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BACKGROUND PAPER

Digital Dividends

Exploring the Relationship Between Broadband and Economic Growth

Michael Minges
ictData.org

Exploring the Relationship between Broadband and Economic Growth

Background Paper prepared for the
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by Michael Minges

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1 Introduction

Broadband can be characterized as high-speed, always-on Internet connectivity. It began to appear in some high-income countries in the late 1990s, using the copper wire in ordinary telephone connections (i.e., digital subscriber line (DSL)) or the coaxial cable in cable television networks (i.e., cable modem). In 2001, the first high-speed mobile networks were launched. Today commercialized fixed broadband networks reach download speeds of 1,000 Mb/s over fiber optic[1] and mobile broadband 300 Mb/s over fourth generation (4G) Long Term Evolution (LTE) networks.[2] By the end of 2014, there were some 748 million fixed broadband subscriptions and 2.7 billion mobile broadband subscriptions around the world.[3]

This relatively recent emergence of broadband has already stimulated much discussion of it being a powerful general-purpose technology.[4] Broadband has driven widespread changes in the Information Technology (IT) sector enabling services such as cloud computing and mobile apps. Equally, it is influencing innovation across many other sectors including health, transport and government. The impact of broadband Internet on the economy is therefore a subject of growing interest.

Economists have often modeled economic growth where output is a function of capital, labor and technology (*Barro and Sali-i-Martin 2004*). Econometric models use proxies to represent these variables such as investment for capital and employment for labor. In order to gauge the impact of broadband, it is used as the technology variable. The econometric models can be divided into three categories: *cross sectional, panel* and *time series*. The cross sectional studies are typically used to gauge the impact across a group of countries. Panel studies are used in observing the changes happening over time across a group of countries. Time series models have typically been used to investigate the impact in a single country. It should be noted that the economic impact of different Information and Communication Technologies (ICTs) have been studied for some time and these models have shaped the emerging framework for analyzing the effect of broadband (Roller and Waverman 2001).

This paper first looks at different studies on the economic impact of broadband illustrating the range of models and data that have been used. It then examines some of the issues that complicate the task of gauging how broadband impacts the economy. The paper concludes with a summary of the key results and suggestions for moving forward.

[1] Hong Kong Broadband Network. 2015. "Home Broadband, Wi-Fi Wireless Broadband & Roaming Data SIM." Accessed November 15. http://www.hkbn.net/new/en/access-plan.shtml#broadband--service-introduction.
[2] "SingTel First in the World to Offer Commercial 300Mbps 4G Service with Huawei Mobile Broadband Device." 2014. *News Release*, July 23. http://info.singtel.com/about-us/news-releases/singtel-first-world-offer-commercial-300mbps-4g-service-huawei-mobile-broadba.
[3] ITU. 2015. "Statistics." Accessed November 15. http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.
[4] World Bank. 2015. "Why Broadband?" Accessed November 15. http://broadbandtoolkit.org/1.3.

2 Studies on the economic impact of broadband

This section reviews three types of studies: i) cross-sectional and panel models covering a group of countries, ii) studies looking specifically at mobile broadband and iii) studies that examine the economic effect of broadband in a single country over time.

2.1 Fixed broadband

2.1.1 Cross sectional

The World Bank (*Qiang et al. 2009*) used a cross sectional analysis to examine the impact of various ICTs including fixed broadband on GDP growth during the period 1980-2006 for 120 developing and developed countries. The framework is based on the endogenous growth model (*Barro 1991*)[5]:

$$GDP_{8006} = \alpha_0 + \alpha_1 \times \mathrm{GDP}_{80} + \alpha_2 \times (\mathrm{I/GDP})_{8006} + \alpha_3 \times \mathrm{PRIM}_{80} + \alpha_4 \times \mathrm{BBPEN}_{8006} + \alpha_5 \times \mathrm{SSA} + \alpha_6 \times \mathrm{LAC} + \mu$$

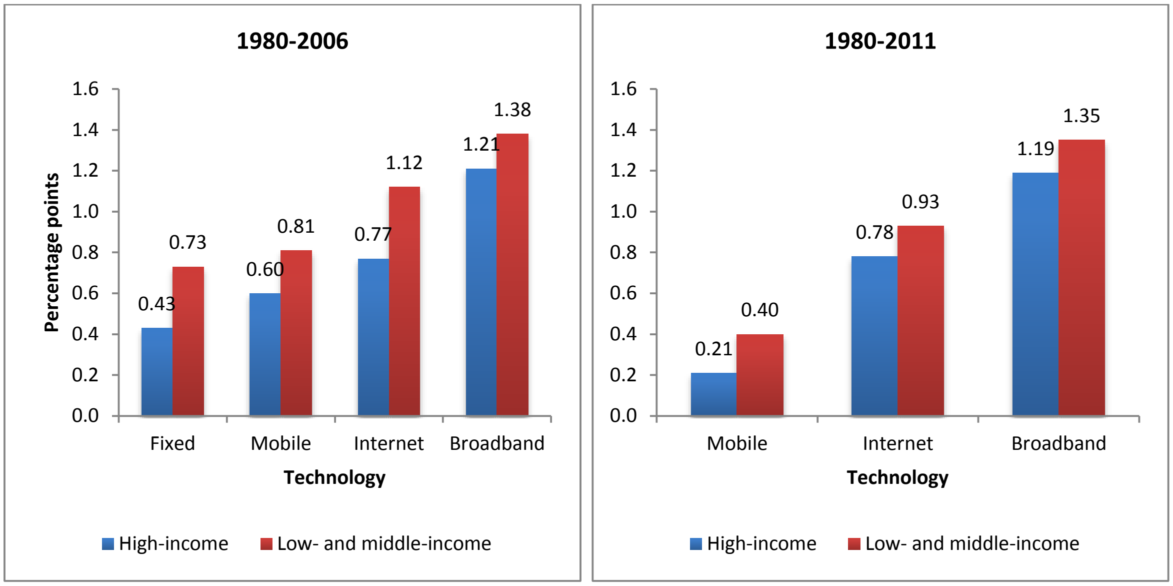
where GDP_{8006} is the average growth rate of real GDP per capita in US$ between 1980-2006, GDP_{80} is per capita GDP in 1980, I/GDP_{8006} is the average ratio of investment to GDP between 1980 and 2006, $PRIM_{80}$ is the primary school enrollment rate in 1980, $BBPEN_{8006}$ is the average fixed broadband penetration and SSA and LAC are dummy variables for countries in Sub-Saharan Africa and Latin America and the Caribbean (LAC) respectively.

The study concludes that a 10 percentage point increase in fixed broadband penetration would increase GDP growth by 1.21% in developed economies and 1.38% in developing ones. However while the coefficient was significant at the 1 percent level for developed economies the significance was only 10% for developing economies. The R^2 for the regression was 0.49. Separate regressions were also run for fixed telephone subscriptions, mobile subscriptions and Internet users. The results suggest that GDP growth will experience a higher increase when adding 10 mobile subscriptions per capita than adding 10 fixed lines but that broadband has the highest GDP growth increase (Figure 2-1).

This model has been updated using recent data (*Scott 2012*). The same model is used but with data for 86 countries for 1980–2011. The results were essentially the same as before with a ten percentage point increase in fixed broadband generating a 1.35% increase in per capita GDP for developing countries and a 1.19% increase for developed countries.

[5] Ironically, Barro later cast doubt on the precision of identifying, which independent variables are relevant for growth. See: Robert J. Barro. 2014. *Convergence and Modernization*. http://rbarro.com/wp-content/uploads/2011/01/convergence-modern-072714.pdf

Figure 2-1: GDP growth impact from 10 percentage point increase in different ICTs, by country economic development category



Source: Qiang et al. 2009 and Scott 2012.

2.1.2 Panel

A panel study with 25 Organization for Economic Co-operation and Development (OECD) countries covering the period 1996–2007 was carried out to estimate various broadband impacts and relationships (*Czernich et al. 2009*). First a production function with logged variables is used to determine the effect of the introduction of broadband:

$$log(y_t) = \alpha + \alpha_t + \alpha 1 \times D_t + \beta 1 \times log(s_t) + \beta 2 \times log(h_t) + \beta 3 \times n_t$$

where t is time, y is real GDP per capita (in 2000 PPP), α is a year dummy, D is a binary value equal to 1 after a country has introduced broadband, s is Capital Formation (% of GDP), h is average number of years of schooling and n is the growth of the working age population. **It finds that GDP per capita growth is 2.7 to 3.9 percent higher after the introduction of broadband** (range reflects the different regressions used). R^2 in this model is 0.86. Education and working age population were found to be insignificant. To measure the effect of broadband diffusion on GDP growth, the above framework is applied with several modifications. The dummy variable of broadband introduction is substituted with broadband penetration (B_t) and the initial level of GDP per capita before broadband introduction (y) is introduced as the endogenous growth theory suggests (*Barro 1991*), while adding the years since broadband appearance to control for timing effects (T), because broadband was introduced in different years for different countries:

$$\Delta \log Y_t = \alpha + \alpha_1 B_t + \beta_1 \Delta \log s_t + \beta_2 \Delta \log h_t + \beta_3 \Delta n_t + \beta_4 \log y + \beta_5 T_i + u_t$$

They conclude that an increase in broadband penetration by 10% increases GDP growth by 0.65%, but their regression has an R^2 equal to 0.30. These frameworks do not determine any causal effects and they might suffer from endogeneity, as the introduction and diffusion of broadband can depend on the economic development of a country. To solve such potential problems, an *instrumental* *variable* approach is used[6] to estimate broadband penetration consisting of several parameters such as the existing traditional telephone and cable television networks, diffusion speed and inflexion point. This estimated broadband penetration is then used in the equation above. **It found that an increase of 10% in broadband penetration would increase GDP per capita growth by 0.9-1.5%.** R^2 of the regressions using such an approach is very low, varying from 0.14 to 0.35.

Another panel study (*Koutroumpis 2009*) uses a macroeconomic production function. The research covers 15 European Union countries based on data collected for the period 2003–06 (60 observations). Variables are transformed to logs with the following equation:

$$log(GDP_t) = a_0 + a_1 \times log(K_t) + a_2 \times log(LF_t) + a3 \times log(PEN_t) + a4 \times log(EDU_t)$$

where t is time, GDP is Gross Domestic Product in millions of euros, K is stock of investment (less telecommunications) in millions of euros, LF is Population with full or part time work aged 15-64 in millions, PEN is fixed broadband penetration and EDU is Population with tertiary education per 100 population aged 25-64. In contrast to most other studies, the capital stock rather than annual fixed capital formation is used. Four different regressions were run using two different techniques (Generalized Method of Moments (GMM)[7] and Three-Stage Least Squares (3SLS)) with two different control parameters (random and fixed country and year effects). **All found broadband penetration to have a significant impact on GDP growth ranging from 0.26% to 0.85% for each ten percentage point increase in penetration.** All regressions had a high R^2 (0.98-0.99).

2.1.3 Non-linear

A non-linear model is used for a study on broadband economic impact in Latin American and Caribbean (LAC) countries (*Zaballos and López-Rivas 2012*). Independent variables were selected from a group of 87 initial indicators assumed to have an impact on the factors affecting GDP (e.g., investment, consumption, public spending, and trade surplus or deficit). The four resulting independent variables were those that were not correlated to each other, which provided the best fit in terms of robustness (maximum self-determination coefficient, minimum coefficient of variation of residuals, and conditions of non-heteroskedasticity, nonautocorrelation, and non-multicolinearity). Data covers 26 LAC countries for the period 2003–09 with the economic impact calculated for three different periods: 2003–05, 2003–07 and 2003–09. The non-linear model was specified as:

$$Y1^n = Z - Z1 + Z2 - Z3 - Z4 + Y - Y^2$$

Where Y1 is GDP per capita, Z is the constant, Z1 is the interest rate spread, Z2 is the interest on new debt, Z3 is multilateral debt, Z4 is net official development aid and Y is fixed broadband penetration per 100 inhabitants. **The results found that a 10 percent increase in fixed broadband penetration triggered an average increase of 3.19 percent in per capita GDP**.

[6] This consists of two stages, where in the first, the instrument is estimated and in the second stage the estimated instrument is used as an independent variable.
[7] GMM is often used as an estimation technique if there are endogenous variables since the least squares estimator may be biased and inconsistent.

Table 2-1: Cross-section/panel models, fixed broadband impact

Study	Number of countries	Years	Increase in GDP per 10 percentage point increase in fixed broadband penetration	Comment
Qiang et al. 2009 (High-income economies)	120	1980–2006	1.2	Impact on per capita GDP
Qiang et al. 2009 (Low-income economies)		1980–2006	1.4	Impact on per capita GDP
Czernich et al. 2009	25 OECD (300 observations)	1996–2007	0.9-1.5†	Impact on per capita GDP
Koutroumpis 2009	15 European Union (60 observations)	2003–2006	0.3-0.9†	Impact on GDP
Zaballos and López-Rivas 2012	26 Latin America and the Caribbean (121 observations)	2003–2009	3.2	Impact on per capita GDP

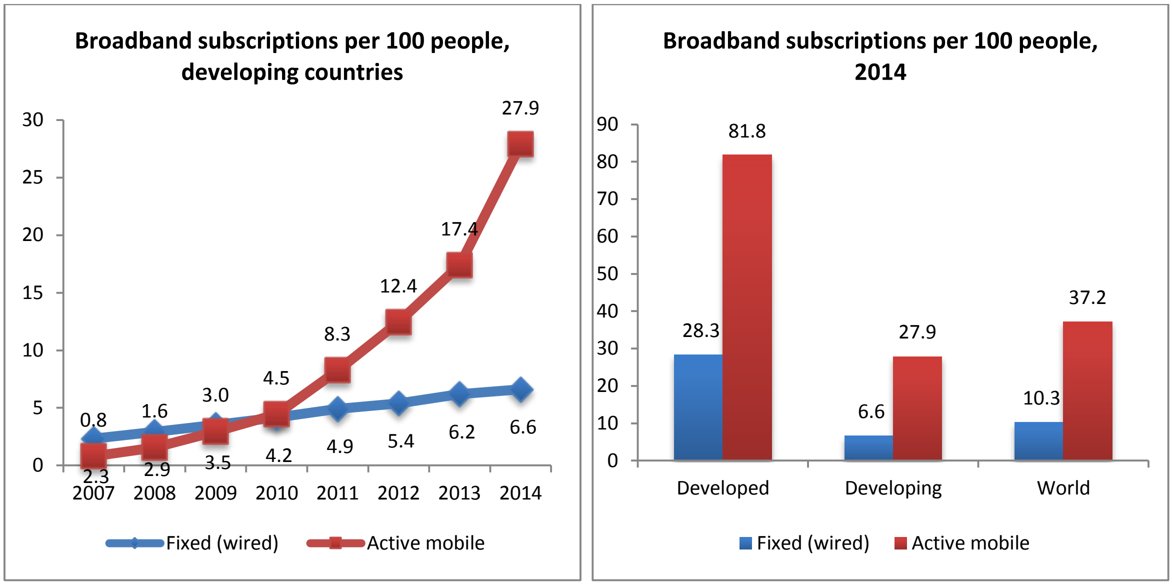
Note: † More than one regression method used.

Source: Adapted from studies listed in first column.

2.2 Mobile broadband

Studies on mobile broadband are particularly relevant given the rapid diffusion of mobile technology in developing countries. Mobile has grown particularly fast due to i) a lenient regulatory environment allowing competition and private sector investment, ii) the ease by which wireless networks can be installed compared to wired infrastructure and iii) flexible payment options (i.e., prepaid cards). By the end of 2014, the International Telecommunication Union (ITU) estimated that fixed telephone connections in developing countries were just 10 per 100 people compared to 91 mobile subscriptions per 100 people. Similarly, high-speed wireless Internet technologies have been more successful in developing countries than wired broadband. By 2014, mobile broadband penetration was over four times higher than fixed broadband penetration in developing countries (Figure 2-2).

Figure 2-2: Fixed and mobile broadband subscriptions



Source: Adapted from ITU data.

One study (*Thompson and Garbacz 2011*) uses panel data for a sample of developed countries covering the years 2005 to 2009. Unlike most studies using use per capita indicators, variables are converted to per household indicators to measure the impact of fixed and mobile broadband on GDP per household. GDP per household is generalized as a function of the following variables:

$$GDPHH = f(KHH, LABHH, LABEDHH, EDHH, EFI, FIXEDBBHH, MOBILEBBHH, time\ dummies)$$

where GDPHH is Gross Domestic Product per household (constant 2000 dollars), KHH is capital stock values updated with Gross Fixed Capital Formation using the perpetual inventory method (per household), LABHH is labor force participation per household, LABEDHH is tertiary enrollment per laborer per household, EDHH is total tertiary enrollment per household, EFI is the Economic Freedom Index, FIXEDBBHH is fixed broadband per household and MOBILEBBHH is mobile broadband per household. The study includes country and time fixed effects, finding that **every 10 percentage point increase in fixed broadband household penetration increases GDP per household by 0.77** (significant at the 10% level). On the other hand, **every 10 percentage point increase in mobile broadband household penetration is found to *reduce* GDP per household by 0.52** (significant at the 1% level). The adjusted R^2 was 0.96. The study concludes that the mobile broadband result could be due to nonproductive applications of mobile broadband technology where it might be an uneconomic substitute or complement to existing fixed broadband. The results are questionable. The study contends that previous research (*Wallsten 2009*) suggests that household penetration of broadband is a better indicator than a per capita measurement. However, instead of using household survey data, the study constructs a synthetic variable dividing broadband subscriptions by the average number of households in the country. This is also repeated for other variables. There is also a possible model misspecification caused by an overbalance of labor and education in the independent variables and including both fixed and mobile broadband penetration together.

In a study prepared for the GSM Association (*Deloitte 2012*), the impact of a substitution from 2G to 3G penetration on GDP per capita growth is estimated. They use a panel of 96 countries for a 4-year period 2008–11. The regression is based on the endogenous growth model with variables converted to natural logs with an implicit lag:

$$\ln(GDPpercap_t) = \gamma \times \ln(GDPpercap_{t-1}) + \alpha_2 \times \ln(GDPpercap_{t-2}) + \beta \times \ln(MobPen_t) + \delta \times \ln(3GPen_t) + X_t'\Gamma + n$$

where t = time (years), GDPpercap = annual growth rate of real GDP per capita, MobPen = mobile penetration; 3GPen = 3G penetration; X' includes government expenditure (as a % of GDP), trade (as a % of GDP), investment (as a % of GDP) and labor force; and n is a country fixed effect. A Generalized Method of Moments (GMM) estimator is used. **The model estimates that a 10% higher 3G penetration results in an increase of 0.15 percentage points in the annual growth rate of GDP per capita**. The study also estimated the impact of mobile data usage across 14 countries finding that a doubling of mobile data consumption raises GDP by 0.5 percentage points.

2.3 Country studies

A number of country level studies on the economic impact of broadband have emerged. They use two basic approaches: national level data generally with quarterly data to ensure sufficient observations or panel data based on the administrative divisions of the country (e.g., states, provinces, counties, districts, etc.). In the latter case, if there are a sufficient number of administrative divisions, these can be substituted for a lack of broadband time series data. The studies generally adopt models based on classical economic growth theory.

2.3.1 Cross-sectional models using administrative units

2.3.1.1 China

A study for China (*Feng and Ma 2013*) develops a simultaneous equation model consisting of a broadband diffusion equation based on users' discrete choice behavior and an economic growth equation, endogenizing the mutual effects between broadband diffusion and economic growth. It uses administrative data covering 31 provinces, municipalities and autonomous regions in China from 2004 to 2009. The regression model uses natural logs to transform the data:

$$\frac{\partial \ln\left(GDP_{it}\right)}{\partial \ln\left(PEN_{it}\right)} = \beta_3 + 2\beta_4 \ln\left(PEN_{it}\right) + \beta_{13} \ln\left(K_{it}\right) + \beta_{23} \ln\left(L_{it}\right)$$

where GDP = Gross Domestic Product, PEN = Fixed broadband penetration, K = Capital stock and L = Manpower. The authors claim that this model corrects for the “pulling effect” of GDP to broadband, examining the “pushing effect” of broadband to GDP. They found that for **every 10 percentage point increase in broadband penetration there was a 2.14% increase in GDP**.

2.3.1.2 Germany

This cross-sectional study (*Katz et al. 2010*) uses data from 424 German *Landkreise* (administrative unit beneath a "Länder"). The regression model calculates the impact on the growth in GDP between 2003 and 2006 for each percentage change in broadband growth. There is an implicit lag for broadband penetration where the values are averaged for 2002–03:

$$G\_GDP_{03-06} = \beta 1 \times GDP\_Capita_{2000} + \beta 2 \times G\_POP_{00-06} + \beta 3 \times G\_BBPEN_{02-03}$$

where $G\_GDP_{03\text{-}06}$ = Growth of GDP between 2003-06, GDP_Capita_{2000} = GDP per capita in 2000 and $G\_BBPEN_{02\text{-}03}$ = Broadband penetration growth between 2002-03. The model predicted that for **each 10% increase in broadband *penetration growth*, GDP growth increases by 0.255** with an adjusted R^2 of 0.63.

2.3.1.3 United States

This study (*Crandall et al. 2007*) uses data for 48 states covering the 2003-05 period to measure the impact of broadband on GDP. It is unique in that other than an employment variable, it uses nontraditional independent factors such as temperatures, union membership and tax rates that the authors believe could account for the growth in output. Although the **effect of broadband is positive, the estimated coefficients are not statistically significant** and the R^2 is relatively low.

2.3.2 Time series models at the national level

2.3.2.1 Ecuador

A study on broadband impact in Ecuador is interesting for its unique methodological approach (*Katz and Callorda 2013*). It is based on micro data from Ecuadoran household surveys carried out between 2009 and 2011. Given the low level of broadband availability in rural areas, only urban zones were considered. The resulting study is based on 24,028 individual observations. The model predicts the increase in household income based on whether it had broadband connectivity. The model specification is:

$$Y2009–11 = \alpha + \gamma Treatment + \beta X + u + t + e$$

where Y is the individual's income; γ estimates the impact of broadband "treatment" (1 if the individual was treated, 0 if not); X is a vector of control variables including age, gender, education, health coverage, type of occupation, and position in the household; u is a provincial fixed effect and t is a yearly fixed effect. The study found that **if a household had broadband the average annual increase in income was US$25.76 (3.67%)**. The results were statistically significant but R^2 was low (0.41).

2.3.2.2 Panama and Philippines

The Broadband Commission for Digital Development and the ITU sponsored two studies on the economic impact of broadband.[8] Both use a production function to estimate the impact:

$$GDP_t = a1 \times K_t + a2 \times L_t + a3 \times BB\_Pen_t$$

[8] ITU. 2012. "Broadband Commission Releases First Country Case Studies." *Press Release*, May 15. http://www.itu.int/net/pressoffice/press_releases/2012/28.aspx#.VkiwF4Q7P2x.

where t = time, GDP = Gross Domestic Product in constant USD (2000), K = Gross fixed capital formation in constant USD (2000), L = Labor force with secondary education and BB_Pen = broadband penetration (two regressions carried out; one for fixed and one for mobile).

The study for the Philippines (*Katz and Koutroumpis 2012b*) looked at the economic impact of both fixed and mobile broadband. It uses quarterly data at a national level for the period 2000-2010. The study ***found no significant impact for fixed broadband penetration***. However, **a ten percentage point increase in mobile broadband penetration was found to contribute 0.32% to GDP**. While the R^2 for both regressions was high, the number of observations was limited (36 for fixed and 25 for mobile).

In contrast, the study for Panama (*Katz and Koutroumpis 2012a*) (covering the same years as the Philippines), found that **a ten percentage point increase in fixed broadband penetration boosted GDP by 0.44%.** One reason is the higher level of broadband penetration in Panama. By 2010 fixed broadband subscriptions per 100 people stood at 7.0 in Panama compared to 1.8 in the Philippines.

2.3.2.3 Senegal

A study for Senegal (*Katz and Koutroumpis 2012c*) covering the years 2004 to 2011 uses a production function to estimate the impact of broadband on economic growth:

$$GDP_t = a1Kt + a2Lt + a3BB\_Pent + !1i$$

The results found **a negative impact for fixed broadband although the results were not statistically significant.** In contrast to other findings that broadband has the biggest economic impact of all ICTs, **simple 2G mobile penetration was found to have a bigger and more significant impact than fixed broadband** on the Senegalese economy. Each 10 percentage point increase in mobile penetration was found to raise GDP growth by 0.44% (at a 10% significance level).

Table 2-2: Summary of national studies

Country	Dependent variable	Independent variables (in addition to broadband penetration)	Observations	Dates	R^2	Fixed BB Multiplier X 10
Philippines	GDP in constant USD (2000)	GFCF in constant USD (2000) Labor force with secondary education	36 (Q)	2001-2010	0.99	0.02†
Senegal	GDP (Growth)	Labor force Fixed Capital Stock	17 (Q)	2003-2011	Not stated	-0.03†
Panama	GDP in constant USD (2000)	GFCF in constant USD (2000)	40 (Q)	2000-2010	0.99	0.45

		Labor force with secondary education				
China	Real GDP	Capital stock Labor force	31 (panel, provinces)	2004-2009	0.99	2.14
Germany	GDP growth 2003:06	GDP per capita 2000 Population growth 2000:06	424 (panel, Landkreise))	2002-03	0.63	0.255 (10% increase in broadband penetration growth)
United States	GDP Nonfarm Private Sector (current)	Mean Annual Temperature Business Tax Climate Index Union Share of Employment Share of College Graduates in Adult Population Average Hourly Earnings Regional (Dummy) Variables	48 (panel, states)	2004	0.63	0.161†

Note: † Not statistically significant.

2.4 Conclusions

A variety of models have been designed to measure the impact of broadband on the economy with different formulas and variables, for both cross-country and within country analysis. In general, they share some common findings:

- Almost every study, despite the methodology and whether it was cross-country or single country, found a positive economic impact from fixed broadband. However, the results were sometimes not statistically significant (particularly for developing countries). There appears to be agreement with most studies that the impact is only noticeable after a certain threshold of broadband penetration though the exact level remains imprecise.

- While most studies suggest a certain threshold of penetration is necessary before a significant economic impact is discernible from fixed broadband, the evidence is inconclusive about whether there are diminishing returns. One study found the higher the level of broadband penetration, the higher the impact due to network effects (*Koutroumpis 2009*).

- The evidence is inconclusive about whether fixed broadband has a bigger impact on the economy compared to other ICTs. This was not tested in every study. In those where it was, one study found that of all ICTs (i.e., fixed telephones, mobile, Internet use and broadband), broadband has the biggest economic impact (*Qiang et al. 2009*). However another study found that in a low-income economy, mobile has a bigger impact, both in terms of basic subscriptions and mobile broadband (*Katz and Koutroumpis 2012c*). One study found that mobile broadband actually has a negative impact possibly due to its complementarity effect and non-productive application (*Thompson and Garbacz 2011*).

There is no consensus about the appropriate framework. Data availability typically imposes a certain econometric model. For example cross sectional studies are often used for groups of countries and time series models for a single country. However there are also panel time series for groups of countries and averaged time period studies for single country analysis. The classical production function with proxies for capital, labor and technology is often used. On the other hand, there are some models with distinctive independent variables. Different estimators are also used ranging from ordinary least squares to non-linear models, with data either unadjusted or transformed through logs. The description of the techniques and emphasis on the econometric implications often dominate studies implying their model is optimum for controlling various factors. Some models run several regressions with different assumptions and provide a range of possible impacts. These statistical debates cast some doubt on results, as there will inevitably be some violation of econometric principles or a poor fit of the data to the model.

3 Analytical issues

There are a number of issues affecting the analysis of the economic impact of broadband. These include variable selection, model design, data availability and definitions, causation and the financial crisis of 2008–09.

3.1 Models

Many of the models are derivations of the classical growth model with broadband representing technological influence. They generally have dependent variables based on some variation of income (GDP) and independent variables for investment and labor. The variable selection varies. The lack of agreement about what a broadband economic impact model should look like creates some reservation about the reliability of the estimates.

While many models derive from economic growth theory, they use different variations for the variables. For example, growth is typically some derivation of national income (e.g., Gross Domestic Product) but varies from GDP per capita (either in constant or non-inflation adjusted values), GDP growth (either based on actual GDP or per capita GDP) to total GDP. Cross sectional models generally convert economic value indicators to a common currency sometimes with market values and other times using purchasing power parities. Some models use logs. All of these factors introduce subtle influences, which affect the results.

According to classical economic theory, the investment indicator should represent the total value of capital stock in the country whereas most of the studies use flow data due to the lack of availability and comparability of stock data.

3.2 Lag

Some of the studies lag the broadband variable under the assumption that its impact on economic output takes a while to register. However there remains a lack of clarity about whether there is a lag effect, and if so, how many periods the lag should be. One study found that lagging broadband penetration did not make much difference with nearly the whole growth-enhancing effect of broadband appearing to be "contemporaneous" with the diffusion of broadband (*Czernich et al. 2009*). Statistical techniques such as cross-correlations can be used to investigate lag effects.[9]

3.3 Data

There are a number of issues with the data needed to carry out broadband economic impact analysis. This includes no (or poor) data, insufficient observations and the challenges of integrating diverse data sets. At least 30 observations are needed for a simple regression and 10 more observations for each additional independent variable.[10] Most models include investment and labor variables in addition to a broadband indicator suggesting a minimum of 50 observations are needed. Cross-sectional analysis generally does not suffer from a lack of observations since they are carried out over a large number of countries. The lack of observations is a shortcoming for national level studies. Most international data sets on fixed broadband penetration are annual times series and begin in 1998 when only ten countries had data. Even those ten would not have sufficient annual observations for an acceptable regression (minimum of 30 whereas annual data from 1998-2013 would only consist of 16 observations).

Two approaches can be taken to generate sufficient observations for a country study. One is to move to a more *discrete time* interval (e.g., quarterly) and the second is to use *national administrative divisions* with the statistics broken down at a provincial, state or lower level. However, obtaining the necessary data is difficult since quarterly data is not always compiled for every indicator needed at a national level. Furthermore, some countries do not have enough regional data for the level of administrative data they publish. Assuming quarterly data was available, then the 100 or so countries that launched broadband by early 2002 would have 48 observations by the end of 2013.

Another challenge is assembling the data set required for the analysis, particularly for national level studies. Given that quarterly data are generally required for national level studies then international data sets are not of much use since they typically only offer annual time series. One exception is Eurostat but data are only available for European Union members. For other countries, suitable data from the relevant government agency must be located and then reformatted to fit into the statistical tool, a process that is often more time consuming than running and modifying regressions. In many instances, particularly for low-income economies, the required data with the necessary time interval are not publicly available, if even compiled at all. When data are available, they were not always in the form of a complete data set for the years required so historical data has to be combined with data that are more recent. Managing such a large data set requires an adequate statistical database management tool.

[9] Three statistical techniques for testing lag data are: Schwarz's Bayesian information criterion (SBIC), the Akaike's information criterion (AIC), and the Hannan and Quinn information criterion (HQIC). See Oscar Torres-Reyna, "Time Series" at http://www.princeton.edu/~otorres/TS101.pdf

[10] See "PPA 696 RESEARCH METHODS" at: http://www.csulb.edu/~msaintg/ppa696/696regmx.htm

3.4 Broadband definitions

There is no agreed upon international definition of broadband. The ITU refers to a minimum speed of 256 kb/s for its statistical collection[11] though it is unknown how strenuously this is enforced. OECD has defined broadband as not being dial-up (*OECD 2013*). This implies that the speed is not as critical but rather the fact that the connection is "always-on."[12] This assumption is arguable since the speed of the broadband connection has been found to have differing economic impacts (

[11] International Telecommunication Union (ITU). 2011. *Handbook for the Collection of Administrative Data on Telecommunications/ICT*. http://www.itu.int/en/ITU-D/Statistics/Pages/publications/handbook.aspx.

[12] It examined the increase in GDP based on the assumption that dial-up had continued to be the only way of accessing the Internet to calculate a broadband bonus.

Box 4-1).

Almost all studies use fixed broadband subscriptions per 100 people as an independent variable. There has been little investigation about whether other indicators might be more appropriate (e.g., household or business penetration). Per capita penetration figures might distort comparisons since household sizes and the ratio of business subscriptions vary. Where models have used household data the methodology has been questionable such as taking broadband subscriptions and simply dividing them by the number of households rather than using survey data.

Care must also be exercised in interpreting results since some studies use broadband penetration whereas a few have used the growth in penetration.

There are significant issues with the inclusion of mobile broadband. First, the ability to use mobile broadband is dependent on the device and coverage. A mobile broadband subscription using a dongle and laptop would likely have different economic implications than using mobile broadband with a handset or smartphone. Second, there are problems with identifying active users versus those with the theoretical ability to use mobile broadband.[13] Third, it is not clear whether broadband should be looked at overall—combining fixed and mobile subscriptions—or each mode should be examined separately. Existing studies always treat mobile and fixed broadband as separate variables.

3.5 Financial crisis

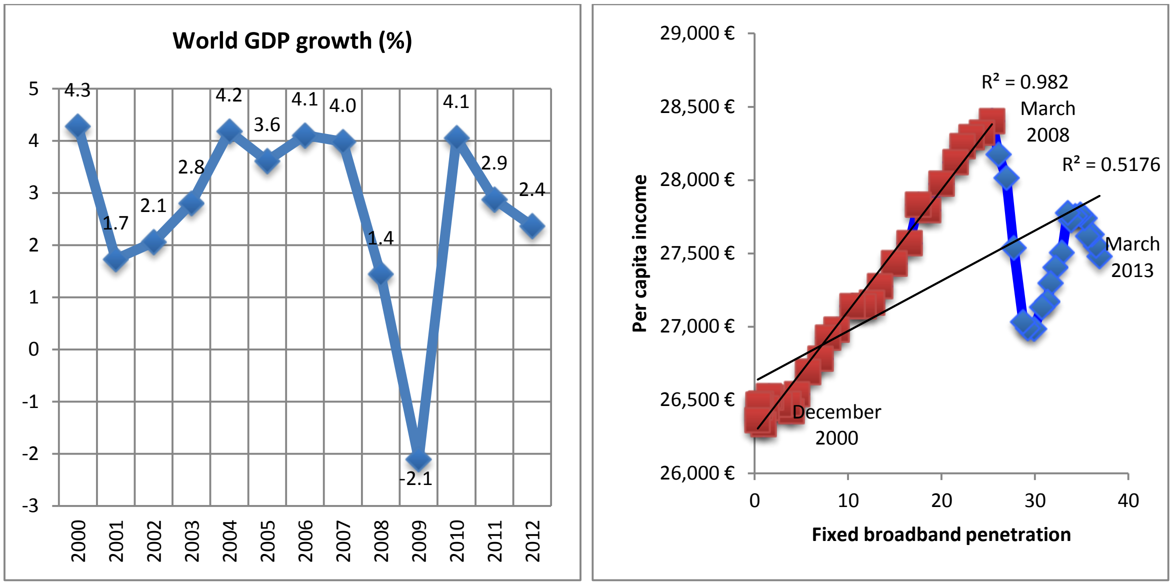
The financial crisis of 2008–09 triggered a sharp fall in global economic output. World GDP growth dropped from 4% in 2007 to 1.4% in 2008 and was a negative 2.1% in 2009 (Figure 3-1, left). The effect was larger for high-income economies but all income groups registered a decline in growth. This affects broadband economic impact models since the decline in economic growth will distort the results. For example, while the relationship between fixed broadband and per capita income in France was quite strong between December 2000 and March 2008, it become significantly less so after that (Figure 3-1, right).[14] Most studies use data before the financial crisis. It is important to gauge broadband economic impact using recent data, particularly since the analysis can then be applied to a wider group of economies where broadband penetration has passed relevant thresholds. Several techniques could be applied to minimize the distorting effect of the financial crisis. For example, a study carried out in Egypt *excluded* two years because of the political crisis in that country.[15] Another option is to *re-estimate* GDP for those years, as if the financial crisis had not occurred. A third is to use a *dummy* variable for the periods of negative economic growth.

[13] ictDATA.org. 2013. "Mobile Internet in Europe," January 16. http://www.ictdata.org/2013/01/mobile-internet-in-europe.html.

[14] The weaker link between fixed broadband penetration and GDP per capita in France after the financial crisis provides some argument against income causation. For example, fixed broadband penetration grew 11.5 percentage points after the financial crisis despite declining GDP per capita.

[15] "Measuring Impact of ICT - EGYPT." 2013. Presented at the Capacity Building Workshop on Measuring the Use and Impact of ICT on Social and Economic Development, Tunis, December 17. http://css.escwa.org.lb/ICTD/3272/2-1.pdf.

Figure 3-1: World GDP growth and relation between fixed broadband and per capita income in France



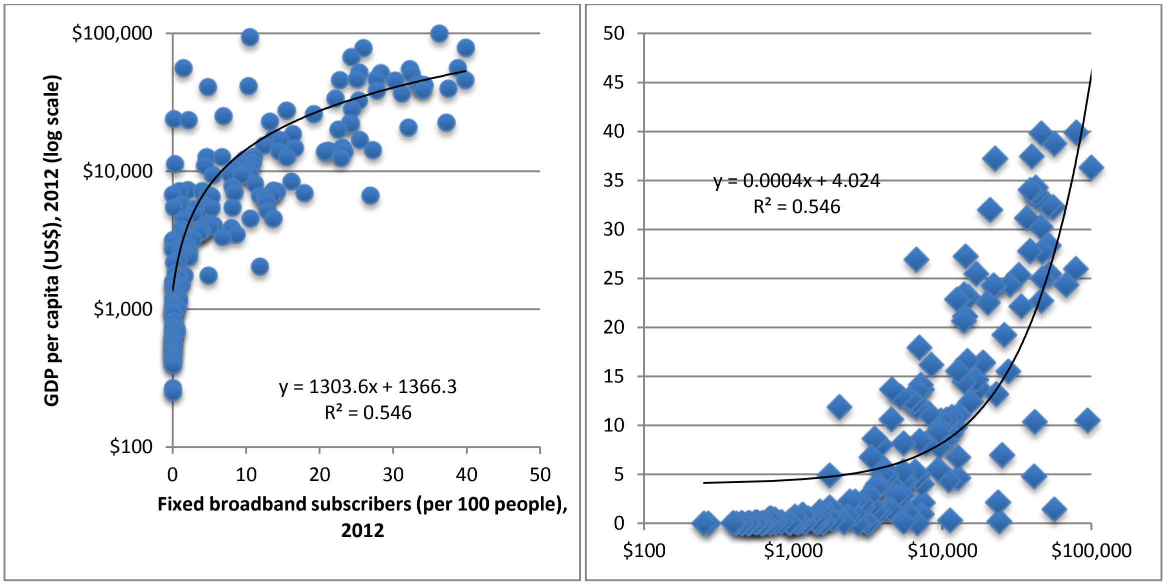
Note: In the left chart, annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2005 U.S. dollars. In the right chart, each marker represents a quarter between 2000 and 2013.

Source: Adapted from World Bank, Eurostat and ARCEP data.

3.6 Causation

One challenge in analyzing broadband and economic growth is the direction of the causality. In other words, does the level of economic development impact broadband penetration or is it the other way around? The simple linear charts below illustrate this dilemma as well as how closely related fixed broadband penetration is to income levels. The charts can be interpreted in two ways: either a ten percentage point increase in broadband increases GDP per capita by US$13,036 or a US$1,000 increase in per capita income increases broadband penetration by 0.4. The causality likely works in both ways. There is typically mutual feedback between the economy and factors that influence it. A downturn in growth affects capital and labor markets through less investment and lower employment. Some of the economic broadband studies feature a structural model with a series of equations including one for demand. Broadband penetration is generally modeled as a function of price and income in the demand equation but is awkwardly linked to the output equation to account for causality. Other models estimate broadband penetration as a function of other factors and use that as the independent variable in an effort to weaken the correlation between income and broadband penetration. Neither is satisfactory and while econometric models are useful tools for estimating relationships, they cannot prove causation.

Figure 3-2: What causes what?



Note: Each bubble represents one country.

Source: Adapted from World Bank data.

4 Recommendations

A wide number of models have been used to study the economic impact of broadband with different frameworks, variables and regression techniques. The lack of uniformity has constrained the analysis of the different economic impacts in individual countries using a common framework.

Mobile broadband has emerged as the high-speed network of choice for developing nations. Much more research is needed on the nature of its impact and use. It is more difficult to model mobile broadband impact due to the "fuzziness" of the variable. Unlike fixed broadband, mobile broadband subscription data are overstated when compared to usage surveys; in the United States there was a significant revision of the official data to account for this. The impact of the device used with mobile broadband is also likely to vary: access from a mobile phone would have different economic significance than from a computer or a machine.

While the focus of this paper has been on the impact of broadband penetration on economic growth, there is a need to extend analysis to other affects (e.g., employment, productivity) as well as other dimensions of broadband (e.g., business penetration, speed, etc.) (Box 4-1).

Box 4-1: Other economic dimensions of broadband

In addition to the economic impact of broadband, other studies have examined different impacts or used different broadband conceptualizations. Several studies have estimated the impact of broadband on employment **finding gains of between 2.5 and 4.0 additional jobs for each broadband job** (*Kelly and Rossotto 2012*). Other studies have estimated the impact of broadband on the employment creation rate; a study (*Katz 2009*) for 12 Latin American countries found that **closing the broadband gap of some 11 million lines would result in an increase of 378,000 jobs**.

One study (*Ericsson 2013*) looked at the *quality* of the broadband connection, measured as the average download speed, to estimate the economic impact finding that **doubling broadband speeds adds 0.3 percent to GDP growth**.

Bibliography

Barro, Robert J. 1991. "Economic Growth in a Cross Section of Countries." *The Quarterly Journal of Economics* 106 (2): 407–43. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=227295

Barro, Robert J., and Xavier Sala-i-Martin. 2004. *Economic growth*. 2nd ed. Cambridge, Mass: MIT Press. http://mitpress.mit.edu/books/economic-growth

Crandall, Robert, William Lehr, and Robert Litan. 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data." *The Brookings Institution, Issues in Economic Policy*, June. http://www.brookings.edu/research/papers/2007/06/labor-crandall.

Czernich, Nina, Oliver Falck, Tobias Kretschmer, and Ludger Woessmann. 2009. *Broadband Infrastructure and Economic Growth*. http://papers.ssrn.com/abstract=1516232.

Deloitte. 2012. *What is the impact of mobile telephony on economic growth?* GSM Association. http://www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf.

Ericsson. 2013. *Socioeconomic Effects of Broadband Speed*. http://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf.

Feng, Yongsheng, and Yuan Ma. 2013. "Broadband Diffusion and Economic Growth—An Empirical Research Based on Provincial Level Data of China."

Katz, Raul. 2009. "Estimating Broadband Demand and its economic impact in Latin America". presented at the III Conference Acorn-Redecom, Mexico City, September 4. http://www.acorn-redecom.org/presentation/acornredecom2009presentationKatz.pdf.

Katz, Raul, and Fernando Callorda. 2013. *Impacto del despliegue de la banda ancha en Ecuador*. http://www.teleadvs.com/wp-content/uploads/Katz-Callorda-DIRSI-version-final-revisada_2.pdf.

Katz, Raul, and Pantelis Koutroumpis. 2012a. *The economic impact of broadband in Panama*. ITU. http://www.itu.int/ITU-D/treg/broadband/BB_MDG_Panama_BBCOM.pdf.

———. 2012b. *The economic impact of broadband in the Philippines*. ITU. http://www.itu.int/ITU-D/treg/broadband/BB_MDG_Philippines_BBCOM.pdf.

———. 2012c. "The Economic Impact of Telecommunications in Senegal." *Communications & Strategies* 2 (86): 21–42.

Katz, Raul, Stephan Vaterlaus, Patrick Zenhäusern, and Stephan Suter. 2010. "The impact of broadband on jobs and the German economy." *Intereconomics: Review of European Economic Policy* 45 (1): 26–34.

Kelly, Tim, and Carlo Maria Rossotto, eds. 2012. *Broadband Strategies Handbook*. Washington DC: World Bank. http://broadbandtoolkit.org/Custom/Core/Documents/Broadband Strategies Handbook.pdf.

Koutroumpis, Pantelis. 2009. "The economic impact of broadband on growth: A simultaneous approach." *Telecommunications Policy* 33 (9): 471–85. doi:10.1016/j.telpol.2009.07.004.

OECD. 2013. *Measuring the Internet Economy*. OECD Digital Economy Papers. Paris: Organisation for Economic Co-operation and Development. http://www.oecd-ilibrary.org/content/workingpaper/5k43gjg6r8jf-en.

Qiang, Christine Zhen-Wei, Carlo Rossotto, and Kaoru Kimura. 2009. "Economic Impacts of Broadband." In *Information and Communications for Development*. Washington D.C.: World Bank. http://siteresources.worldbank.org/EXTIC4D/Resources/IC4D_Broadband_35_50.pdf.

Roller, Lars-Hendrik, and Leonard Waverman. 2001. "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach." *American Economic Review* 91 (4): 909–23.

Scott, Colin. 2012. "Does Broadband Internet Access Actually Spur Economic Growth?" http://www.eecs.berkeley.edu/~rcs/classes/ictd.pdf.

Thompson, Herbert, and Christopher Garbacz. 2008. "Broadband Impacts on State GDP : Direct and Indirect Impacts." In *17th Biennial Conference of the International Tele-communications Society, Montreal, June 24-27.*, 1–17. http://www.imaginar.org/taller/its2008/62.pdf.

———. 2011. "Economic Impacts of Mobile Versus Fixed Broadband." *Telecommunication Policy* 35 (11): 999–1009. doi:10.1016/j.telpol.2011.07.004.

Wallsten, Scott. 2009. "Understanding International Broadband Comparisons: 2009 Update". Technology Policy Institute. http://www.techpolicyinstitute.org/files/understanding%20international%20broadband%20comparisons%202009%20update%207-9.pdf.

Zaballos, Antonio García, and Rubén López-Rivas. 2012. *Socioeconomic Impact of Broadband in Latin American and Caribbean Countries*. Inter-American Development Bank. http://publications.iadb.org/handle/11319/5754?locale-attribute=