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## The Economic Impact of Mobile Broadband Speed

By

### Harald Edquist\*

#### PREPARED FOR THE INTERNATIONAL TELECOMMUNICATION SOCIETY BIENNIAL CONFERENCE, 21–23 JUNE 2021, GOTHENBURG, SWEDEN

#### Abstract

Based on panel data of 116 countries in 2014–2019, this paper investigates the association between mobile broadband speed and labor productivity. It finds no robust contemporaneous relationship, but there is a significant and robust effect when a one-year lag of mobile broadband speed is introduced (significant at 3.7 and 0.9 percent levels for fixed and random effects estimation, respectively). The interpretation of the results is that a 10 percent increase in mobile broadband speed in period t-1 is associated with 0.2 percent increase in labor productivity, cetris paribus.

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### 1. Introduction

"Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker" (Paul Krugman 1994)

Productivity is a measure of how efficiently resources are used to produce goods and services. By producing in a more efficient way, it is possible to use the resources that are released in other production processes or increase the volume produced in existing processes. Thus, productivity growth is crucial for a country's welfare and standard of living. Moreover, increased productivity will release resources that make it possible to improve other important indicators such as health, pollution, security and education.

Innovations based on new technology are important for productivity development (Schumpeter 1939; Bresnahan and Trajtenberg 1995). Since the beginning of the 21th century mobile broadband has diffused at a tremendous rate on a global scale. In 2020, mobile broadband subscriptions reached 6.4 billion (Ericsson 2020). This has created great opportunities for economic development through faster distribution of information and increased competition among firms. Moreover, many low-income countries have been leapfrogging by investing in mobile broadband.

There are a number of studies showing that mobile phones and broadband have been important for economic and productivity growth (see Bertschek 2015 *et al.*; Vu *et al.* 2020). However, there is limited knowledge about the economic impact from speed in the mobile networks. With the launch and roll out of 5G in many countries the speed in the mobile networks will increase considerably. Therefore, it is important to understand if mobile broadband speed is linked to productivity.

Based on a panel of 116 countries, this paper finds no robust contemporaneous association between mobile broadband speed and labor productivity. However, there is a significant and robust association when a one-year lag of mobile broadband speed is introduced. The results suggest that one-year lag of download speed is significantly associated with labor productivity at 3.7 and 0.9 percent levels based on fixed and random effects estimations, respectively. The interpretation of the results is that a 10 percent increase in mobile broadband speed in period t-1 is associated with 0.2 percent increase in labor productivity, cetris paribus.

#### 2. Previous Research

Many different studies that have investigated the economic impact from communication equipment. Excellent overviews are provided by Bertschek *et al.* (2015) and Vu *et al.* (2020). Hardy (1980) found that already in the 1980s telephones were contributing to economic development. Moreover, Röller and Waverman (2001) established a causal link between telecommunications and aggregate output in 21 OECD countries throughout 1970–90.

Several studies have found positive impact from fixed and mobile broadband on economic development. Qiang and Rossotto (2009) found an association between fixed broadband penetration and growth in GDP per capita in both developed and developing countries. Czernich *et al.* (2011) estimated that a 10 percentage points increase in fixed broadband penetration raised annual GDP per capita growth by 0.9–1.5 percentage points.

Waverman *et al.* (2005) showed that mobile telephony had a positive and significant impact on growth in developing countries. Gruber and Koutroumpis (2011) found that investment in mobile telecommunication infrastructure had a considerable contribution to economic and productivity growth. Moreover, Thomson and Garbacz (2011) found significant impact from mobile broadband on GDP per household based on 43 different countries in 2005–2009. These results were further supported by Edquist *et al.* (2018) who estimated, based on a two stage model, that on average a 10 percent increase in mobile broadband adoption caused a 0.8 increase in GDP in 2002–2014.

Even though there is a vast literature on the economic effects from fixed as well as mobile broadband there is much less written about the impact of speed in the broadband networks. It might seem obvious that many of the advanced services offered on the Internet require high broadband speed. According to Ahlfeldt *et al.* (2017) videostreaming, e-commerce and telecommuting are just a few of the possibilities that come with a faster Internet. Rohman and Bohlin (2012) investigated the economic impact from broadband speed in fixed networks in 34 OECD countries in 2008–2010. They found that the coefficient of fixed broadband speed was statistically significant. The results implied that the doubling of fixed broadband speed contributed to 0.3% economic growth compared to growth rate in the base year. These results were further supported by Kongaut and Bohlin (2014) who found supporting evidence that fixed broadband speed contributed to GDP and the effect were greater in countries with lower incomes.

There is also evidence that fixed broadband speed effected the English property prices in 2005–2010. Ahlfeldt *et al.* (2017) found that disconnecting an average property from a high-speed first-generation broadband connection would depreciate its value by 2.8%. Based on Swedish municipality data Zaber *et al.* (2017) found an association between broadband speed and variables associated with the quality of life. An interesting finding was that fixed broadband speed was associated with better math and English skills.

The evidence so far has pointed at strong associations between fixed broadband speed and economic development. However, to my knowledge, there is no research published on the association between mobile broadband speed and economic development. There are a number of reasons why mobile broadband compared to fixed broadband should influence economic development. Firstly, mobile broadband enables a faster distribution of information of new ideas. Secondly, it should have a larger effect on competition as it makes it possible for consumers to compare prices and conduct market transactions regardless of location. Thirdly, mobile broadband should have positive impact on innovation as information is more accessible and thus more easily spread to more people. Finally, it makes it possible for countries to leapfrog and thus focus primarily on investment in mobile and not fixed broadband infrastructure. The question that remains to be investigated is if the speed in the networks also matters for economic development.

#### 3. Methodology

To investigate the association between mobile broadband speed and labor productivity, the methodology in this paper is based on econometric methods. The econometric model is based on the neoclassical production function (Solow 1956). Assuming an augmented Cobb-Douglas production function, we have the following equation:

$$Y_{i,t} = TFP_{i,t}K_{i,t}^{\beta_K}L_{i,t}^{\beta_L}$$

$$\tag{1}$$

where  $Y_{i,t}$  is real GDP,  $K_{i,t}$  is capital,  $L_{i,t}$  is labor input and *TFP* is Hicks-neutral total factor productivity, all for country *i* at time *t*.

By taking natural logarithms of equation (1) the following equation is derived:

$$\ln Y_{i,t} = \beta_K \ln K_{i,t} + \beta_L \ln L_{i,t} + \ln TFP_{i,t}$$
<sup>(2)</sup>

where  $\beta$  represents the output elasticity of each input. By dividing by labor (L):

$$\ln(Y/L)_{i,t} = \beta_K \ln(K/L)_{i,t} + \ln TFP_{i,t}$$
(3)

Thus, labor productivity (Y/L) is a function of the capital labor ratio (K/L) and TFP which is measured as a residual. In the econometric specification the impact from median mobile broadband speed is added, measured in logarithmic form. Moreover, a measure of human capital (HK) has also been added as a control variable:

$$\ln(Y/L)_{i,t} = \beta_1 + \beta_2 \ln speed_{i,t} + \beta_3 \ln (K/L)_{i,t} + \beta_4 \ln HK_{i,t} + \delta T_t + (\alpha_i + \varepsilon_{i,t})$$
(4)

 $T_t$  is a set of year dummy variables in order to control for common shocks.  $\alpha_i$  is a set of unobserved country-specific effects and  $\varepsilon_{i,t}$  is the error term. The *speed* variable is the median downlink speed registered by Ookla® Speedtest® in country *i* at time *t* (see section 4).

An alternative way of expressing equation (4) is in terms of first differences:

$$\Delta \ln(Y/L)_{i,t} = \beta_1 + \beta_2 \Delta \ln speed_{i,t} + \beta_3 \Delta \ln(K/L)_{i,t} + \beta_4 \Delta \ln HK_{i,t} + \delta_t + v_{i,t}$$
(5)

where  $\delta_t$  are year dummies, capturing common economic shocks, and  $v_{i,t}$  is the differenced residual.

#### 4. Data

Data of the mobile broadband speed is based on the Ericsson analysis of *Speedtest Intelligence*<sup>®</sup> data from Ookla (see Ookla 2020). The database presents data from millions of tests and readings collected via Speedtest, which is an app service used to test the uplink and downlink speed of a particular mobile device. This paper focuses primarily on the downlink speed which is measured in kilobits per second (kbps). Data on GDP, employment, capital measurement and human capital is based on the Penn World Tables 10.0 (Feenstra *et al.* 2015). GDP is based on real national-accounts growth rates in 2017 US\$. Purchasing Power Parities have been used to convert national currency GDP into a common denominator i.e. US\$. Data on employment is measured as number of persons engaged. Thus, labor productivity is measured as GDP per person engaged.

A measure of capital was constructed based on capital stock for the base year 2017 and then extended by the yearly growth rates of total capital services measured in constant prices. Moreover, an index of human capital was retrieved from the Penn World Tables 10.0. The index is based on the average years of schooling and an assumed rate of returns to education around the world.

The robustness section (section 6) includes data on unique mobile Internet subscribers per 100 persons engaged to control for mobile broadband diffusion. The data is based on GSMA Intelligence Database (2021) and consists of total unique users who have used Internet services on their mobile device at the end of the period.<sup>1</sup> To control for fixed broadband diffusion fixed broadband subscribers per 100 inhabitants is included. That data is provided by the World Telecommunication/ICT Indicators database (International Telecommunication Union 2020).

In total, a balanced panel of 116 countries for the period 2014–2019 are included in the regression analysis. *Table 1* shows a list of the countries that are included divided into OECD and non-OECD countries. The sample includes 37 OECD countries and 79 non-OECD countries. In the robustness section we include data for unique mobile broadband subscriptions and fixed broadband subscriptions per 100 persons engaged. Since there are a few missing values for fixed broadband subscriptions the robustness regressions are based on an unbalanced panel of 115 countries.<sup>2</sup>

*Table 2* shows descriptive statistics of the variables used throughout the analysis. It shows that labor productivity (GDP per person engaged) and the median mobile broadband speed varies

<sup>&</sup>lt;sup>1</sup> Mobile internet services are defined as any activity that consumes mobile data (i.e. excluding SMS, MMS and cellular voice calls).

<sup>&</sup>lt;sup>2</sup> There is no data available for Sierra Leone, thus the country is not included in the robustness regressions.

considerably among countries. Average labor productivity was \$53 199 per person engaged expressed in 2017 US\$. The average median downlink speed for the countries was 11 355 kbps. The maximum value was 55 387 kbps (Iceland) and the minimum value was 146 kbps (Ukraine).

#### 5. Results

A fixed effects (FE) model controls for or partials out the effects of the country specific components. An alternative to the fixed effects model is the random effects (RE) model which is used when variation across countries is assumed to be random and not correlated with the dependent and independent variables in the model. Even though the Hausman test rejects the random effects model as the most appropriate, this paper presents results based on both fixed and random effects estimation.<sup>3</sup>

*Table 3* shows the results based on pooled, fixed and random effects estimation. Once capital labor ratio and human capital is included in the regressions, there is no significant association between mobile broadband speed and labor productivity. The capital labor ratio is strongly associated with labor productivity while human capital is insignificant.

*Table 4* investigates the lagged effect from median download speed. The results suggest that one-year lag of download speed is significantly associated with labor productivity at the 5 percent level based on fixed effects estimation and at the 1 percent level based on random effects estimation.<sup>4</sup> The interpretation of the results is that a 10 percent increase in mobile broadband speed in period t-1 is associated with 0.2 percent increase in labor productivity, cetris paribus. These results indicate that investments in mobile broadband speed partly effectuates with a one-year lag. Results based on two-years lag of median speed are insignificant.

The research literature on General Purpose Technologies support the findings of technology effecting productivity with a lag (David 1990). One possible explanation is that complementary investment in organizational capital are necessary to reap the productivity

<sup>&</sup>lt;sup>3</sup> Based on a Hausman test the hypothesis that the random effects model is most appropriate is rejected. The Hausman test for the fixed and random effects model including time specific effect gives a statistic of 28.94 with a Prob>chi2 = 0.0003.

<sup>&</sup>lt;sup>4</sup> Significance at 3.7 and 0.9 percent levels for fixed and random effects estimation, respectively

effects from investments in new technology. Brynjolfsson and Hitt (2003) found that computer capital was correlated with total factor productivity for U.S. firms when the average growth rates over longer time periods were used. The estimated coefficient increased in size when the length of the growth period increased. There are also other studied showing lagged effects from ICT on productivity (see Basu *et al.* 2004; Basu and Fernald 2007; Edquist and Henrekson 2017). Thus, it takes time until the full effects from higher mobile broadband speed is transferred into higher productivity.<sup>5</sup>

*Table 5* shows that mobile broadband speed is insignificant once the regressions are based on first differences. The magnitude of the estimates increases when longer differences based on 2 and 3 years are used, but the estimates are still insignificant at the 10 percent level. One reason could be the time length of our investigated period is limited.

#### 6. Robustness

This section tests the robustness of the results based on different country groups and additional data. The countries included in the analysis are different in terms of economic development. Therefore, the sample is divided into OECD and non-OECD countries. *Table 6* shows that there are no significant results for OECD countries neither for the contemporaneous nor for the lagged coefficients. For the non-OECD countries the contemporaneous coefficient is significant at the 5 percent level based on random effects estimation, but not significant based on fixed effects estimation. Moreover, the coefficient for the one-year lagged mobile broadband variable is significant for both fixed and random effects estimation at the 5 and 1 percent level, respectively.

Chinn and Fairlie (2007) pointed out the digital divide across countries in terms of computer and fixed Internet penetration. One possible explanation is that non-OECD countries benefit more by investing in mobile broadband speed because they have not been able to invest as much in fixed infrastructure. Thus, countries could leapfrog by increasing their mobile broadband speed capability and eventually catch up in economic development with OECD countries. Another possibility is that the sample size of the OECD countries is too small to generate significant results.

<sup>&</sup>lt;sup>5</sup> Another possible interpretation would be that longer differences results in less measurement error.

An important factor for the impact of mobile broadband speed is how many people that have access to the network. Therefore, unique mobile broadband subscriptions per 100 persons engaged is included as a control variable. Moreover, the alternative to using mobile broadband is to use fixed broadband. Therefore, fixed broadband subscriptions per 100 persons engaged is also added as a control variable. Unique mobile- and fixed broadband subscriptions per 100 persons engaged are included in log form. Thus, diminishing returns to technology is assumed, which implies that the economic impact from the early subscriptions are more important than subscriptions at a later stage. The rationale behind this would be that the persons with highest marginal returns are the first ones to adopt the new technology.

*Table 7* shows that the association between mobile broadband speed and labor productivity is insignificant based on both fixed and random effects estimations, once mobile and fixed broadband subscriptions per 100 persons engaged are included in the regression. However, the one-year lagged mobile broadband speed variable is associated with labor productivity at the 5 and 1 percent level based on fixed and random effects, respectively.

*Table 7* also includes regressions with both the contemporaneous and the lagged variable in a finite distribution lag model. The one-year mobile broadband speed lagged variable is significant at the 5 percent and 1 percent level based on fixed and random effects estimation, respectively. However, the contemporaneous association between mobile broadband speed and labor productivity is insignificant based on both estimation techniques. Finally, a F-test is used to test whether the contemporaneous and one-year lagged mobile broadband speed is jointly significant. The hypothesis that the two variables are jointly equal to zero can be rejected at the 5 percent level for the two specifications (3 percent level for the fixed effects model and 2 percent level for the random effects model).

#### 7. Simultaneity

One general problem with studies investigating the economic impact from ICT and particularly broadband is simultaneity. One approach has been instrumental variables that are correlated with the explanatory variable but not with the error term (see Czernich *et al.* 2011 and Edquist *et al.* 2018). However, it has not been possible to find valid instruments for mobile broadband speed. An additional approach is to use lagged variables as instruments, but

this method has been criticized by Reed (2015) who finds that it does not enable one to escape simultaneity bias.

An alternative method to lagged variables would be to use lagged values as instruments in 2SLS and GMM estimations. However, this would only work if the lagged values do not themselves belong in the respective estimation equations and if they are sufficiently correlated with the simultaneously determined explanatory variables (Reed 2015). Based on earlier findings of the impact of ICT (Brynjolfsson and Hitt 2003; Basu *et al.* 2004, Basu and Fernald 2007; Edquist and Henrekson 2017), it is likely that lagged mobile broadband speed variable is a part of the estimation equation. Hence, this method to correct for simultaneity is refrained.

#### 8. Conclusions

Productivity growth is crucial for a country's welfare and standard of living. Increased productivity will release resources that make it possible to improve other important indicators such as health, pollution, security and education. Research show that mobile phones and mobile broadband have been important for economic and productivity growth (see section 2). However, there is limited knowledge about the economic impact from speed in the mobile networks.

Based on panel data of 116 countries in 2014–19, this paper finds no strong evidence of an association between mobile broadband speed and labor productivity. However, the significance level increases substantially when a one-year lag of mobile broadband speed is introduced. The results suggest that a one-year lag of medium download speed is significantly associated with labor productivity at 3.7 and 0.9 percent levels for fixed and random effects estimations, respectively. The interpretation of the results is that a 10 percent increase in mobile broadband speed in period t-1 is associated with 0.2 percent increase in labor productivity, cetris paribus.

Once the sample is divided into OECD and non-OECD countries the results only remain robust for non-OECD countries. One possible explanation is that non-OECD countries benefit more by investing in mobile broadband speed because they have not been able to invest as much in fixed infrastructure. Moreover, the results are robust once we introduce unique mobile and fixed broadband subscribers as control variable in the regressions. With the launch and roll out of 5G in many countries the speed in the mobile networks will increase considerably. Therefore, it is important to understand if mobile broadband speed is linked to productivity growth. The findings in this paper suggest that investment in mobile broadband speed provides hope for a journey of continued productivity growth in many countries.

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## 10. Tables

#### Table 1 OECD and non-OECD countries included in the regressions

OECD countries (37)	Australia, Austria, Belgium, Canada, Chile, Colombia, Czech Republic,
	Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland,
	Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New
	Zealand, Norway, Poland, Portugal, , Slovakia, Slovenia, South Korea, Spain,
	Sweden, Switzerland, Turkey, United Kingdom, United States
	Angola, Argentina, Armenia, Bahrain, Barbados, Benin, Bolivia, Botswana,
	Brazil, Bulgaria, Burkina Faso, Burundi, Cameroon, Central African Republic,
	China, Costa Rica, Cote D'Ivoire, Croatia, Cyprus, Dominican Republic, Ecuador,
	Egypt, Fiji, Gabon, Guatemala, Honduras, Hong Kong, India, Indonesia, Iran,
	Iraq, Jamaica, Jordan, Kazakstan, Kenya, Kuwait, Kyrgyzstan, Laos, Lesotho,
Non-OECD countries (79)	Macau, Malaysia, Malta, Mauritania, Mauritius, Moldova, Mongolia, Morocco,
	Mozambique, Namibia, Nicaragua, Niger, Nigeria, Panama, Paraguay, Peru,
	Philippines, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Serbia,
	Sierra Leone, Singapore, South Africa, Sri Lanka, Sudan, Swaziland, Taiwan,
	Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Ukraine, Uruguay,
	Venezuela, Zimbabwe

### Table 2Descriptive statistics (2014–2019)

Variable	Mean	St. Dev.	Min	Max	No. obs
Labor productivity (in 2017 US\$ per person engaged)	53199	39622	570	209112	696
Speed (downlink speed in kbps)	11355	9593	146	55387	696
Capital labor ratio (in 2017 US\$ per person engaged)	252214	214376	3730	860084	696
Human capital index	3	0.7	1	4	696
Unique mobile internet subscribers (as per 100 persons engaged)	110	42	3	198	696
Fixed broadband subscriptions (as per 100 persons engaged)	36	29	0.03	104	675

Note: Speed data based on Ericsson analysis of Speedtest Intelligence® data from Ookla, Q3 2020.

	Dependent variable: log of labor productivity (GDP in 2017 US\$ per person engaged)						
	Pooled re	ooled regression		d effects	Randor	m effects	
Log of median speed	0.85***	0.07	0.01	0.01	0.02	0.02	
(downlink speed in kbps) ( <i>ln speed</i> )	(0.089)	(0.054)	(0.014)	(0.011)	(0.014)	(0.010)	
Log of capital labor ratio		0.69***		0.57***		0.70***	
(Capital services in 2017 US\$ per person engaged) (ln(K/L))		(0.065)		(0.132)		(0.080)	
Log of human capital		0.38		-0.35		0.16	
(lnHK)		(0.289)		(0.280)		(0.265)	
Constant	3.62***	1.34*	10.37***	3.99**	10.32***	1.91**	
Constant	(0.755)	(0.735)	(0.111)	(1.536)	(0.166)	(0.807)	
Country fixed effects	No	No	Yes	Yes	No	No	
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	
$R^2$	0.43	0.89	0.13	0.35	0.13	0.34	
Number of observations	696	696	696	696	696	696	

## Table 3Regressions investigating the associations between labor productivity and speed in<br/>mobile broadband networks

*Note:* The estimates are based on pooled OLS and fixed effects. Cluster robust standard errors are presented in parenthesis. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5% and 10% levels, respectively. Speed data based on Ericsson analysis of *Speedtest Intelligence*® data from Ookla, Q3 2020.

	Depend	ent variable:	DP in 2017 US\$ per			
	Pooled regression		Fixed e	ffects	Random effects	
Lag of log of median speed (downlink speed in kbps) ( <i>ln</i> <i>speed</i> ) (t-1)	0.06 (0.051)		0.02** (0.009)		0.02*** (0.008)	
Lag of log of median speed (downlink speed in kbps) ( <i>ln</i> <i>speed</i> ) (t-2)		0.05 (0.048)		0.007 (0.007)		0.01 (0.007)
Log of capital labor ratio (Capital services in 2011 US\$ per person engaged) (ln(K/L))	0.70*** (0.069)	0.70*** (0.074)	0.58*** (0.150)	0.62*** (0.161)	0.70*** (0.087)	0.73*** (0.088)
Log of human capital ( <i>lnHK</i> )	0.38 (0.293)	0.39 (0.296)	-0.26 (0.290)	-0.28 (0.328)	0.22 (0.289)	0.23 (0.301)
Constant	1.32* (0.728)	1.33* (0.724)	3.74** (1.709)	3.34* (1.786)	1.75** (0.845)	1.55* (0.813)
Country fixed effects	No	No	Yes	Yes	No	No
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
$R^2$	0.89	0.89	0.34	0.31	0.33	0.30
Number of observations	580	464	580	464	580	464

# Table 4Regressions investigating the associations between labor productivity and speed in<br/>mobile broadband networks

*Note:* The estimates are based on pooled OLS and fixed effects. Cluster robust standard errors are presented in parenthesis. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5% and 10% levels, respectively. Speed data based on Ericsson analysis of *Speedtest Intelligence*® data from Ookla, Q3 2020.

	Dependent variable: Δlog of labor productivity						
	First differences	Two years differences	Three years differences				
$\Delta \log$ of median speed ( $\Delta ln \ speed$ )	0.002 (0.006)	0.01 (0.009)	0.02 (0.012)				
$\Delta \log$ of capital labor ratio $(\Delta ln(K/L))$	0.60*** (0.105)	0.56*** (0.121)	0.55*** (0.131)				
Δlog of human capital (ΔlnHK)	-0.41 (0.289)	-0.33 (0.274)	-0.28 (0.277)				
Constant	0.002 (0.006)	-0.002 (0.011)	-0.003 (0.020)				
Year dummies	Yes	Yes	Yes				
$R^2$	0.22	0.25	0.26				
Number of observations	580	464	348				

# Table 5Regressions investigating the association between the log change in labor productivity<br/>and log change in mobile broadband speed

*Note*: The estimates are based on pooled OLS. Cluster robust standard errors are presented in parenthesis. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5% and 10% levels, respectively. Speed data based on Ericsson analysis of *Speedtest Intelligence*® data from Ookla, Q3 2020.

	Dependent variable: log of labor productivity (GDP in 2017 US\$ per person engaged)								
		Fixed e	ffects		Random effects				
	OECD	Non-OECD	OECD	Non-OECD	OECD	Non-OECD	OECD	Non-OECD	
Log of median speed (downlink speed in kbps) ( <i>ln speed</i> )	-0.007 (0.013)	0.02 (0.014)			-0.007 (0.013)	0.03** (0.013)			
Lag of log of median speed (downlink speed in kbps) ( <i>ln</i> <i>speed</i> ) (t-1)			0.0008 (0.011)	0.03** (0.012)			0.001 (0.011)	0.03*** (0.011)	
Log of capital labor ratio (Capital services in 2011 US\$ per person engaged) $(\ln(K/L))$	0.55*** (0.073)	0.62*** (0.163)	0.47*** (0.086)	0.64*** (0.187)	0.55*** (0.065)	0.72*** (0.093)	0.49*** (0.064)	0.73*** (0.102)	
Log of human capital ( <i>lnHK</i> )	0.005 (0.360)	-0.17 (0.269)	0.11 (0.403)	-0.09 (0.273)	0.27 (0.305)	0.18 (0.261)	0.36 (0.317)	0.22 (0.293)	
Constant	4.20*** (1.040)	3.05 (1.931)	5.03*** (1.093)	2.71 (2.160)	3.90*** (0.867)	1.57 (0.965)	4.48*** (0.842)	1.39 (1.018)	
Country fixed effects	Yes	Yes	Yes	Yes	No	No	No	No	
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
$R^2$	0.73	0.34	0.72	0.33	0.73	0.33	0.72	0.33	
Number of observations	222	474	185	395	222	474	185	395	

 Table 6
 Regressions investigating the associations between labor productivity and speed in mobile broadband networks in OECD and non-OECD countries

*Note*: The estimates are based on pooled OLS and fixed effects. Cluster robust standard errors are presented in parenthesis. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5% and 10% levels, respectively. Speed data based on Ericsson analysis of *Speedtest Intelligence*® data from Ookla, Q3 2020.

# Table 7Robustness check investigating the association between labor productivity and speed in mobile broadband networks including unique<br/>mobile broadband and fixed broadband subscriptions

		Dependent varia	ble: log of labor prod	uctivity (GDP in 201	7 US\$ per person en	gaged)
		Fixed effects				
Log of median speed (downlink speed	0.02		0.02	0.02		0.02
Lag of log of median speed (downlink speed in kbps) ( <i>ln speed</i> ) (t-1)	(0.012)	0.02**	0.02**	(0.012)	0.02**	0.02***
Log of capital labor ratio (Capital services in 2011 US\$ per person engaged) $(ln(K/L))$	0.59*** (0.136)	0.61*** (0.156)	0.61*** (0.151)	0.71*** (0.086)	0.73*** (0.093)	0.72*** (0.089)
Log of human capital ( <i>lnHK</i> )	-0.36 (0.293)	-0.31 (0.317)	-0.29 (0.304)	0.18 (0.272)	0.23 (0.298)	0.24 (0.288)
Log of unique mobile broadband subscriptions per 100 persons engaged ( <i>lnMB</i> )	-0.02 (0.030)	-0.03 (0.029)	-0.03 (0.029)	-0.02 (0.033)	-0.02 (0.032)	-0.03 (0.032)
Log of fixed broadband per 100 person engaged ( <i>lnFB</i> )	-0.01 (0.009)	-0.01* (0.008)	-0.01 (0.008)	-0.004 (0.010)	-0.006 (0.009)	-0.008 (0.010)
Constant	3.87** (1.602)	3.51** (1.776)	3.45* (1.814)	1.79* (0.925)	1.57* (0.947)	1.52 (0.984)
Country fixed effects	Yes	Yes	Yes	No	No	No
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> <sup>2</sup>	0.37	0.35	0.36	0.35	0.34	0.34
Number of observations	675	563	563	675	563	563

*Note*: The estimates are based on pooled OLS and fixed effects. Cluster robust standard errors are presented in parenthesis. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5% and 10% levels, respectively. Speed data based on Ericsson analysis of *Speedtest Intelligence*® data from Ookla.