP data. I also exclude China and its territories from the sample because these economies initiated shut down protocols well before March-2020 (leaving few observations prior to shelter-in-place policies), though the effects on their networks are apparent in the data. In all, analysis is performed on 108 countries with 20 weekly observations each.

III. Statistical Analysis

Ookla's speed data is obtained from voluntary speed tests. It is a convenience sample, so there may be sampling bias in the data. Also, bias may derive from the dramatic increase in the number of speed tests occurring (in many countries) in March-2020. Also, the type of user and, for mobile services, the typical location of users, may have changed, perhaps dramatically, in response to shelter-in-place orders. Such bias is unavoidable and a caveat to this analysis.

As the data is a sample of users, the average weekly speed data have sampling variation. Statistical testing is required to determine whether the observed changes in average download speeds before-and-after the COVID shelter-in-place policies are out of the ordinary or else consistent with random variation in the data. The statistical procedure is a means-difference test implemented for each country by Least-Squares regression:

$$y_t = \beta + \Delta POST + \varepsilon_t , \tag{1}$$

where y_t is the speed (either fixed or mobile) in period t, *POST* is a dummy variable equal to 1.0 after shelter-in-place policies were implemented, and ε_t is the econometric disturbance term. The estimated coefficient β measure the average speed in the pre-COVID period and Δ measures the change in average speed during the COVID period. Thus, the average speed during the COVID period is $\beta + \Delta$. A t-statistic on Δ is a direct test of the null hypothesis that speeds did not change (that is, $\Delta = 0$). Ideally, the magnitude of traffic changes on speeds could be evaluated, but I do not have data on traffic changes for individual countries. I leave that analysis to future research.

Equation (1) requires that the *POST* variable be defined. Most countries implemented shelter-in-place policies in March-2020. Thus, I define the pre-COVID period as all weeks in the sample through February-2020. The COVID period is then defined as all weeks in April-2020, thereby excluding March-2020 from the sample as a transition period. Since the number of observations for each country is 16 weeks for country-specific analysis, I use the t-statistic for hypothesis tests.

Figure 1. Fixed Speed Changes by Income

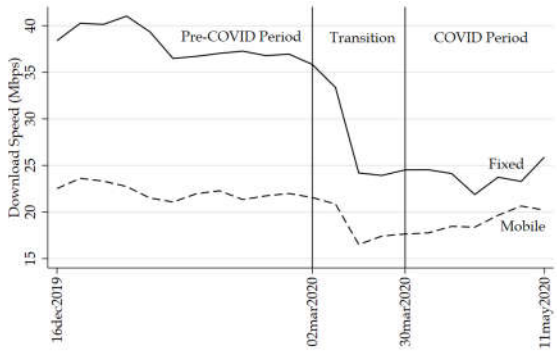


Figure 1 illustrates the weekly data for Peru, with vertical lines bounding the month of March. The speed changes in Peru for fixed services are particularly pronounced, though there is also a material decline in speed for mobile services. The shift in speed occurs during the transition window (as is the case for nearly all counties), which is excluded from the estimation sample. Equation (1) compares means in the Pre-COVID period and the COVID period. By excluding the transition period (March-2020), the analysis may miss sharp but temporary declines during the transition window. As such, the effects quantified by Equation (1) are sustained through the week beginning May 11, 2020.

In a separate analysis, I include the March-2020 data and estimate the following regression,

$$y_t = \beta + \sum_{t=12}^{20} \lambda_t^{POST} + \varepsilon_t, \tag{2}$$

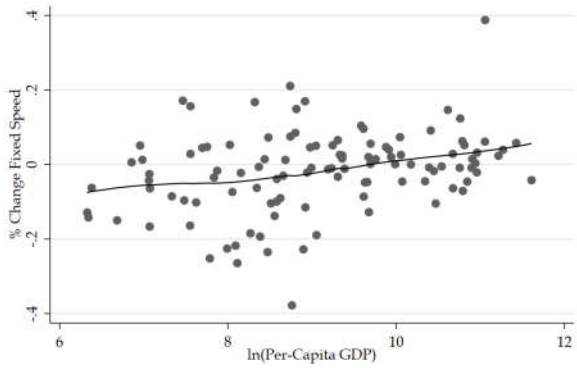
where λ_t are weekly fixed effects for all weeks after February-2020. There are 11 weeks before March-2020 and 11 weeks after February-2020. The λ_t coefficients are the means differences for each weak relative to the pre-COVID period, and the pattern in these coefficients (and their significance levels) can be used to look for statistically significant means differences during the transition month March and then through the remainder of the sample period.

A. *Results for Fixed Broadband*

Table A-1 in the Appendix summarizes the results for Equation (1) estimated individually for each country. For fixed connections, 54 of 108 countries experienced a speed reduction, and 33 of these changes are statistically different from zero at the 10% level or better. The average speed reduction is 9.2% while the average speed increase is 6.6%, so there is an asymmetry in the responses. Despite the claim that the Coronavirus "is breaking the Internet," fixed download speeds in the United States were stable with no statistically-significant changes in

speed.[7] Reductions in speed of more than 5% are found for 32 countries including, in order of size, Peru, Morocco, Nigeria, Algeria, Libya, Philippines, Jordan, Tunisia, Venezuela, Sri Lanka, Pakistan, Sudan, Nepal, Afghanistan, Ecuador, Ethiopia, Oman, Lebanon, Dominican Republic, Italy, Albania, India, North Macedonia, Ghana, Iraq, Turkey, Myanmar, Guatemala, Japan, Kenya, France, Indonesia, and Mozambique. Of these countries, the reduction in speed is not statistically different from zero for either Ethiopia or Mozambique. Statistically significant speed reductions of an amount less than 5% are observed for Bangladesh, Canada, Croatia, Luxembourg, Portugal, Singapore and Trinidad and Tobago. Statistically significant *increases* in fixed broadband speeds are found for Austria, Belarus, Brazil, Chile, the Czech Republic, Denmark, Estonia, Finland, Germany, Jamaica, Kuwait, Lao PDR, Mexico, Mongolia, Norway, Panama, Qatar, the Russian Federation, Serbia, Slovak Republic, South Africa, Sweden, Switzerland, Thailand, Ukraine, the United Arab Emirates, Uruguay, and Vietnam.

Figure 2. Fixed Speed Changes by Income



Most of the countries experiencing large reductions (5% or more) have relatively low per-capita GDP. Among these countries, only France, Italy and Japan have a per-capita GDP exceeding $20,000. Figure 2 provides a scatter plot and a Lowess smoother for the estimated percentage changes in speed (Qatar is the positive outlier and Peru is the negative outlier). A linear fit of the percent change in speed on the natural log of per-capita GDP has a constant term of 0.253 and a slope coefficient of 0.026 (R^2 = 0.098), though the figure reveals substantial variation in the speed change across income.

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[7] *See, e.g.,* S. Meinrath, *The Coronavirus Pandemic is Breaking the Internet*, THE HILL (May 2, 2020) (available at: https://thehill.com/opinion/technology/495806-the-coronavirus-pandemic-is-breaking-the-internet-and-what-to-do-about-it).

Figure 3. Fixed Speed Changes by Speed

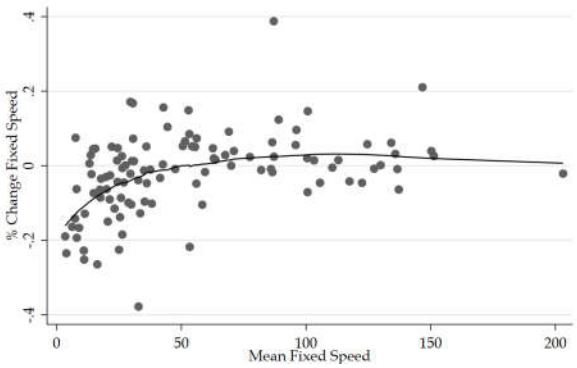
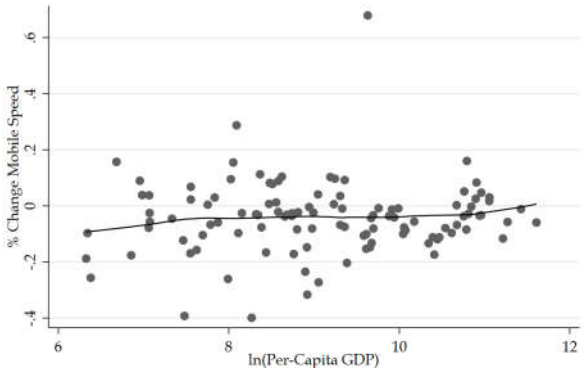


Figure 3 illustrates the relationship between the percent change in fixed speed and mean fixed speed. Larger reductions in speed are observed for countries with slower fixed broadband networks. The Lowess curve flattens at around 50 Mbps. Note that the correlation coefficient between per-capita GDP and mean fixed speed is 0.70, so Figures 2 and 3 offer related descriptions of the data.

B. *Results for Mobile Broadband*

Table A-2 summarizes the estimates of Equation (1) for mobile broadband speeds, of which 77 experienced speed reductions of some size; 66 countries had statistically significant reductions in speed. Mobile networks appear to have suffered more under the weight of increased usage. The average speed reduction is 9.9% while the average speed increase is 8.9%, so the changes are more symmetric than for fixed networks. In the United States, however, download speeds for mobile networks rose by 2.54% (a relatively small but still statistically significant rise in speed). Fifty countries experienced reductions in mobile download speeds more than 5%, and for all but one the change was statistically different from zero (Maldives): Sri Lanka, Ghana, Dominican Republic, Venezuela, the Philippines, Mozambique, Libya, Malaysia, Ethiopia, Tanzania, Kuwait, Peru, Sudan, Georgia, India, Chile, South Africa, Croatia, Cyprus, Oman, Lao PDR, Israel, Ireland, Italy, Spain, Uruguay, Honduras, Turkey, Czech Republic, Afghanistan, Morocco, the United Arab Emirates, Portugal, Finland, Belarus, Maldives, Poland, New Zealand, Bangladesh, Greece, Tunisia, the Russian Federation, Kazakhstan, France, Nigeria, Luxembourg, Moldova, Switzerland, Kenya, and Slovenia. Other countries with statistically significant reductions in speed smaller than 5% include Australia, Austria, Belgium, Hungary, Indonesia, Latvia, Myanmar, Saudi Arabia, Serbia, Singapore, and Thailand.

Figure 4. Mobile Speed Changes by Income



While many of the countries in this list have relatively low per-capita GDP, income is less relevant in this group (see Figure 4). The slope of a linear fit of the change in speed on the natural log of per-capita GDP is not statistically different from zero. Higher income countries experienced a sizable decline in speed include Cyprus, the Czech Republic, Finland, France, Greece, Ireland, Israel, Italy, Kuwait, Luxembourg, New Zealand, Portugal, Slovenia, Spain, Switzerland, and the United Arab Emirates. Countries with statistically-significant increases in speed include Albania, Armenia, Brazil, Bulgaria, Costa Rica, Germany, Guatemala, Iraq, Jamaica, Japan, Jordan, Mexico, Nepal, Netherlands, Panama, Paraguay, Sweden, Trinidad and Tobago (the positive outlier), Ukraine, the United States, and Vietnam, most of which have per-capita GDP of less than $20,000. There is no linear relationship between the change in mobile speed and log per-capita GDP.

Figure 5. Mobile Speed Changes by Speed

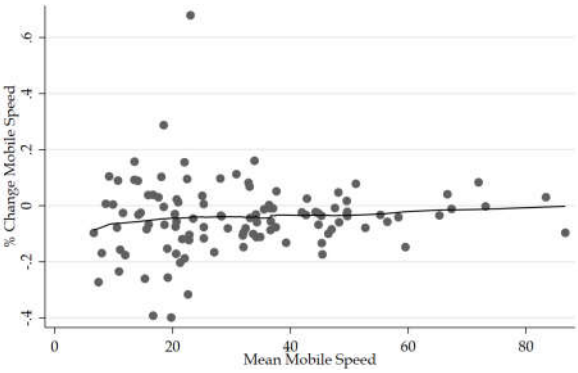


Figure 5 shows that the changes in mobile speed are related to mean network speed, but not as strongly as for income. There is no linear relationship between the two. The variance in the

changes is plainly larger at lower speeds. Between Figures 3 and 5, faster networks appear to be more resilient to sizable traffic increases, though more so for fixed networks.

C. *Weekly Changes*

Equation (2) permits the estimation of weekly-specific differences in speed after February-2020. Results are summarized in Table A-3. For expositional purposes, the results are presented as patterns in the coefficients where "0" indicates no statistically significant change in speed, "-" indicates a statistically-significant reduction in speed, "+" indicates a statistically significance increase in speed, and "/" indicates the transition from March to April. Statistical significance in measured at the 10% level. For instance, fixed networks in Peru have the pattern "0---/-----" indicating statistically-significant reductions in download speeds starting the second week of March-2020 and persisting throughout the sample period, as is illustrated in Figure 1. For the United States, the pattern for fixed download speed is "0000/00000" indicating no statistically significant changes in downloads speeds in any period. As the patterns are unique to each country, I do not discuss these results in detail.

IV. Peer Performance

The analysis above calculates the mean difference for each country individually. Here, I compute the mean difference for each country relative to its peers, where its peers are based on broadband speed. A Finite Mixture Model ("FMM") is used to classify each country into one of two groups based on average download speed.[8] For each country, I then estimate the following regression but include in the sample all countries in its peer group,

$$\ln(y_{i,t}) = \delta D_i \cdot POST + \lambda_t + \mu_i + \varepsilon_{i,t}, \quad (3)$$

where D_i is a dummy variable indicating the country of interest, λ_t is a time fixed effect, and μ_i is a country fixed effect. The coefficient δ measures the difference in the percent change in log speed for country i relative to its peers.

A. *Fixed Network Speed*

The FMM divides the sample into two groups.[9] The "slower" speed group contains 60 countries with an average speed of 23.1 Mbps. The "faster" speed group contains 50 countries

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[8] G. J. McLachlan and D. Peel, FINITE MIXTURE MODELS (2000).

[9] The procedure assigns a probability for group membership, and I divide the sample into groups with a cutoff of 0.50.

with an average speed of 91.7 Mbps. Estimating Equation (1) for each peer group (adding in country fixed effects), the slower-speed group has an average decline in speed of 6.4% while the faster-speed group has an average increase in speed of 2.8%. Both changes are statistically different from zero at better than the 1% level. It appears that lower speed fixed networks (and, by correlation, networks in lower-income countries) are more vulnerable to increases in traffic.

Table A-4 summarizes the changes in fixed speeds for each country relative to its peers. Forty-eight countries have disparate performance among their peers of which 23 are reductions in speed. For fixed broadband, speeds in the United States are consistent with the peer groups (the δ coefficient is not statistically different from zero). Countries with statistically-significant *declines* in relative speeds include Afghanistan, Algeria, Canada, Ecuador, France, Italy, Japan, Jordan, Libya, Luxembourg, Morocco, Nepal, Nigeria, Pakistan, Peru, the Philippines, Portugal, Singapore, Sri Lanka, Sudan, Trinidad and Tobago, Tunisia, and Venezuela. Countries with statistically-significant *increases* in speed relative to their peer group include Belarus, Bosnia and Herzegovina, Chile, Georgia, Germany, Greece, Honduras, Jamaica, Kuwait, the Kyrgyz Republic, Lao PDR, Lebanon, Maldives, Mexico, Mongolia, Nicaragua, Qatar, Serbia, South Africa, Tajikistan, Thailand, the United Arab Emirates, Uruguay, Uzbekistan, and Vietnam.

Figure 6. Relative Fixed Changes by Income

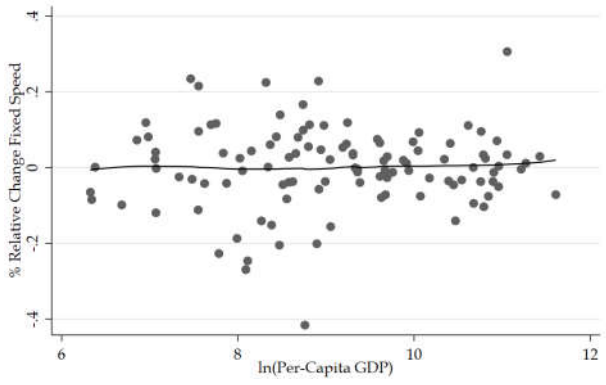

Figure 6 shows the relationship between the changes relative to peer-group and log per-capita GDP. Once the sample is divided into groups, the positive relationship between speed changes is no longer present. Due to the positive correlation of fixed speed and income, dividing the countries into speed-based peer groups appears to fully account for the effect of income. The means of fixed speed and per-capita GDP for the "Slower" and "Faster" peer groups are 23.4 Mbps and $6,604 and 91.7 Mbps and $32,880.

B. *Mobile Network Speed*

For mobile speeds, the FMM divides the sample into a "slower" speed group with 47 countries (average speed 16.6 Mbps) and a "faster" speed with 63 countries (average speed

43.2 Mbps). Estimating Equation (1) for each peer group (adding in country fixed effects), the slower-speed group has an average decline in speed of 6.7% while the high-speed group has an average reduction in speed of 3.8%. Both changes are statistically different from zero at better than the 1% level. While both peer groups saw a reduction in download speeds for mobile networks, the slower speed networks were affected more by the increases in traffic.

Table A-4 summarizes the changes in mobile speeds for each country relative to its peers. Fifty-eight countries are found to have disparate performance among peers. The United States has a positive and statistically significant increase in relative speed among its peers. Countries with statistically-significant *declines* among peers include Chile, Croatia, Cyprus, the Czech Republic, Dominican Republic, Ethiopia, Finland, Georgia, Ghana, India, Ireland, Italy, Kuwait, Libya, Malaysia, Morocco, Mozambique, Oman, Peru, Philippines, Poland, Portugal, South Africa, Spain, Sri Lanka, Sudan, Tanzania, Turkey, the United Arab Emirates, Uruguay, and Venezuela. Countries with statistically-significant *increases* in relative speed among peers include Albania, Armenia, Bolivia, Brazil, Bulgaria, Cambodia, Costa Rica, Denmark, Germany, Guatemala, Iraq, Jamaica, Japan, Jordan, Kyrgyz Republic, Mexico, Nepal, Netherlands, Panama, Paraguay, Qatar, Sweden, Tajikistan, Trinidad and Tobago, Ukraine, the United States, and Vietnam. The pattern of speed changes and per-capita GDP is almost identical Figure 6, so I do not reproduce that figure here.

V. Conclusion

Using Ookla download speed data, I provide estimates of the effect of rising Internet use following the COVID pandemic on fixed and mobile download speeds for a large sample of countries. Download speeds for fixed and mobile networks have fallen by a statistically-significant amount for about half the countries in the sample (109 total). In several countries, speeds have increased. Slower networks appear to suffer the most under the burden of increased traffic, and, saying almost the same thing, countries with relatively low per-capita GDP are more likely to see their network speeds decline. For the U.S., fixed networks proved resilient to traffic surges as there were no statistically-significant changes in download speeds during the COVID period. Download speeds for U.S. mobile networks have increased (by a statistically-significant amount) since March-2020.

Table A-1. Changes in Fixed Broadband Speeds

Country	Pre	Post	Diff	Country	Pre	Post	Diff
Afghanistan	7.8	6.7	-14.19%**	Libya	11.9	9.2	-22.77%***
Albania	31.3	28.0	-10.41%***	Lithuania	101.9	103.4	1.44%
Algeria	4.2	3.2	-23.5%***	Luxembourg	118.2	113.2	-4.2%**
Argentina	37.3	36.9	-1.02%	Malaysia	82.3	81.3	-1.15%
Armenia	26.2	26.0	-0.64%	Maldives	15.0	15.7	4.6%
Australia	42.2	42.4	0.33%	Mexico	35.0	36.8	5.16%**
Austria	53.3	56.1	5.21%**	Moldova	58.3	57.4	-1.68%
Azerbaijan	20.1	19.5	-3.02%	Mongolia	28.9	33.7	16.76%***
Bahrain	27.6	27.7	0.08%	Montenegro	48.1	47.7	-0.89%
Bangladesh	24.5	23.5	-4.3%***	Morocco	17.9	13.2	-26.47%***
Belarus	50.9	55.2	8.5%***	Mozambique	8.2	7.7	-6.26%
Belgium	86.0	85.3	-0.88%	Myanmar	17.8	16.3	-8.54%***
Bolivia	17.6	17.0	-3.49%	Nepal	21.3	18.1	-14.99%***
Bosnia and Herzegovina	30.8	31.2	1.23%	Netherlands	111.8	113.5	1.5%
Brazil	50.0	53.2	6.55%***	New Zealand	110.0	109.4	-0.5%
Bulgaria	54.9	57.6	5.03%	Nicaragua	13.4	13.8	2.85%
Cambodia	21.6	21.0	-2.56%	Nigeria	12.0	9.0	-25.2%***
Canada	124.0	118.3	-4.59%***	North Macedonia	29.6	26.7	-9.93%***
Chile	93.3	102.2	9.6%***	Norway	121.7	128.8	5.78%***
Colombia	29.6	29.0	-2.14%	Oman	36.4	31.7	-12.79%***
Costa Rica	35.3	34.8	-1.28%	Pakistan	9.5	7.9	-16.66%***
Croatia	36.6	34.8	-4.7%**	Panama	86.9	89.0	2.42%**
Cyprus	27.2	25.9	-4.49%	Paraguay	33.2	31.9	-3.87%
Czech Republic	54.6	58.6	7.34%***	Peru	38.2	23.8	-37.8%***
Denmark	130.9	138.9	6.14%**	Philippines	27.1	21.0	-22.55%***
Dominican Republic	24.0	21.2	-11.5%***	Poland	93.4	98.6	5.56%
Ecuador	26.9	23.2	-13.8%***	Portugal	105.5	100.7	-4.58%**
El Salvador	14.0	13.7	-2.26%	Qatar	76.4	106.0	38.77%***
Estonia	61.3	64.2	4.69%**	Romania	149.2	153.1	2.59%
Ethiopia	11.7	10.2	-12.88%	Russian Federation	63.1	64.1	1.59%**
Finland	84.3	89.6	6.28%***	Saudi Arabia	62.6	63.8	2.0%
France	138.7	129.9	-6.38%***	Serbia	49.5	56.9	14.87%***
Georgia	23.8	24.2	1.42%	Singapore	204.9	200.5	-2.12%*
Germany	83.4	93.6	12.35%**	Slovak Republic	69.5	72.3	3.95%*
Ghana	37.3	33.7	-9.63%*	Slovenia	69.6	69.7	.01%
Greece	26.1	26.8	2.57%	South Africa	28.5	33.4	16.97%***
Guatemala	15.1	14.0	-7.36%**	Spain	127.1	126.1	-0.8%
Honduras	14.3	14.9	4.47%	Sri Lanka	28.2	23.0	-18.48%***
Hungary	129.9	130.0	0.15%	Sudan	6.7	5.6	-16.4%**
India	39.8	35.7	-10.18%***	Sweden	134.5	138.7	3.17%**
Indonesia	20.4	19.1	-6.28%***	Switzerland	148.0	153.8	3.95%**
Iraq	22.5	20.5	-9.04%*	Tajikistan	21.5	22.6	5.1%
Ireland	76.6	78.4	2.34%	Tanzania	13.2	13.3	0.59%
Israel	87.4	85.9	-1.73%	Thailand	135.9	164.5	21.05%***
Italy	60.9	54.5	-10.47%***	Trinidad and Tobago	56.5	53.8	-4.8%***
Jamaica	29.6	31.8	7.25%**	Tunisia	8.8	7.1	-19.34%***
Japan	102.9	95.6	-7.09%***	Turkey	26.8	24.5	-8.62%**
Jordan	57.8	45.2	-21.78%***	Ukraine	49.5	52.1	5.27%***
Kazakhstan	41.9	40.5	-3.28%	UAE	95.5	109.5	14.64%***
Kenya	17.8	16.6	-6.42%**	United Kingdom	66.8	68.7	2.86%
Kuwait	69.0	75.4	9.13%**	United States	136.9	135.7	-0.9%
Kyrgyz Republic	30.3	30.7	1.27%	Uruguay	42.4	46.9	10.41%***
Lao PDR	27.4	32.1	17.13%**	Uzbekistan	23.8	24.9	4.74%
Latvia	99.8	101.9	2.01%	Venezuela	3.7	3.0	-18.96%***
Lebanon	7.7	8.2	7.51%	Vietnam	41.0	47.5	15.64%***

Statistical Significance: *** 1% ** 5% * 10%.

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Table A-2. Changes in Mobile Broadband Speeds

Country	Pre	Post	Diff	Country	Pre	Post	Diff
Afghanistan	6.9	6.2	-9.71%**	Libya	11.9	9.1	-23.49%***
Albania	49.9	53.8	7.82%***	Lithuania	48.0	47.7	-0.83%
Algeria	8.8	8.9	0.67%	Luxembourg	49.8	46.8	-5.93%**
Argentina	25.4	25.5	0.59%	Malaysia	23.2	18.5	-20.37%***
Armenia	30.1	33.5	11.24%***	Maldives	29.9	27.5	-8.09%*
Australia	65.8	63.5	-3.47%*	Mexico	27.6	30.3	9.7%***
Austria	50.6	49.1	-2.84%**	Moldova	34.9	32.8	-5.91%*
Azerbaijan	28.9	27.8	-3.78%	Mongolia	20.7	20.1	-3.01%
Bahrain	36.6	36.3	-0.89%	Montenegro	42.1	41.1	-2.38%
Bangladesh	11.0	10.1	-7.83%**	Morocco	33.7	30.4	-9.69%***
Belarus	16.2	14.9	-8.4%***	Mozambique	21.2	15.7	-25.65%***
Belgium	50.6	48.7	-3.71%***	Myanmar	23.8	22.7	-4.6%
Bolivia	17.7	18.2	2.98%*	Nepal	12.6	14.6	15.71%***
Bosnia and Herzegovina	34.6	33.5	-3.12%*	Netherlands	70.0	75.8	8.33%***
Brazil	24.9	25.8	3.52%***	New Zealand	53.3	49.1	-7.91%***
Bulgaria	66.0	68.7	4.08%***	Nicaragua	20.6	21.1	2.26%
Cambodia	15.8	16.4	3.78%	Nigeria	16.3	15.2	-6.69%**
Canada	73.2	73.0	-0.26%	North Macedonia	50.1	49.0	-2.17%
Chile	20.4	17.3	-15.31%***	Norway	67.0	66.2	-1.16%
Colombia	18.7	18.7	-0.43%	Oman	41.4	35.9	-13.21%***
Costa Rica	18.3	20.2	10.28%*	Pakistan	15.0	14.6	-2.54%
Croatia	63.0	53.7	-14.77%***	Panama	13.4	14.7	9.2%**
Cyprus	48.2	41.7	-13.36%***	Paraguay	14.0	15.3	8.89%*
Czech Republic	48.2	43.4	-10.01%***	Peru	22.2	18.4	-17.17%***
Denmark	49.5	50.4	1.72%	Philippines	16.7	12.4	-26.04%***
Dominican Republic	25.7	17.5	-31.67%***	Poland	33.8	31.0	-8.05%***
Ecuador	21.1	21.4	1.23%	Portugal	37.9	34.6	-8.71%***
El Salvador	11.8	11.5	-2.61%	Qatar	83.3	85.8	3.02%
Estonia	46.2	44.5	-3.61%	Romania	37.4	37.0	-0.97%
Ethiopia	23.2	18.9	-18.79%***	Russian Federation	20.9	19.4	-7.49%***
Finland	48.6	44.5	-8.43%***	Saudi Arabia	59.7	57.2	-4.14%
France	46.2	43.1	-6.79%***	Serbia	44.7	43.7	-2.26%*
Georgia	28.6	23.9	-16.61%***	Singapore	55.9	54.1	-3.31%*
Germany	37.0	38.9	5.14%***	Slovak Republic	35.5	35.0	-1.29%
Ghana	19.2	11.7	-39.24%***	Slovenia	38.0	35.9	-5.6%***
Greece	38.9	35.9	-7.7%***	South Africa	33.5	28.5	-14.78%***
Guatemala	21.3	24.5	15.48%***	Spain	36.6	32.5	-11.16%***
Honduras	24.0	21.5	-10.43%***	Sri Lanka	22.6	13.6	-39.91%***
Hungary	43.2	41.8	-3.34%**	Sudan	8.6	7.2	-16.92%***
India	11.8	10.0	-15.72%***	Sweden	47.7	49.9	4.72%*
Indonesia	14.4	13.9	-3.24%	Switzerland	58.4	55.0	-5.74%***
Iraq	9.5	10.4	10.43%*	Tajikistan	10.3	11.2	8.96%
Ireland	26.7	23.6	-11.64%***	Tanzania	13.2	10.9	-17.63%***
Israel	23.0	20.3	-11.91%***	Thailand	28.4	27.4	-3.56%**
Italy	36.4	32.3	-11.2%***	Trinidad and Tobago	19.8	33.2	67.91%***
Jamaica	32.2	34.9	8.18%***	Tunisia	26.6	24.6	-7.64%
Japan	32.1	37.3	16.02%***	Turkey	35.1	31.6	-10.08%***
Jordan	17.4	22.4	28.73%***	Ukraine	22.0	24.1	9.51%***
Kazakhstan	19.2	17.9	-6.8%**	UAE	89.3	80.7	-9.65%***
Kenya	20.9	19.7	-5.68%**	United Kingdom	36.4	36.4	.25%
Kuwait	50.1	41.4	-17.38%***	United States	42.5	43.6	2.54%*
Kyrgyz Republic	16.5	17.1	3.87%	Uruguay	33.4	29.8	-10.62%***
Lao PDR	23.6	20.7	-12.29%***	Uzbekistan	9.8	9.9	0.42%
Latvia	34.2	32.7	-4.36%**	Venezuela	8.4	6.1	-27.26%
Lebanon	46.0	44.7	-2.66%	Vietnam	32.3	34.4	6.8%**

Statistical Significance: *** 1% ** 5% * 10%.

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Table A-3. Patterns in Means Differences

Country	Fixed	Mobile	Country	Fixed	Mobile
Afghanistan	0000/0000-	0000/00000	Libya	-0--/-----	00--/----0
Albania	0---/-----	0000/00+++	Lithuania	0000/00000	+0--/-0-++
Algeria	000-/-----	00--/--0++	Luxembourg	+000/000-0	0000/00000
Argentina	0000/00000	000-/00000	Malaysia	0000/00000	00--/-----
Armenia	0+00/00000	0000/0++0+	Maldives	0000/0+000	0000/00000
Australia	0000/00000	0+0-/--000	Mexico	++00/00000	0000/+++++
Austria	0000/0000+	+---/--00-	Moldova	++00/00000	++0-/---00
Azerbaijan	0000/00000	0000/00000	Mongolia	00++/+++++	0000/00000
Bahrain	0000/00000	000-/00000	Montenegro	000-/00000	00+0/-0000
Bangladesh	0000/00-0-	00--/----0	Morocco	00--/-----	00--/----0
Belarus	0+++/++000	00--/-0-00	Mozambique	0000/-0000	00--/-----
Belgium	0000/000-0	00-0/00-0-	Myanmar	000-/0--00	0000/---00
Bolivia	0000/00000	--0+/00000	Nepal	000-/-----	++++/+++++
Bosnia and Herzegovina	0000/00000	000-/00000	Netherlands	0+00/00000	00++/+++++
Brazil	++00/000++	000-/00+++	New Zealand	0000/00000	0+0-/0--00
Bulgaria	0000/000++	0000/000++	Nicaragua	++00/00000	0000/00000
Cambodia	0000/00000	+0--/00000	Nigeria	00--/-----	0000/00000
Canada	000-/---00	0000/00000	North Macedonia	000-/----0	00--/00000
Chile	++00/+++++	00--/-----	Norway	0+++/++0++	++00/00000
Colombia	0000/00000	00--/-00+0	Oman	----/---00	00--/-----
Costa Rica	+0--/-0000	0---/000++	Pakistan	00--/-----	-0--/---++
Croatia	0000/-0-00	00--/-----	Panama	00--/0++00	000-/00+++
Cyprus	0000/00000	00--/-0--0	Paraguay	0000/000-0	00-0/000++
Czech Republic	0000/0000+	000-/----0	Peru	0---/-----	00--/-----
Denmark	0000/00000	00-0/0-++0	Philippines	0000/--000	00--/-----
Dominican Republic	0000/-----	00--/-----	Poland	0000/00000	0---/---00
Ecuador	00-0/-----	0-0-/000+0	Portugal	++00/00-00	00--/---00
El Salvador	0000/00000	0000/00000	Qatar	0+++/+++++	0000/0000+
Estonia	0000/000+0	00-0/00000	Romania	0000/00000	000-/00000
Ethiopia	0000/00000	0000/00000	Russian Federation	0+++/+000+	000-/-----
Finland	++0+/+00++	00--/---00	Saudi Arabia	0000/0000+	00--/---00
France	0000/00-00	00--/-----	Serbia	++++/+++++	000-/--000
Georgia	0++0/00000	000-/----0	Singapore	00--/--000	0000/00000
Germany	++00/00000	0000/0+++0	Slovak Republic	0+00/0000+	++-0/00000
Ghana	0000/00000	0000/---00	Slovenia	0+00/00000	0---/-00-0
Greece	0000/0000+	00--/---00	South Africa	0000/0++++	000-/-----
Guatemala	0000/00000	+00-/+++++	Spain	0000/00000	00--/----0
Honduras	0000/00000	0---/--00-	Sri Lanka	00--/-----	00--/-----
Hungary	0000/00000	000-/00000	Sudan	0000/-0000	00--/---00
India	00--/-----	00--/-----	Sweden	0000/+000+	0000/000+0
Indonesia	000-/-000-	000-/--000	Switzerland	+000/0000+	00--/-0000
Iraq	---0/---0+	---0/000++	Tajikistan	0000/00000	0000/00000
Ireland	0000/0000+	00--/---0-	Tanzania	0000/00000	----/-0-00
Israel	00-0/00000	0---/----0	Thailand	++++/+++++	0000/00000
Italy	0---/-----	0---/-----	Trinidad and Tobago	0000/0--00	0000/+++++
Jamaica	000+/00000	00-0/000+0	Tunisia	0---/-----	-0--/---00
Japan	0000/00---	0+++/+++++	Turkey	000-/-0000	00--/----0
Jordan	0000/00000	00-0/+++++	Ukraine	0000/++00+	0000/00+++
Kazakhstan	0000/00-00	000-/---00	UAE	0+++/+++++	000-/---00
Kenya	0+--/---0-	0000/00000	United Kingdom	0000/0000+	0000/0000-
Kuwait	0-00/00000	----/-----	United States	0000/00000	++0-/000++
Kyrgyz Republic	000-/00000	0000/00000	Uruguay	0000/000+0	0---/-0-00
Lao PDR	0+00/+0000	0000/-----	Uzbekistan	0000/00000	0000/0000+
Latvia	0000/00000	0---/-0-00	Venezuela	00--/----0	0---/-----
Lebanon	0---/---0+	0---/-0000	Vietnam	0000/+++++	0000/+0000

Note: 0 No Stat. Sig. Change; - Stat. Sig. Reduction; + Stat. Sig. Increase; / March-April transition.

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Table A-4. Peer Comparison, Fixed & Mobile Broadband

Country	Fixed	Mobile	Country	Fixed	Mobile
Afghanistan [S, S]	-8.1%*	-3.06%	Libya [S, S]	-18.22%***	-18.81%***
Albania [S, F]	-4.4%	12.25%***	Lithuania [F, F]	-1.23%	2.97%
Algeria [S, S]	-18.51%***	6.94%	Luxembourg [F, F]	-6.89%**	-2.11%
Argentina [S, F]	6.47%	4.63%	Malaysia [F, S]	-3.87%	-14.89%***
Armenia [S, F]	6.24%	15.8%***	Maldives [S, F]	11.78%**	-3.97%
Australia [S, F]	7.32%	0.29%	Mexico [S, F]	12.61%**	14.29%***
Austria [F, F]	2.46%	0.96%	Moldova [F, F]	-4.05%	-2.44%
Azerbaijan [S,F]	3.8%	0.19%	Mongolia [S, S]	25.22%***	4.39%
Bahrain [S, F]	7.05%	3.06%	Montenegro [F, F]	-3.6%	1.34%
Bangladesh [S, S]	2.26%	-1.46%	Morocco [S, F]	-21.82%***	-6.35%**
Belarus [F, S]	5.7%*	-1.83%	Mozambique [S, S]	0.12%	-20.8%***
Belgium [F, F]	-3.63%	0.07%	Myanmar [S, S]	-2.43%	2.18%
Bolivia [S, S]	3.9%	10.63%*	Nepal [S, S]	-9.37%**	24.57%***
Bosnia and Herzegovina [S, F]	8.32%*	0.72%	NetherlandS [F, F]	-1.25%	12.81%***
Brazil [F, F]	3.81%	7.7%***	New Zealand [F, F]	-3.22%	-4.37%
Bulgaria [F, F]	2.14%	8.28%***	Nicaragua [S, S]	10.04%**	9.9%
Cambodia [S, S]	4.17%	11.54%*	Nigeria [S, S]	-20.3%***	0.14%
Canada [F, F]	-7.29%***	3.74%	North Macedonia [S, F]	-3.79%	1.72%
Chile [F, S]	6.75%**	-9.48%*	Norway [F, F]	3.00%	2.81%
Colombia [S, S]	4.83%	6.78%	Oman [S, F]	-6.9%	-9.95%***
Costa Rica [S, S]	5.47%	18.65%***	Pakistan [S, S]	-11.24%**	4.11%
Croatia [S, F]	1.82%	-11.7%***	Panama [F, S]	-0.38%	17.2%***
Cyprus [S, F]	2.24%	-10.07%***	Paraguay [S, S]	2.75%	16.86%***
Czech Republic [F, F]	4.57%	-6.49%**	Peru [S, S]	-34.03%***	-11.5%**
Denmark [F, F]	3.47%	5.68%*	Philippines [S, S]	-17.05%***	-21.2%***
Dominican Republic [S, S]	-5.55%	-27.23%***	Poland [F, F]	2.95%	-4.6%*
Ecuador [S, S]	-7.93%*	8.61%	Portugal [F, F]	-7.26%***	-5.22%*
El Salvador [S, S]	4.48%	4.12%	Qatar [F, F]	35.86%***	7.14%**
Estonia [F, F]	1.96%	0.16%	Romania [F, F]	-0.06%	2.98%
Ethiopia [S, S]	-6.3%	-12.24%**	Russian Federation [F, S]	-1.17%	-0.95%
Finland [F, F]	3.45%	-4.95%*	Saudi Arabia [F, F]	-0.77%	-0.55%
France [F, F]	-9.01%***	-3.19%	Serbia [F, F]	11.98%***	1.59%
Georgia [S, F]	8.48%*	-13.59%***	Singapore [F, F]	-4.89%*	0.49%
Germany [F, F]	10.%***	9.42%***	Slovak Republic [F, F]	1.16%	2.61%
Ghana [S, S]	-3.02%	-35.43%***	Slovenia [F, F]	-2.71%	-1.94%
Greece [S, F]	9.71%**	-4.17%	South Africa [S, F]	25.66%***	-11.6%***
Guatemala [S, S]	-0.84%	24.17%***	Spain [F, F]	-3.47%	-7.77%***
Honduras [S, S]	11.99%**	-4.13%	Sri Lanka [S, S]	-13.13%***	-36.26%***
Hungary [F, F]	-2.6%	0.5%	Sudan [S, S]	-10.58%**	-11.13%**
India [S, S]	-4.11%	-10.03%*	Sweden [F, F]	0.41%	8.99%***
Indonesia [S, S]	0.15%	3.73%	Switzerland [F, F]	1.18%	-2.08%
Iraq [S, S]	-3.63%	18.75%***	Tajikistan [S, S]	12.61%**	17.45%***
Ireland [F, F]	-0.41%	-8.41%***	Tanzania [S, S]	7.53%	-11.63%**
Israel [F, S]	-4.47%	-5.75%	Thailand [F, F]	18.11%***	0.27%
Italy [F, F]	-13.1%***	-7.87%***	Trinidad and Tobago [F, S]	-7.61%***	82.13%***
Jamaica [S, F]	14.95%***	12.76%***	Tunisia [S, F]	-14.08%***	-4.49%
Japan [F, F]	-9.82%***	20.94%***	Turkey [S, F]	-2.29%	-6.64%**
Jordan [F, S]	-23.61%***	38.3%***	Ukraine [F, S]	2.5%	17.86%***
Kazakhstan [S, S]	3.37%	-0.2%	UAE [F, F]	11.77%***	-6.32%**
Kenya [S, S]	-0.21%	1.23%	United Kingdom [F, F]	0.04%	4.23%
Kuwait [F, F]	6.61%**	-14.67%***	United States [F, F]	-3.62%	6.64%**
Kyrgyz Republic [S, S]	8.46%*	11.71%*	Uruguay [F, F]	7.78%***	-7.2%***
Lao PDR [S, S]	26.43%***	-6.11%	Uzbekistan [S, S]	12.37%**	7.5%
Latvia [F, F]	-0.74%	-0.65%	Venezuela [S, S]	-14.43%***	-22.46%***
Lebanon [S, F]	10.41%**	1.14%	Vietnam [S, F]	24.02%***	11.29%***

Statistical Significance: *** 1% ** 5% * 10%.

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