Telecommunications and economic development – The 21st century: making the evidence stronger

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Abstract

A review of the literature on the relation between telecommunications and economic development published since the turn of this century is undertaken. Two stages have been considered: until 2008, most contributions continued to examine the role of telecommunications taken together; since 2009, the impact of broadband –and, to a lesser extent, of mobile communications– dominates the research agenda. All in all, the role of telecommunications as a catalyst to leverage economic growth has been conclusively proven over the years. Taking into consideration the shortcomings of previous research, suggestions for future work are also provided.

Keywords

telecommunications; economic development; growth; basic infrastructure; broadband; mobile communications

1. Introduction

In March 2000, the Nasdaq index started a drop that did not land until two years and a half later when the index reached the 22% of the peak value. In April of the same year, the 3G spectrum auction raised a staggering 36.9 billion EUR in United Kingdom; in August, a similar auction raised 50.8 billion EUR in Germany. However, a few months later, the *telecoms crash*, of which spectrum auctions prices are considered one of its main causes, was competing with the *dotcom bubble* as the most catastrophic new-century crash. In September (always 2000), world leaders came together at the United Nations Headquarters to adopt the United Nations Millennium Declaration, committing their nations to a global partnership to reduce extreme poverty and setting out a series of goals known as the Millennium Development Goals. Targets were associated to the goals; one of them, the number 18, reads "in cooperation with the private sector, make available the benefits of new technologies, especially information and communications". Fixed- and mobile-telephone subscriptions, as well as Internet users, per 100 inhabitants were indicators identified to track that target.

As can be seen, the turn of the millennium seemed to be sending somewhat confusing signals about the real benefits of the new economy and, particularly, about the true role that fell

to telecommunications in an economy of the 21st century. But did doubts still remain? Was it not already evident that telecommunications contribute to economic prosperity? Were assumptions (and expectations) excessively inflated?

The academia had attempted to do its work during the previous century but, as the paper linked to this demonstrates, there was still a long way to travel. This even more so considering that the words "broadband" and "mobile" were absent in precedent analyses. Consequently, the scientific interest in the topic continued and, indeed, is continued down to the present time. This article is aimed at compiling and analysing all the contributions made since the turn of the century. It conducts a review of the literature on the relation between telecommunications and economic development published from year 2000 onwards (until the end of 2018).

What kind of contributions have been considered? Several clarifications need to be made. Only those works that deal with the impact of strictly telecommunications are included; that is to say that papers on the economic impact of information and communication technologies (broadly considered) fall outside of the analysis. Further to this, the literature search is also limited to the extension of telecommunication services, therefore excluding documents focusing on online applications and services; in particular, Internet studies are chosen only when the variable used is "Internet users", "Internet capacity" or similar. More, the study is limited to the examination of those articles that validate (or refute) hypotheses about the *macroeconomically-measurable* impact of telecommunications; of course, this does not mean forgetting that telecommunications do also have a huge *microeconomic* impact on people's lives that is just as significant, if not more so, than the macroeconomic one. "Measurable impact" implies that non-empirical papers are not saved; unlike in the past, essays and descriptive papers play in this century a very minor role in further developing this story. Finally, our interest lies in those works that have gone through a peer-review process[1]; in other words, with a few notable exceptions (those works that have been repeatedly cited), working papers, reports from consultancy firms, documents from national competition authorities –or even from international bodies– have been left out. This decision does not imply any value judgment on the quality of such documents. Simply, trying to include them in any analysis would lead to a much larger scale and full of problems work –very different visibility and availability, national languages, arduous appraisal of quality on a case-by-case basis.

[1] The selected articles were chosen, after individual assessment, among those retrieved from the databases Econlit, Scopus and Web of Science. Search terms were a combination of "economic development" (and derivatives as "growth" / "impact") with "telecommunications", "broadband", "mobile communications", "telephony" (topic field: title, abstract, keywords). The references from the selected articles were reviewed to identify other possible pertinent works.

Within these limits, this article attempts, first, to put a bit of order in this story, and, second, to suggest a research agenda –considering the shortcomings of past contributions as well as the advancements of statistics and technology– that can guide future studies in the area. The first part is divided into two sections: the period until 2008, in which most works continued to consider telecommunications as a whole, and the period from 2009 onwards in which the study of the impact of broadband –and, to a lesser extent, of mobile communications– has become commonplace. Indeed, in the absence of outstanding global milestones in the chronological sequence of the sector's events, the year 2008 has been taken as a convenient dividing line between research periods just for this noticeable change of course in research. Overall conclusions end the article.

In doing a literature review, the article also tries to serve as a repository for all –to the best knowledge of authors– the studies already performed in the area. It should benefit future research that in turn will help us to better understand the economic role of telecommunications.

2. From 2000 to 2008 – The consolidation years

The nineties of the 20th century had drawn to a close leaving behind scarce and heterogeneous qualitative research. In the next few years, the research efforts became more intense and, at the same time, more structured in line with previous works. That happened progressively: firstly, it can be seen, looking at Table 1, that the number of contributions increased significantly only as of 2006; secondly, in the very first years of the 21st century some works that may be regarded as seminal –in the sense of blazing trails that others followed– were published. Another feature characterises this period: 'telecommunications' kept being the most frequent word in articles' titles; in other words, studies on the particular impact of mobiles or broadband –very common, almost the standard, from 2009 on– were rare and pretty limited in scope and depth.

Starting with those papers that deserve a particular mention, three of them fell into the category of "foundational"[2]. In chronological order, Madden and Savage (2000) developed a growth model which includes telecommunications capital as an argument in an aggregate production function, which is something that many others did after them. Röller and Waverman (2001) did not use a single equation model but estimated a structural model that endogenises telecommunication investment (through a micromodel of supply and demand) in a macro

[2] It is not (it cannot be) the goal of this article to assess in detail the virtues or weaknesses of each paper. Therefore, the "importance" attached to each work is mainly weighted by the replication of the model in other papers and by the citations received.

production equation. Again, this is an approach that has been often replicated in the next years. Last, Datta and Agarwal (2004) also introduced methodological improvements: they used a (dynamic fixed effects) panel data approach applied to a growth equation similar to the one first proposed by Robert J. Barro in 1991, which allows testing for conditional convergence by adding to a neoclassical model a set of variables reflecting differences in the steady-state equilibrium.

Aside from applications of those models in different situations, and from interesting but unusual –in the sense of not further repeated– approaches (such as the methodology proposed by Correa (2006) for measuring the impact of telecommunications investment on national and sectoral productivity, or the stochastic production frontier model put forward by Thompson and Garbacz, 2007), a main strand of the literature of the time attempted to empirically infer the direction of influence (i.e., causality) between telecommunications infrastructure and economic growth. Elaborating on the results of the studies that apply causality tests, the hypothesis that contends that telecommunications infrastructure is a necessary precondition to economic growth is not broadly supported. Just Dutta (2001) and Dvornik and Sabolić (2006) reached that conclusion. Brock and Sutherland (2000) and Beil, Ford, and Jackson (2005) support the opposing hypothesis: causality runs instead from economic growth to telecommunications infrastructure; i.e., telecommunications infrastructure is merely an outcome of economic growth. Finally, a bidirectional causality (economic growth and telecommunications infrastructure complement and reinforce each other) is found in the analyses of Chakraborty and Nandi (2003) and Wolde-Rufael (2007). Interestingly enough, this last paper (Wolde-Rufael, 2007) came back to the same data set used by Beil, Ford and Jackson (2005); just transforming the data into natural logarithms and using another version of the Granger causality test, the results (bidirectionality) differ dramatically from those of the original paper in which is told that "*the findings are robust across lag lenghts*". This is a clear illustration of how dangerous it could be to present conclusions as unequivocal facts.

In spite of the not-so-clear image that emerges from the "causality" papers, the role of telecommunications as an ingredient –or even the leavening– in the cake of growth is shown by most research. Röller and Waverman (2001), Cieślik and Kaniewska (2004), and Torero, Chowdhury and Bedi (2006) use the term "casual" (in all three cases, casual link running from telecommunications to growth). Others talk of "positive relationship" (Madden and Savage, 2000; Yilmaz, Haynes and Dinc, 2002; Datta and Agarwal, 2004; Zahra, Azim and Mahmood, 2008), "strong or substantial contribution" (Correa, 2006; Giesecke, 2006), "key factor" (Ding and Haynes, 2006), "important role" (Haynes, Yilmaz and Dinc, 2006), "significant effect" (Sridhar and Sridhar, 2007), or "positive impact" (Ding, Haynes and Liu, 2008). Some of them dare to suggest specific figures: according to Torero, Chowdhury and Bedi (2006), a 1 percent

increase in the telecommunications penetration rate could be expected to lead to a 0.03 percent increase in GDP; according to Röller and Waverman (2001), about one-third of the economic growth in OECD countries between 1971 and 1990 may be attributed to growth in telecommunications infrastructure.

The discordant notes in this melody are played by Björkroth (2006), for whom "*in relatively developed economies, the effect of telecommunications on growth may arise from investments in user segments, rather than from investment expenditure on the supply side*", and also by Narayan and Sun (2007), who found a "rather weak effect" of telecommunications – though in this case authors themselves justified the results by the fact that improvement in telecommunication networks in China occurred in the early to mid 1990s, while they had studied a much broader period starting in 1952. Also with data from China, Shiu and Lam (2008) conclude that causality running from telecommunications development to GDP exists in affluent regions but not in low-income provinces. It is not the only paper in which results are nuanced or conditioned on various factors. For instance, Röller and Waverman (2001) alert that telecommunications begin to exert an influence on output only when a penetration threshold of about 40 percent is reached. In general, any paper that considered simultaneously developing and developed countries (or regions) found a nonlinear relationship between teledensity and economic output or, at least, devoted some lines to qualify the comprehensive conclusions drawn. The overall economic and political context is always important: Thompson and Garbacz (2007) make the effect of telecommunications conditional on institutional reforms; Chakraborty and Nandi (2003) conclude that the lack of privatisation initiatives prevents telecommunications infrastructure and economic growth from reinforcing each other; the above mentioned paper from Brock and Sutherland (2000) found causality from GDP to telecommunications using data from the former USSR over the period 1960-1988, a period in which telecommunications were "neglected".

Those articles that refer to broadband or mobile communications have been intentionally left out from the previous paragraphs. As already told, they are few and limited. Considering the period covered by this section, this is fully understandable in the case of broadband. The length of time series and even the very definition of broadband hampered any research effort. Without reason for this, almost all available works focus on gathering evidence about the effect over employment of broadband deployment in particular counties of the United States (Shideler, Badasyan and Taylor, 2007; Lobo, Novobilski and Ghosh, 2008; Van Gaasbeck, 2008; plus Crandall, Lehr and Litan, 2007, state level instead of county level; plus Ford and Koutsky, 2005, general economic growth instead of employment, always on a particular county). In the case of mobile communications, penetration levels would have justified, by contrast, a more intense research activity already in this period. However, just three

papers have been found: Waverman, Meschi and Fuss (2005) –by far the most influential of them despite not having been published in an academic journal– who identified mobile diffusion as a distinctive feature of economic growth in developing countries; Yang and Olfman (2006), who revealed that the impact of cell phones is well above the impact of wireline communications; and Sridhar and Sridhar (2007), who instead did not found significant differences between landlines and cell phones. Finally, a late-in-the-period article researches the impact of Internet adoption (users) on growth (Noh and Yoo, 2008): it is found to be positive but reduced by income inequality.

Table 1. Quantitative research on the relation between telecommunications and economic growth 2000–2008

Reference	Results	Methodology	Data (geographical area)	Data (period)
Brock and Sutherland (2000)	Telecommunication investment is a consequence of economic growth and not a stimulus	Causality tests (Granger / modified Sims)	Former USSR	1960-1988
Madden and Savage (2000)	Significant positive cross-country relationship between telecommunications capital and economic growth, even when using alternative measures of telecommunications capital	Aggregate Cobb-Douglas production function	Global (43 countries)	1975-1990
Dutta (2001)	Evidence for causality from telecommunications to economic activity levels is substantially stronger than evidence for causality in the opposite direction (same pattern for both industrialised and developing countries)	Causality test (Granger)	Global (30 countries)	1970-1993
Röller and Waverman (2001)	Significant positive causal link between telecommunications infrastructure and aggregate output, especially when a critical mass of telecommunications infrastructure is present	Structural analysis – Production function which endogenises telecommunications investment	21 OECD countries	1970-1990
Yilmaz, Haynes and Dinc (2002)	A state's output growth rate is positively related to its rate of telecommunications investment, and negatively related to the rate of telecommunications investment by other states.	Aggregate Cobb-Douglas production function	United States (state level)	1970-1997
Yilmaz and Dinc (2002)	Variation in returns on telecommunications investment across states (which may be due to the inefficient utilisation of telecommunications infrastructure as a factor of production)	Aggregate Cobb-Douglas production function	United States (state level)	1984-1997
Chakraborty and Nandi (2003)	Telecommunications infrastructure and GDP are indeed cointegrated (bidirectional causality) in the long run (particularly for countries with a relatively high degree of privatisation in the sector)	Cointegration and causality test (Granger)	12 Asian developing countries	1975-1999
Cieślik and Kaniewska (2004)	Positive and statistically significant causal relationship between telecommunications infrastructure and regional income	Nested regional production function	Poland (regional level)	1989-1998
Datta and Agarwal (2004)	Strong and positive relationship between telecommunications infrastructure and economic growth	*Barro-type* growth equation	22 OECD countries	1980-1992
Beil, Ford and Jackson (2005)	Investment by telecommunications firms is caused by, but does not cause, economic activity	Causality tests (Granger / Sims)	United States	1947-1996
Ford and Koutsky (2005)	Sizeable effect on economic growth of an extensive, fiber-optic broadband network deployed by a municipal government	Ad hoc growth equation (considering a growth-stimulating technology)	Florida (county level)	1997-2004
Waverman, Meschi and Fuss (2005)	Differences in the penetration and diffusion of mobile telephony explain some of the differences in growth rates between developing countries	Following *Röller and Waverman (2001)* + *Barro-type* growth equation	Global (38 developing countries)	1996-2003
Björkroth (2006)	No evidence that the investment expenditures of telecommunications operators significantly alter the pace of economic growth	*Ram-type* production function	Finland, Sweden and Norway	1970-2001

Reference	Results	Methodology	Data (geographical area)	Data (period)
Correa (2006)	Telecommunications is a strong contributor to the performance of the economic system as a whole. They contribute its share of total output efficiently but they also contribute to overall economy-wide productivity growth via its influence on other industries	Within-industry productivity growth measures from input–output databases and *Peterson* index of direct and indirect productivity gains	United Kingdom	1963-1996
Ding and Haynes (2006)	Telecom infrastructure endowment is a key factor in explaining regional economic growth. Telecom investment is subject to diminishing returns: regions at an earlier stage of development are likely to gain the most from investment in telecom infrastructures	*Barro-type* growth equation	China (regional level)	1986-2002
Dvornik and Sabolić (2006)	Strong correlation between telecommunications and economic development. Causality in the direction from telecommunication investments towards GDP	Causality test (Granger)	East European countries	1991-2001
Giesecke (2006)	Growth of the telecommunications sector contributes to a substantial rise in national real GDP and real consumption	General equilibrium model (particular for the Australian economy)	Australia	1996-2002
Haynes, Yilmaz and Dinc (2006)	Telecommunications infrastructure plays an important role in output growth	Modified Cobb-Douglas production function	United States (state level)	1994-1997
Torero, Chowdhury and Bedi (2006)	Positive causal relationship between telecommunications infrastructure and GDP. The impact is particularly pronounced for lower and higher middle-income countries	Following *Röller and Waverman (2001)*	Global (113 countries)	1980-2000
Yang and Olfman (2006)	The relationship between wireless usage and economic performance was positive and significant when beginning to be adopted. The economic benefit of using wireline telecommunication is nominal or non-significant.	Ad hoc regression (used in a sequential manner)	Global (78 countries)	1993-1998
Crandall, Lehr and Litan (2007)	Nonfarm private employment and employment in several industries is positively associated with broadband use. The effect on output growth is less precise; the statistically significant effects are concentrated in the service industries	Ad hoc regressions	United States (state level)	2003-2005
Narayan and Sun (2007)	Telecommunication technology has a statistically insignificant impact on growth both in the long run and in the short run. Telecommunication investment also displays a weak relationship with per capita income in the long-run equilibrium	Ad hoc economic growth equation	China	1952-1999
Shideler, Badasyan and Taylor (2007)	Broadband availability increases employment growth in some industries but not in others	Ad hoc growth model	Kentucky (county level)	2003-2005
Sridhar and Sridhar (2007)	Significant effects of main landline and cell phone penetration on economic growth	Following *Röller and Waverman (2001)*	Global (63 countries)	1990-2001
Thompson and Garbacz (2007)	Increase in telecommunication penetration, together with institutional reforms, benefit the world as a whole, but particularly its poorest nations, by improving the efficiency of how these and other resources are used	Stochastic production frontier function	Global (93 countries)	1995-2003
Wolde-Rufael (2007)	Bi-directional causality between telecommunications investment and economic growth	Causality test (Granger)	United States	1947-1996

Reference	Results	Methodology	Data (geographical area)	Data (period)
Ding, Haynes and Liu (2008)	Positive impact of telecommunications infrastructure on regional economic growth	*Barro-type* growth equation	China (regional level)	1986-2002
Lobo, Novobilski and Ghosh (2008)	Broadband expenditures result in income and taxes largely exceeding the expenditure while creating a significant number of new jobs	IMPLAN (Impact analysis for planning) input-output model	Hamilton count (Tennessee)	2001-2005
Noh and Yoo (2008)	Positive impact of Internet adoption on growth that is reduced by income inequality (because the digital divide incurred by the income inequality hinders economic growth)	Ad hoc growth equation	Global (60 countries)	1995-2002
Shiu and Lam (2008)	Causality running from telecommunications development to real GDP is found only in provinces in affluent regions, but not in low-income provinces	Ad hoc regression including lagged variables	China (regional level)	1978-2004
Van Gaasbeck (2008)	Increase in the penetration of broadband within California has a positive and significant effect on growth in employment and total payroll	Ad hoc growth equation	California (county level)	2001-2006
Zahra, Azim and Mahmood (2008)	Relationship between telecommunications development and per capita GDP growth is highly positively, even after controlling for several variables	*Barro-type* growth equation	Global (24 countries)	1998-2006

Source: author's elaboration

3. From 2009 to 2018 – The *broadband years*

Notwithstanding qualifications and cautious assessments, by the end of the first decade of the 21st century, the importance of telecommunications for economic development could be considered, from a strictly academic point of view, thoroughly proven. As had just been seen in the previous section, 'telecommunications' was mainly understood as traditional access lines. However, at the time universal access to basic services –either fixed or mobile– had been reached for many years in a large number of countries. Restricting the analysis to periods in which that condition holds would make it harder for telecommunications to reach statistical significance, whatever the model chosen; in other words, to have a nation-wide telephone network is a basic condition for economic activity that no longer gives a competitive advantage. Already at that time, as it keeps happening right now, the challenge, obviously, laid in knowing (demonstrating) the impact of the deployment and use of advanced networks.

Broadband became thus the new key word. Papers about the impact of *just telecommunications* continue to be published but they are either focused on particular areas in which networks were deployed later than in richest countries (Markova, 2009; Bogojevic, Gospic and Petrovic, 2010; Ghosh and Prasad, 2012; Atsu et al., 2014; Kumar, Kumar and Patel, 2015), or use time series long enough (Chakraborty and Nandi, 2011; Levendis and Lee, 2012; Ahmed and Ridzuan, 2013) or use old data (Kellenberg, 2009).

Coming back to broadband, Pantelis Koutroumpis has the honour of having published the first work that assessed in a comprehensive way the effect of broadband (Koutroumpis, 2009). The number of citations (almost 150 in the Web of Science) rewards his pioneering research. He applied the structural model first used by Röller and Waverman (2001) to a dataset compiling annual data from 22 OECD countries for the 6-year-period between 2002 and 2007, a period which "*does manage to capture a very important part of the growth of broadband networks in the OECD sample*". He concluded that there are increasing returns to broadband telecommunications investments, which are consistent with the persistence of network effects, on condition that a critical mass of 30% –"*which effectively translates in half of the population having access to a broadband connection*"– is reached. There is a second article on the influence of broadband on economic growth whose academic impact –at least in terms of citations– is even greater than the one of Koutroumpis. Czernich et al. (2011) estimated the effect of broadband infrastructure in the panel of OECD countries during 1996–2007. They found that after a country had introduced broadband, GDP per capita was 2.7–3.9 percent higher on average than before its introduction. In terms of subsequent diffusion, a 10 percent increase in broadband penetration raised annual per capita GDP growth by 0.9–1.5 percentage points.

Just as an aside, it is not the only paper that put figures to the impact of broadband. In another very early work, Qiang, Rossotto and Kimura (2009) had obtained similar results: they concluded that there is a 1.38/1.21 (high-income economies / developing countries) percentage points increase in per capita GDP growth for each 10 percent increase in broadband penetration. Much later, Alderete (2017) reports that, on average, a 1 percent increase in broadband increases economic growth by 0.14 percentage points.

None of the subsequent publications has reached the category of "reference paper". With a couple of exceptions, all contributions confirm a positive impact of broadband use on macroeconomic aggregates –even during the financial crisis, see Badran (2012) and Castaldo, Fiorini and Maggi (2018)– though some of them introduce several nuances to this general rule. Thompson and Garbacz (2011) reported significant effect only for wireless broadband (even if the paper was published as far back as 2011), an effect that is greater for low income countries. Kolko (2012) alerts to the fact that economic growth boosted by broadband does not necessarily entail higher wages or reduction of the unemployment rate (in the later case, contrarily to the results of Whitacre, Gallardo and Strover, 2014). Rohman and Bohlin (2012), as well as Gruber, Hätönen and Koutroumpis (2014) and Kongaut and Bohlin (2017), explain that the speed of the connection matters. Ivus and Boland (2015), and also Nadiri, Nandi and Akoz (2018), make clear that the effects are not uniformly distributed across the whole economy. In this line, Aissaoui (2017) clarifies that positive influence of broadband is reduced when digital divides are manifest. The exceptions mentioned above are the conclusions of Thompson and Garbacz (2011) for fixed broadband, and those of Bojnec and Fertő (2012) who –in a pretty unclear article– found no significant role of the total broadband per inhabitant on the per-capita GDP growth; instead, they found it for the "improved access channels per inhabitant" –it is not disclosed, however, what this definition means and how to differentiate it from broadband.

As already explained in the previous section, considering penetration evolution –and, consequently, data availability– it is only logical that the focus is put on broadband since about ten years ago. It is not the case for mobile communications but, anyway, the fact is that most papers on the impact of mobile alone are also written from 2009 on. A great number of these contributions analyse the situation in developing countries or areas, in particular in the African continent (Lee, Levendis and Gutiérrez, 2012; Cleeve and Yiheyis, 2014; Wamboye, Tochkov and Sergi, 2015; Albiman and Sulong, 2016; Donou-Adonsou, Lim and Mathey, 2016; or Njoh, 2018, who links cell phone subscription and the human development index). According to Gruber and Koutroumpis (2011) the impact of mobiles is considerably smaller for low penetration countries (contribution to annual GDP growth is 0.11 percentage points in low income countries while it is 0.20 percentage points in high income countries), i.e., a minimum

level of penetration is required for mobile communications to deploy all their positive effects over the economy (see also Albiman and Sulong, 2016).

Finally, a few papers investigate the effect of Internet use (not necessarily through a broadband connection). The most interesting among them is probably the one written by Meijers (2014), who challenges that internet use has a direct and positive impact on economic growth; on the contrary, according to his findings, the impact would be indirect: a 10 percentage points increase in internet users leads to a 3.9 percentage points increase of the "openness ratio" which in turn leads to a 0.17 percentage points increase of economic growth.

Table 2. Quantitative research on the relation between telecommunications and economic growth 2009–2018

Reference	Results	Methodology	Data (geographical area)	Data (period)
Choi and Yi (2009)	Increase in the penetration of the Internet plays a positive and significant role in economic growth	*Barro-type* growth equation	Global (207 countries)	1991-2000
Kellenberg (2009)	Telecommunications have a positive and significant direct effect on domestic growth. There are greater marginal returns for countries with higher investment levels. Once indirect effects are accounted for, the total effects are higher than direct estimates would suggest	General equilibrium model in a small open economy context	Global (28 countries)	1983-1998
Koutroumpis (2009)	Significant causal positive link between broadband infrastructure and growth, especially when a critical mass of infrastructure is present	Following *Röller and Waverman (2001)*	22 OECD countries	2002-2007
Markova (2009)	The stock of telecommunications infrastructure ensures a significant part of the economic growth in transition countries and is significantly important. The causal relationship in the opposite direction is proven as well	*Barro-type* growth equation	21 transition countries	1992-2003
Qiang, Rossotto and Kimura (2009)	Robust and noticeable growth dividend from broadband access. Broadband seems to have a higher growth impact relative to communications technologies such as fixed and mobile telephony and the Internet	*Barro-type* growth equation	Global (120 countries)	1980-2006
Bogojevic, Gospic and Petrovic (2010)	Economic and telecom developments are closely related. Also strong correlation between the rate of employment and telecommunication development	Correlation	Serbia (municipality level)	1999-2010
Katz et al. (2010)	Economic returns (employment and economic output) amply justify the need to move ahead with the announced broadband investment plans	Input-output analysis and regression-based forecasting	Germany	Forecasts (2010-2020)
Lam and Shiu (2010)	Bidirectional relationship between real GDP and telecommunications development for high-income countries (in less-developed countries, it runs from GDP to teledensity). When the impact of mobile telecommunications is measured separately, the bidirectional relationship is global	Regression including lagged variables	Global (105 countries)	1980-2006
Chakraborty and Nandi (2011)	Mainline teledensity and per capita growth strongly reinforce each other for countries that are relatively less developed. In contrast, there is, at best, weak evidence of bi-directional causal links between the two variables for countries that are relatively more developed	Cointegration and causality test (Granger)	Global (93 developing countries)	1987-2007
Czernich et al. (2011)	Introduction and diffusion of broadband have an important impact on growth in GDP per capita.	Ad hoc production function (with constant returns to scale)	25 OECD countries	1996-2007
Gruber and Koutroumpis (2011)	Contribution of mobile telecommunications infrastructure to economic growth is significant but considerably smaller for low mobile penetration countries (low income countries) than for high penetration countries	Following *Röller and Waverman (2001)*	Global (192 countries)	1990-2007
Thompson and Garbacz (2011)	Mobile broadband has an important direct effect on GDP, but fixed broadband has an effect no different than zero. Low income countries derive significantly more benefit from mobile broadband	Following *Thompson and Garbacz (2007)*	Global (43 countries)	n.a.
Badran (2012)	Positive impact of broadband penetration on the economic growth even during the financial crisis	*Barro-type* growth equation	Global (22 emerging countries)	1998-2008
Bojnec and Fertő (2012)	No significant role of the total broadband per inhabitant on the per-capita GDP growth. The "improved access channels per inhabitant" [not defined] play a positive and significant role in the per-capita GDP growth.	Following *Choi and Yi (2009)*	34 OECD countries	1998-2009

Reference	Results	Methodology	Data (geographical area)	Data (period)
Chavula (2012)	Fixed telephony, mobile telephony and the Internet usage have a significant impact on growth in the upper-middle-income countries, while only the mobile telephone penetration has a significant impact on growth in both the upper-low-income and the low-income countries in Africa	*Barro-type* growth equation	Africa (49 countries)	1990-2007
Farhadi, Ismail and Fooladi (2012)	Positive relationship between growth rate of real GDP per capita and ICT use index (as measured by the number of internet users, fixed broadband internet subscribers and the number of mobile subscription per 100 inhabitants). The effect is higher in high income countries	Ad hoc regression including lagged variables	Global (159 countries)	2000-2009
Ghosh and Prasad (2012)	GDP responds positively to a onetime shock in telephone connections but returns to its initial levels after 4 years	Cointegration and causality test (Granger)	India	1980-2007
Katz and Koutroumpis (2012)	Mobile phones have a measurable impact on economic growth. The economic effect of broadband cannot be measured (very early stages of adoption)	Following *Röller and Waverman (2001)*	Senegal	2004-2011
Kolko (2012)	Positive relationship between broadband expansion and local economic growth. However, both the average wage and the employment rate are unaffected by broadband expansion	Ad hoc regression including lagged variables	United States (Zip code level)	1992-2006
Lee, Levendis and Gutiérrez (2012)	Mobile cellular phone expansion is an important determinant of the rate of economic growth. Its contribution has been growing in importance in the region, and it is even greater wherever land line phones are rare	Following *Datta and Agarwal (2004)*	Sub-Saharan Africa (44 countries)	1975-2006
Levendis and Lee (2012)	The impact of teledensity on growth is positive, and increases with the level of telephone penetration	Following *Datta and Agarwal (2004)*	Asia-Oceania (29 countries)	1981-2006
Lim and Chen (2012)	Telecommunication infrastructure (fixed and mobile) has a significant effect on economic growth. The magnitude of the growth effect is inversely related to the level of infrastructure	Following *Röller and Waverman (2001)*	17 APEC (Asia-Pacific Economic Cooperation) countries	1982-2003
Rohman and Bohlin (2012)	Doubling the broadband speed will contribute to 0.3% growth compared with the growth rate in the base year. The impact will be relatively greater for countries that experienced lower economic growth during previous years	Following *Koutroumpis (2009)*, i.e., *Röller and Waverman (2001)*	33 OECD countries	2008-2010
Ahmed and Ridzuan (2013)	Long-run relationship between GDP and telecommunications investment	Standard production function	8 ASEAN (Association of Southeast Asian Nations) countries	1975-2006
Ng, Lye and Lim (2013)	Broadband penetration has a significantly positive relationship with GDP growth	Following *Thompson and Garbacz (2011)*	10 ASEAN (Association of Southeast Asian Nations) countries	1998-2011
Atsu et al. (2014)	Unidirectional causality between telecommunications investment and economic growth which runs from telecommunications investment to economic growth	Augmented aggregate production function	Ghana	1976-2007
Cleeve and Yiheyis (2014)	Increased mobile penetration contributes to the growth rate of GDP. On the contrary, the increase in mobile telephone use is not significantly influenced by GDP growth	Ad hoc structural analysis	36 African countries	1995-2010
Gruber, Hätönen and Koutroumpis (2014)	Broadband diffusion impacts on economic growth. There is a growth impact from moving away from basic broadband, but the incremental speed impact levels off	Following *Röller and Waverman (2001)*	27 EU countries	2005-2011

Reference	Results	Methodology	Data (geographical area)	Data (period)
Meijers (2014)	Internet use does not have a positive impact on economic growth. However, internet use causes openness to international trade and that trade impacts economic growth. Internet use shows to be more impacting trade in nonhigh income countries than in high income countries	*Barro-type* growth equation + Simultaneous equation model	Global (162 countries)	1990-2008
Pradhan et al. (2014)	Bidirectional causality between telecommunications (land lines plus mobile phones plus internet users) and economic growth	Cointegration and causality test (Granger)	G-20 countries	1991-2012
Sahin, Can and Demirbas (2014)	Telecommunications investment has positive effects on growth in EU12, EU15 and EU27 groups	*Barro* government spending model	27 EU countries	1980-2010
Whitacre, Gallardo and Strover (2014)	High levels of broadband adoption in rural areas positively (and potentially causally) impact income growth, and negatively influence unemployment growth. Similarly, low levels of broadband adoption lead to declines in the number of firms and total employment numbers	Propensity score matching	United States (county level)	2001-2010
Enowbi Batuo (2015)	Telecommunications (fixed and mobile lines) contribute in a major way to the economic development. Furthermore, investment in telecommunications is subject to increasing returns	Following *Datta and Agarwal (2004)*	44 African countries	1990-2010
Ivus and Boland (2015)	Deployment of broadband promotes rural employment and wage growth in service industries. Goods industries are not impacted	Ad-hoc regression	Canada (community level)	1997-2011
Kumar, Kumar and Patel (2015)	Unidirectional causality from telecommunications to output per worker, and capital per worker (bigger contribution in the long-run than in the short-run)	Cobb–Douglas production function	Small Pacific Island States	1979-2012
Ortiz, Sosa and Díaz (2015)	The role of telecommunications (fixed, mobile, broadband) alone on economic growth is limited unless is also accompanied by investments in education (which allows a more efficient use of those technologies)	Cointegration techniques	Global (12 countries)	1980-2013
Pradhan, Arvin and Norman (2015)	Short-run and long-run causal links between ICT infrastructure (telephone landlines, mobile phones, internet users, internet servers, and fixed broadband) and economic growth	Cointegration and causality test (Granger)	21 Asian countries	2001-2012
Wamboye, Tochkov and Sergi (2015)	Fixed-line and mobile telecommunications have a positive and significant impact on growth after penetration rates reach a certain critical mass	Ad hoc regression including lagged variables	43 sub-Saharan African countries	1975-2010
Albiman and Sulong (2016)	Mobile phone and Internet are main economic growth drivers; fixed telephone lines contributed only after considering the whole period (and not particular different periods). The effect can only be evident when penetration rate reaches a certain threshold	*Barro-type* growth equation	45 sub-Saharan African countries	1990-2014
Donou-Adonsou, Lim and Mathey (2016)	Internet and mobile phones contribute to economic growth. The contribution of the Internet is about four times that of mobile phones	Following *Datta and Agarwal (2004)*	47 sub-Saharan African countries	1993-2012
Ghosh (2016)	Convex, non-linear relationship between per capita income and cellular penetration	Ad-hoc structural analysis	12 MENA (Middle East and North Africa) countries	2001-2012
Sezer and Abasiz (2016)	Number of Internet and telephone subscribers increase per capita GDP growth rate	Ad-hoc regression	34 OECD countries	1968-2013
Ward and Zheng (2016)	Mobile services contribute much more to growth than fixed telephony but the effect diminishes as the provincial economy develops more	*Barro-type* growth equation	China (province level)	1991-2010
Aissaoui (2017)	Broadband has a positive effect on economic growth but this effect is reduced by the digital divide	Ad-hoc regression including lagged variables	Global (19 countries)	2000-2012

Reference	Results	Methodology	Data (geographical area)	Data (period)
Albiman and Sulong (2017)	Fixed telephone penetration has a highest impact on economic growth than mobile telephony; in both cases, the impact on lower-income countries is insignificant. Internet only has positive and significant impact on lower-middle-income countries	Cobb–Douglas production function	29 sub-Saharan African countries	1990-2014
Alderete (2017)	Fixed broadband has a statistically significant impact on economic growth	Following *Koutroumpis (2009)*, i.e., *Röller and Waverman (2001)*	20 Latin American countries	2010-2014
Harb (2017)	Internet is a significant growth determinant, particularly in high-income Arab and Middle East countries. Telecom investments did not affect growth	Solow growth model	Global (93 countries) but results limited to Arab and Middle East countries	1995-2014
Kongaut and Bohlin (2017)	Faster broadband speed stimulates higher GDP per capita; the effects are greater in countries with lower income	Structural analysis (starting from a Cobb-Douglas production function)	All OECD countries	n.a.
Qureshi and Najjar (2017)	Inverse or indirect relationship between growth in ICT usage (mobile communications, broadband and Internet subscriptions) and per capita GDP growth; i.e., the rate of growth in GDP decreases as the rate of growth in ICT usage increases	Several ad hoc regression	32 very small island states	2009-2012
Castaldo, Fiorini and Maggi (2018)	Positive correlation between broadband diffusion and economic growth, even after controlling for countries initial endowment of ICT and for the years of economic crisis	*Mankiw, Romer and Weil* output steady-state equation	23 OECD countries	1996-2010
Nadiri, Nandi and Akoz (2018)	Increased use of high speed broadband networks generate productivity gains through cost savings in all industries (though impact varies significantly across industries). The social rate of return on investment in communications infrastructure at the aggregate economy level is significant	Augmented cost function	United States	1987-2008
Njoh (2018)	Positive link between cell phone subscription and the human development index. This also holds true for Internet access but neither for fixed phones nor for broadband	Cobb-Douglas production function	All African countries	2013
Pradhan, Mallik and Bagchi (2018)	Broadband adoption and number of Internet users are cointegrated with per capita GDP growth even in the long run	Cointegration and causality test (Granger)	G-20 countries	2001-2012
Toader et al. (2018)	Positive and strong effect of using ICT infrastructure on economic growth but the magnitude of the effect differs depending on the type of technology (greater for mobile telephony than for broadband or Internet)	Ad hoc regression	European Union countries	2000-2017

Source: author's elaboration

4. Discussion and future work – The way ahead

Three are the factors that will determine future work in this area[3]: the technological evolution in telecommunications, the improvement of ICT statistics, and the scientific advancement of methods, tools and even theory.

Starting with the first aspect, the relationship between GDP growth and telecommunications is non-linear, as several studies make clear (Ghosh, 2016, for cellular penetration, or Qureshi and Najjar, 2017). That means that the effect of *old* telecommunication services becomes progressively blurred until it disappears. Nowadays, nobody would consider fixed telephony, not even mobile voice services, as a variable that influences growth. They have become a necessary, but not a sufficient condition for economic activity to flourish. It is clear that competitive advantages are gained through the use of latest or *new* communication technologies. Therefore, it can be taken for granted that, in a few years, the first studies on the positive impact of ultra-fast broadband or 5G mobile technologies will be published.

Turning to the improvement of data quality, in recent years ICT statistics in general, and telecommunications statistics in particular, have been significantly enhanced by a range of national and international initiatives. At the same time, national statistical offices keep improving –and harmonising– their procedures and outcomes; in general terms, economic and social statistics are more reliable, detailed and timely than they used to be. A higher temporal frequency and spatial granularity of data enables much richer and nuanced analyses, both at national and regional level. These developments would make it possible to overcome some of the problems that can be identified in past studies:

- There is an inevitable lag between network growth and innovation on the one hand, and research on the other. While recognising this, it is also true that the usefulness of many contributions is reduced by the use of outdated data. Although now is much less the case than it used to be, more timely statistics should help to do more in reducing the lag. This is particularly important, bearing in mind the fast pace at which technologies and networks are likely to continue to change.

[3] It should be recalled again that this article focuses only in the impact of telecommunications narrowly identified as such. For some years to come, this type of studies still will make sense in spite of the fact that telecommunications are more and more blurred with the other components of the ICT technological system. Its role as a key component of that ICT system, or as the support of advanced applications and services, is a different –and complex– story. In the long term, when borders between ICT components definitely vanish, this will be the only story to tell.

- Conclusions are frequently derived from cross-country comparisons. The different conditions which may occur in different countries can distort results. Quoting Waverman et al. (2006): "*in many of these* [developing] *countries, growth has been low due to a host of issues – poor governance, lack of capital, low skill levels, and the like. It is difficult to show that mobile telephony increases growth rates where growth is low*".

- In the same vein, investigating the relationship between telecommunications and a single macroeconomic aggregate (for instance, GDP) would not be enough. Changes in GDP per capita or in unemployment rate could only tell part of the story. Without due consideration of the effects on productivity, innovation or quality of jobs, however difficult this may be, the assessment could be incomplete.

- The same applies to the side of telecommunication statistics. The *have it / don't have it* applied to telephone services has given way to a much more heterogeneous offer of products and services. Quality of connections is increasingly important. Using one single metric (for instance "broadband subscribers") may also be misleading.

- Particularly in the case of those articles studying the impact of technologies whose use is still far from widespread, it often happens that they suffer from what Ford (2018) calls "selection bias": "*broadband (and higher speed broadband) is not randomly distributed across geography, but rather is deployed in areas where the ratio of demand to costs is favorable, complicating the task of discovering broadband's influence on economic outcome*". This will remain to be an issue for any researcher who wanted to analyse the impact of emerging technologies.

- Finally, the problems arising from the non-linearity of cause-effect relations must be addressed. In the words of Holt and Jamison (2009): "*One of the difficulties learned from studies of the effects of ICT is that impacts evolve, perhaps even going through periods of negative growth, while businesses experiment with applications and reorganise their operations. This implies that time series studies used to analyze the impact of broadband on economic growth should consider non-linear effects*".

Lastly, the improvement of both econometric models and methods –along with the availability of more powerful tools– will enable better ways of using, analysing and presenting data. Next to this, the recent guideline –promoted by most publishers– supporting sharing of data will allow a more robust replication and extension of research. So far, it appears to be a general –with striking exceptions– lack of criticism and discussion of previous works, which may be in part due to the difficulties in assessing them just with the information provided in the paper. The Wolde-Rufael (2007) vs. Beil, Ford and Jackson (2005) example cited in Section 2 is

a prime example of how discussion can be moved forward when data are available... and when there is willingness and critical thinking to perform such an exercise.

5. Conclusions

The arrival of a new socioeconomic paradigm known as the information society started to be announced more than half a century ago. Digitalisation of economies is ongoing since then. In such a scenario, it seems clear that an appropriate telecommunications network allowing information flows is a key factor for participating in the global economy. To what extent this statement is true is a question to which an answer should be much appreciated by policy makers and society at large. It is therefore no surprise that researchers have invested considerable effort in scientifically providing evidence of it.

In the 21st century, this effort can be initially viewed as the follow-up of achievements of the previous century. Progressively, however, research was adapted to the new era of technologies –and to the new insights into their role. The word telecommunications is disappearing from titles and abstracts. Mobile communications and, in particular, broadband have taken its place. Indeed, thanks to the *broadband influence*, there has been a revival of interest in the topic in recent years. The text-mining of the whole corpus of papers published in *Telecommunications Policy* made by Gómez-Barroso et al. (2018) shows that the frequency of use of the word "development" (declining from 2nd place in 1981-1985 to 17th place in 2006-2010) had risen in the period 2011-2016 (12th position), while broadband reached the no. 9 (not in the 20 top positions before 2006).

All the evidence collected in the bibliographical review made by this article suggests that there is a throughout positive demonstrable impact of telecommunications –as a whole sector, or broadband connections or mobile telephony– on economic outcomes, even when the financial crisis had unfolded. In the early years of the century, contributions advanced along the paths that had been opened up in the last decade of the 20th century (see xxx). Cronin et al. (1991) –first using causality tests–, Norton (1992) and Antonelli (1993) –first including telecommunication-related variables in particular growth equations models–, and Antonelli (1996) –first "explaining" the residual of a traditional production function by the changes in the uses of telecommunications services– keep deserving a word of recognition. In theoretical terms, most subsequent works build on those foundations. There have been no major changes during the last years. Some interesting and potentially promising different research avenues (input-output models, stochastic production frontier function) have been left relatively unexplored. Obviously, the difference lays in the increasing rigour and depth with which the models are built and validated, and in the completeness and accuracy of the databases used. All

in all, research in the field can be considered pretty mature. It is clear, nevertheless, that more can be done. The previous section offers some guidelines for taking research forward.

An aspect that cannot be ignored is how this research has added value to government decisions. Gómez-Barroso et al. (2018) devote a section to this issue, in general terms, concluding that "*the extent and manner in which this* [decision makers taking advantage of the progresses and ideas published in academic journals] *has happened is impossible to elucidate*". It can nevertheless be accepted that research is but one among the many sources of information for policy makers (Nutley, Walter, & Davies, 2003), and scientists should not expect a direct casual impact of their contributions: they are more likely to influence the climate of ideas, which in turn can shape public policy (John, 2013). Probably, an unelected and more permanent government audience, such as civil servants, may be more receptive to academic advice (Cairney, 2015). This advice should be more influential when researchers are hired to produce –or coproduce– publicly funded reports. The impact on policy making of documents of these kind –put aside in this article because of the reasons mentioned in the introduction– is most probably greater than the impact of academic papers. For researchers, this *extra job* comes at the cost of a lost of freedom: the process involves managing ambiguous loyalties, reconciling different interests, and negotiating competing goals (Orr & Bennett, 2012).

As a final remark, it should be highlighted that the impact of telecommunications goes further than just macroeconomic outcomes. In the course of this century, mobile telephony has made an overwhelming expansion in developing countries. Mobile phones are now present in the lives of poorest people of the world. Even if it is not reflected in national statistics or in international measurements for poverty reduction, their impact on the social and economic reality of those who devote much energy to juggling complicated lives is increasingly felt and, in most cases, clearly beneficial. Most of the papers that had dealt with the power of telecommunications to transform lives and livelihoods are based on anecdotal evidence, and therefore are out of the radar of the usual development causality studies. However, those examples are useful –or rather needed– to understand the full potentiality of telecommunications to change the world.

Despite this, information and communication technologies are not the only force changing economies, societies and cultures. Not everything is technology and technology cannot change everything. Moreover, there are risks of inequality that are inherent in any innovation. All this should not be forgotten. Or more precisely, it is important to remember it from time to time.

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