# Does broadband Internet access actually spur economic growth?

Colin Scott

December 7, 2012

In this paper I attempt to answer a relatively straightforward question: does broadband Internet access spur economic growth? Here, broadband refers to any Internet connection that is "always on and faster than the traditional dial-up access." [1], and economic growth refers to gross domestic product (GDP) of individual countries[1].

Intuitively, it seems clear that access to broadband Internet should engender economic growth. For example, access to broadband allows individuals educate themselves (thereby contributing to a nation's overall human capital stock), helps organizations streamline business procedures and cut costs, yields access to new buyers and sellers in remote markets, enables new business models (consider telemedicine), facilitates more efficient market prices by reducing information asymmetry, forms an important part of an overall business environment that is conducive to growth, and catalyzes the forming of organizations between individuals who normally wouldnt be connected.

Indeed, the ICTD research community generally believes that broadband spurs economic growth [2]. In fact, several groups are leading major projects based on this assumption. Berkeley's Tier group [3] is working on building cheaper, easier to deploy long-distance wifi technologies. University of California Santa Barbara has a group looking at satellite and cellular technologies for rural communities [4]. IIT Delhi in India is working on content distribution networks for rural areas in India [5], and New York University is working on maintenance challenges in rural broadband networks [6]. If their assumption is true, their results stand to directly impact global devel-

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[1]This paper does not directly consider a microeconomic analysis of broadband access

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opment goals; consider that over 70% of the world, including 30% of the U.S. population, lives without Internet, primarily in rural areas [7].

Likewise, many policy decisions are based around the assumption of broadband's economic value. Several countries already have subsidized broadband deployments in order to encourage economic growth. In 2008, for example, the government of Brazil worked with five wired broadband providers to build a broadband network to connect public schools in over 3,000 municipalities by the end of 2010 [8].

Despite these efforts, there is relatively little empirical data in support of this belief! Previous literature has examined the macroeconomic effect of GDP in OECD (developed) countries [9], as well as individual communities [10] and qualitative benefits for individual firms [11]. But few studies have performed a broad macroeconomic analysis across both developed and developing countries. The only substantial study I know of is a World Bank report from 2009, which found that a 10 percent increase in broadband penetration correlates with a 1.3 percent increase in GDP [12].

One major reason for the sparsity of empirical studies in this area is that broadband is a relatively recent technology; it first started appearing in developed countries in the late 1990's, and has only become pervasive in developing countries in the last few years. The World Bank study itself used data from 2007, when broadband was just beginning to appear in the developing world.

With 5 years of hindsight since the World Bank study, we are in a much better position to evaluate the long-term economic effects of broadband penetration. In this paper I seek to revisit the World Bank's macroeconomic analysis of broadband's effect on GDP, hoping to corroborate their results.

More specifically, in this paper I perform an econometric analysis that is equivalent to the World Bank study, but includes 5 years of additional data dating through 2011. I examine the same random variables, drawn from the same data sources: the International Telecommunication Union World Telecommunication Indicators Database [13] and the World Bank World Development Indicators Online Database [14], covering over 120 developing and developed countries since 1980.

My initial results do indeed corroborate the World Bank's findings. Specifically, my main finding is that a 10% increase in broadband penetration is correlated with a 1.35% increase in GDP for developing countries, and a 1.19% increase for developed countries. This suggests that in general, broadband deployment is a valuable investment for spurring economic

growth.

The rest of this paper is organized as follows. In section §1, I review related work and outline sociological reasons for broadband's effect on economic growth. In section §2, I describe the dataset and methodology used. Lastly, in section §3 I present my results, and in §4 I conclude.

# 1 Previous Literature and Sociological Reasons for Broadband's Effect on Economic Growth

There are two main threads in the literature on the economic effects of broadband. First, many papers from both academia and industrial research consider economic benefits for individual firms and communities within OECD (developed) countries. For example, a study by MIT measured qualitative and quantitative differences over time between communities in the United States who adopted early broadband technologies, versus communities who were late to adopt the technology [10]. At least one study, similar in spirit but not in scope to the World Bank study, looked at the macroeconomic effects of broadband penetration across 20 OECD countries [9]. Nonetheless, relatively few studies have examined the effects of broadband on developing economies [15], the main focus of this paper.

A second line of related work examined the extent to which broadband technologies are economically preferable to narrowband technologies such as cell phones or dial-up. For example, one study found that the typical broadband user spends 64% more time on Internet the typical narrowband user [16]. I touch on the macroeconomic differences between broadband and narrowband in §3, but it is not the main purpose of this paper.

Regardless of positioning ourselves against related work, it is helpful to consider the microeconomic and sociological reasons that underlie the belief that broadband spurs macroeconomic growth. Following Quiang et al.[15], I outline four scopes of sociological effects induced by broadband:

**Benefits for individuals**. As an information technology, broadband has the potential to increase the human capital stock of the countries that deploy it; with high-speed Internet connections, individuals have the opportunity to enhance their knowledge and skills through resources such as online courses, blogs and wikis [17]. Even access to recreational technologies such social networking sites has the potential to grow individuals' social networks and

expose them to different cultural values. Finally, broadband access has the potential to empower individuals to drive innovations of products based on their own needs, rather than waiting for institutional forces to make the changes for them. For example, high-speed Internet enables participation in community-lead open source projects [18].

**Benefits for firms**. Broadband Internet access has immediate potential to lower costs and raise productivity for private companies. For example, one paper cites that a collection of U.S. firms were able to save $155 billion in operating costs as a result deploying broadband [11]. The reasons for reduced costs depend largely on the company's business model. One company in Britain, for example, was able to save 60 million pounds in employee's medical expenses and overall productivity by using broadband to allow employees to work from home and connect remotely to internal computing resources [19].

In more extreme cases, broadband gives companies the potential to completely alter their business models. For example, industries with products that can be distributed entirely through electronic means, such as the advertising, movie, music, or gaming industries, can (and do) change their business strategies when their customers have access to high-speed Internet [20]. Moreover, broadband yields access to foreign markets that companies would otherwise not have been able to reach; one study found that if the number of companies with Internet access within a country increases by 1 percent, there is a corresponding boost of 4.3 percent in exports, and a 3.8 percent boost in exports from companies in low-income counties selling to high-income countries [21].

**Benefits for communities**. Broadband also plays a role in creating stronger communities at the municipality level. For example, if a community subsidizes residential and commercial broadband deployment, it stands to foster a better environment for businesses to grow in. A study from MIT compared early-adopters of broadband versus late-adopters between 1998 and 2001, and found that communities with broadband experienced higher employment growth rates, more startup businesses, and higher rent prices (a proxy for the perceived value of living in the community) than communities that did not adopt broadband [10]. Broadband also plays a crucial role in reducing information asymmetry (where customers do not have sufficient information to make informed buying decisions), thereby creating a more efficient market for both buyers and sellers. Lastly, broadband helps communities deploy public services that otherwise might be intractable. For example, services such as telemedicine and online education benefit the overall com-

munity at a low cost if broadband is pervasive. This is especially relevant for remote communities; consider, for example, the use of telemedicine to reach villages in the Upper Amazon [22], where it would otherwise take three days by canoe to bring a sick or injured person to the nearest doctor.

**Benefits for the overall economy**. Broadband deployment in theory may carry positive externalities with it that affect the overall economy. Several speculative studies have predicted the macroeconomic effects of broadband on individual countries. One study by a technology company research lab[2] found in 2003 that increased broadband deployment had the potential to contributed $500 billion to the United States economy [16].

Besides the microeconomic reasons already described, there are several reasons why broadband deployment might yield macroeconomic benefits. One major reason is that access to the Internet facilitates overall trade with foreign economies in services and globalization [23]. In support of this reasoning, it has been shown that the existence of broadband is an important factor in whether foreign countries decide to place investments in growing markets [24]. Broadband also stands to transforming research and development, the means by which countries make technological progress. One study in this space surveyed the role broadband plays in generating inventions [25]. Another cited that broadband encourages collaboration, access to data, and round-the-clock development [26]. Broadband can also help governments streamline public services, thereby facilitating a more conducive business environment. E-governance and electronic customs processes are examples of such streamlined services [27]

Lastly, broadband technologies arguably have benefits that extend past direct economic effects. For example, some have argued that Internet access has played a role in organizing political revolutions and spreading democracy [28]. This line of inquiry is outside the scope of this paper.

## 2  Data And Methodology

Given the large number of sociological reasons why broadband should impact economic growth in theory, it seems that we should be able to quantitatively measure the actual impact over the decade of broadband's existence. The largest study I know of that performed such an analysis on a large scale, the World Bank study [12], used data from 2007. In this section I describe

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[2]With a vested interest?

the data sources used in that study in detail, cover preprocessing and sanity checks I performed on the data, and describe the methodology I used to corroborate and update the World Bank's result.

## 2.1 Data Sources

The data from Quiang et al.'s study came from two sources:

1. The International Telecommunication Union World Telecommunication Indicators Database [13] provides data on communications technology in over 200 developed and developing regions. The specific metrics used for this study include mobile and cellular telephone subscriptions, overall fraction of the population using the Internet, and broadband penetration numbers, dating from 2001-2011.

2. The World Bank World Development Indicators Online Database [14] maintains over 1,500 metrics ranging from GDP to number of acres allocated to forestation across over 200 countries. We rely on this database for GDP, primary school enrollment rates, and investment share from 1980-2011.

The two databases differed in some ways, so I needed to perform preprocessing on the data to make it usable. For example, I enumerated all country names, and converted all names to a canonical format so that the datapoints could be matched up programatically between the two sources. In cases of ambiguity with respect to which specific metrics Quiang et al.used for their original analysis (e.g. raw GDP versus GDP adjusted for PPP), I experimented with the output to ensure that it closely matched Qiang's final results.

I also relied on country classifications from the World Bank [29] to bucket countries into high, low and middle income countries. These metrics were used as dummy variables in the regression analysis, described below.

## 2.2 Methodology

Quiang et al.considered two quantitative methodologies before deciding on one that would be robust given the somewhat sparse World Bank data. Their chosen method used an econometric regression over 6 variables, varying over

120 countries. Specifically, their dependent variable was raw GDP per country averaged over 1980-2007, which was regressed onto six independent variables:

1. Average broadband penetration per 100 people (variable name: GDP_8011) .

2. GDP per capita in 1980 (variable name: GDP_80).

3. Broadband subscriptions per hundred people (variable name: BBND).

4. Ratio of gross investment to GDP (variable name: I_Y_8011).

5. Primary school enrollment (a proxy for human capital) (variable name: PRIM_80).

6. Dummy variable for countries in Sub-Saharan Africa (variable name: SSA).

7. Dummy variable for countries in Latin America and the Caribbean (variable name: LLC)

The authors also added a dummy variable to bucket countries into low and middle versus high income countries. The values of the variables used in this regression (with up-to-date data) are plotted over time in Figure 2.2 at the back of this paper.

The analysis seeks to discount the possibility that other confounding factors were the real cause of GDP growth. In truth, there are infinitely many factors that could contribute to GDP growth[3]. Nonetheless, economists generally agree that macroeconomic growth is well-modeled as a function of human capital (which is assumed to not have diminishing returns – reasonable considering that knowledge begets knowledge), physical capital, and initial physical capital. If we add these well known factors of growth to our regression, we will have a fairly good assurance of how much relative effect broadband deployment has on GDP growth.

More formally, this collection of variables is known as an endogenous growth model[4]. In our regression, human capital is measured through pri-

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[3]For this reason it's impossible to truly establish causation

[4]This is in contrast with exogenous growth models, which assume that technological process is a constant, external factor with diminishing returns, and is the main driver of growth

mary school enrollment[5] (PRIM_80), and the ratio of money placed in investments versus GDP per country is a measure of available physical capital (I_Y_8011). We include dummy variables for Sub-Saharan Africa (SSA) and Latin America (LAC) to account for the general belief that these regions see less pronounced returns to telecommunications infrastructure, perhaps due to sparse population density.

In sum, our regression specification is as follows:

$$GDP\_8011 = \alpha_1 GDP\_80 + \alpha_2 I\_Y\_2011 + \alpha_3 PRIM\_80 +$$
$$\alpha_4 BBND + \alpha_5 SSA + \alpha_6 LAC + \alpha_7 H + \mu$$

where H is a dummy variable to distinguish high income from middle and low income countries.

Qiang et al.verified the validity of the endogenous growth model by comparing the data with predictions made under the theoretically ideal model. They found that several predictions held; for example, they confirmed that average growth rate of GDP is negatively correlated with initial GDP per capita, and positively correlated with investment share (I_Y_2011).

## 3 Results

Following Qiang et al.'s lead, I have attempted to run a similar regression on more recent data. This section presents my findings. The code used to perform this analysis is publicly available on GitHub [30].

### 3.1 Main Results

The first step I took was to attempt to reproduce Qiang et al.'s original results as a sanity check. I restricted my dataset to the same date range used in the original paper, but was unable to reproduce exactly the same output, although the numbers were fairly close (I found a 0.145 coefficient for broadband, as opposed to the original 0.138). There are several possible reasons for this. In general, the details of Qiang's analysis were not fully specified[6], which forced me to make educated guesses about how the computation was performed. First, it was unclear whether Qiang marked the

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[5]Although secondary school enrollment is arguably a more appropriate proxy, the data was significantly more sparse

[6]I tried contacting Christine to ask her some questions about the code, but to no avail. I imagine she's pretty busy as a World Bank manager.

broadband values before 2001 (when data first became available) as zeros, or as empty values. I found that marking them as zero yielded closer results. Second, the original paper did not specify which regression method was used to compute the output. I chose ordinary least squares simply because I have a (non-zero) conceptual understanding of how it works, but there may have been more appropriate regression methods for the data. Lastly, it was not clear exactly which 120 countries were used in the original analysis. I was only able to find 86 countries that had full data from 1980-2011. It seems likely that this is the main reason that I was not able to reproduce exactly the same output.

Nonetheless, the sanity check was sufficiently close to the original result, and I decided it was sound to proceed with the updated data. My main results are shown in Table 3.1. The salient feature of the table is that broadband penetration has a coefficient of 0.119 for developed countries and 0.135 for developing countries, which is roughly an order of magnitude larger than the other variables included in the regression. This is closely in line with Qiang et al.'s earlier results, suggesting that their results are robust over time. The main difference between Qiang results and mine after considering more recent data is that the coefficient for I_Y_8011 is significantly smaller, a difference I am unable to explain.

| Variable | Coefficient | t-Statistic | Qiang Coefficient | Quiang t-Statistic |
|---|---|---|---|---|
| Constant | 4.837 | 5.70 | -1.726 | -1.83 |
| GDP_80 | -0.000 | -0.60 | -0.100 | 3.86 |
| I_Y_8011 | 0.03 | 1.18 | 0.164 | 5.46 |
| PRIM_80 | -0.013 | -1.93 | 0.001 | -0.18 |
| BBNDH | 0.119 | 0.18 | 0.138 | -1.96 |
| BBNDL | 0.135 | 0.18 | 0.121 | 2.87 |
| SSA | -0.900 | -1.87 | -1.018 | 2.19 |
| LAC | -1.07 | -2.17 | -0.655 | -1.55 |
| Number of Countries | 87 | 87 | 120 | 120 |

Table 1: Main Result: Regression Separating Effects of Broadband Penetration, Including Qiang et al.'s 2007 Results

The negative coefficients for South America and Sub-Saharan African regions supports the general belief that these areas have less pronounced benefits telecommunications infrastructure.

## 3.2 Comparison with other communications technologies

I also examined the economic effects of broadband versus other technologies, including cellular penetration (variable name: MOBILE), and dial-up penetration (variable name: INTERNET). The results are shown in table 3.2.

In agreement with Qiang's earlier results, I found that the coefficient of broadband is approximately six times that of mobile, and roughly twice that of dial-up. This suggests that there are indeed comparitive benefits of broadband infrastructure versus narrowband technologies.

| Indicator | -1 | -2 | -3 | -4 |
|---|---|---|---|---|
| Constant | 3.424 (5.26) | 4.837 (5.70) | 4.242 (5.19) | 4.74 (5.55) |
| GDP_80 | -0.000 (-2.39) | -0.000 (-0.60) | -0.000 (-2.7) | -0.000 (-0.88) |
| I_Y_8011 | 0.073 (3.38) | 0.03 (1.18) | 0.03 (1.29) | 0.033 (1.34) |
| BBNDH | | 0.119 (0.18) | | |
| BBNDL | | 0.135 (0.18) | | |
| MOBILEH | | | 0.021 (1.83) | |
| MOBILEL | | | 0.040 (1.83) | |
| INTERNETH | | | | 0.078 (0.42) |
| INTERNETL | | | | 0.093 (0.42) |
| PRIM_80 | -0.012 (-2.07) | -0.013 (-1.93) | -0.013 (-1.94) | -0.013 (-1.82) |
| SSA | -0.735 (-2.14) | -0.900 (-1.87) | -0.92 (-1.97) | -1.13 (-2.31) |
| LAC | -0.484 (-1.37) | -1.07 (-2.17) | -1.28 (-2.59) | -1.11 (-2.20) |
| Number of Countries | 120 | 87 | 90 | 88 |
| $R^2$ | 0.24 | 0.24 | 0.25 | 0.24 |

Table 2: Regression for Per Capita Growth Over All Variables

## 3.3 Shortcomings and Future Work

One potential issue with this analysis is that it's entirely possible that the correlation is due to reverse causality. That is, it may be the case that increases in GDP cause increased demand for broadband services, and not the other way around (the hope of this paper). The authors of the World Bank report ran a Hausman test (a statistical test designed to discount this possibility) to determine whether reverse causality exists. They were unable

to reject the null hypothesis, meaning that it's still unclear which direction the causality runs. I hoped to re-run the Hausman test on the original data, but unfortunately ran out of time to do so.

There were a number of other questions I wanted to ask given more time. First, I'm still not entirely sure how to interpret the statistical significance of the results; I have a vague understanding of what t-statistics mean, but I'm not sure what values are reasonable. In the next few days I hope to sit down with a friend who knows more about statistics than I do and understand the results more deeply. Second, I would like to extend the analysis used in the original Qiang paper. For example, are the results robust to different growth models? What if I added additional variables to the regression such as crime rates, corruption, or the relative expense of broadband? In many ways, it would be far more intellectually interesting if I were able to dispute some of Qiang's findings, rather than corroborate them[7]. Lastly, I wanted to go beyond my original question, and ask whether from a policy perspective, broadband is a preferable investment versus other potential development initiatives. My intuition is that broadband is probably quite useful for middle income countries who are in a good position to modernize, but I doubt that broadband is a valuable investment for bottom of the pyramid consumers, where more fundamental infrastructure is not available.

## 4    Conclusion

In conclusion, my results corroborated Qiang et al.'s. Specifically, my main finding was that a 10% increase in broadband penetration is correlated with a 1.35% increase in GDP for developing countries, and a 1.19% increase for developed countries. This suggests that in general, broadband is a valuable investment for spurring economic growth.

In retrospect, the experience of walking through the econometric analysis taught me a ton about economics, statistics and the sociological reasons for broadband's effect on economic growth. If anything, one thing I learned was that I have much more to learn about economics![8]. And last but not least, this experience reinforced one of my long-held beliefs: data analysis is really fun!

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[7]Of course, it's also good that broadband does in fact correlate with GDP :P

[8]I still don't completely understand the meaning of regression output and growth models!

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Figure 1: Variables Used in Regression



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