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BUSINESS SCHOOL
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The effect of Broadband spread on growth in GDP

Master thesis in Economics

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Jönköping	May 2012

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Date: 2012- 06- 11

Subject terms: GDP, economic growth, information and communications technology, broadband

Abstract

This paper investigates whether there is a correlation between broadband use and economic growth by using an endogenous growth model along with previous studies of broadband use and theories for its spread an equation was developed accordingly.

The estimation was done using data from the World Bank and ITU for the years 2002-2008, with minor imbalance in the dataset. Moreover, the estimation was done using two-way fixed effects and heteroskedasticity and autocorrelation robust errors, given tests for heteroskedasticity and autocorrelation in the regressions. The result from the regressions showed that broadband spread has a significant effect on GDP growth, while the significance of the coefficients for human capital do vary with education stage.

In the analysis of the subject it was also shown that there are more underlying matters to be dealt with to give a fair estimation and conclusion, such as the difference between markets and difference in speed of broadband which may could have given slightly different results. Also that the range of time for broadband is relatively short, a longer range could have given a better estimate. Furthermore, the analysis shone light on that there are both weaknesses by spread of broadband as exacerbation of poverty and strengths as possibility to savings in healthcare and increase spread of education via broadband. In addition to this there is possibly reversed causality and the fact that all ICT technology are general purpose technologies has the impact that one should see the results with somewhat scepticism.

In conclusion, the positive effect from broadband spread on economic growth is stated-with an addition, that more data and taking account of broadband differences globally would be needed in a future research to fully establish the effect, as well as mentioned limitations to result should be taken into account.

Acknowledgements

I would like to thank my tutors Johan Klaesson and Johan Larsson in their assistance and coaching in my work with this thesis. I would also like to thank my family, my girlfriend and classmates for encouragement, wisdom and support throughout the time it has taken to write this thesis.

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1 Introduction

What has emerged with broadband within the society is to a large extent the possibilities for networking, trade and direct advertising throughout the networks. The implication of this for business is the reduced necessity of physical presence for business meetings of different kinds, which reduces travelling costs and hours of inproductivity in travelling. Though granted, when business take part in the manufacturing sector, it might be more relevant with physical precense to inspect a product.

Furthermore, studies have shown that as broadband facilitates a workstation at home instead of being in an office, leads to a higher efficiency for the worker at home compared to the one being in an office. This has a major advantage in larger metropolitan areas where congestion is highly likely to appear, as transportation in general could be reduced by 10-20%. (Fuhr, Pociask, 2007, p6) It is also a profiting situation for business as it reduces the need for costly officebuildings as well as lower cost of stress from the congestion, which may lead to healthier personell. Thus three actors benefits from a situation where employees can work from home, the employer, the employee and the commuter who could possibly spend less time in traffic if less people need to commute to an office. To bring forth another aspect that benefits from the decrease in commuting is the environment, whereas it could reduce the CO_2 released by the transportation.

Another use of of broadband may be the increased trade, both in tangibles and intangibles. Sites such as Amazon or eBay, may not be the result of broadband but internet in general. Despite this there may be a reason to include these sites anyway, with increased technology the products sold may be displayed before purchase in a manner that was not possible, giving the customer an increased levelfor reassurance that the product might be what the customer is looking for.The critique against this argument is that not every product can be displayed with for instance a movie or a sound-clip, neither is the possibility for every company to develop such commercials as they are costly in production with the skills that requires skilled technicians for a high end result that would convince the customer. The American Consumer Institute(ACI) still though projects that the growth of business to consumer(B2C) will increase from 6% to 10% of retail trade between 2006 and 2011 (Fuhr, Pociask, 2007, p6), though it is entirely dependent on the spread of broadband in the general population.

As for intangibles, or more precisely what used to be considered tangibles, music and movies on the internet has been given quite a boost after broadband was introduced, both in legal form and illegal form. Forms of businesses and forums that have promoted these products are iTunes, Spotify, myspace and Hulu to name a few. The use of downloading complete records directly from a site have an ambiguous economic impact, the positive aspects may include higher income to the recording company and the artist as the distribution costs declines from not shipping physical goods. Also, the customer may gain from this as in general this may cut out cost from an intermediary company. The other side of this coin is the loss of job opportunities, as for instance most record stores will go into bankruptcy and a minor effect on shipping companies. Moreover, the result of the e-materializiation(physical products turned into digital products) has the advantage of not needing the physical space, meaning that warehouses and retailers would need less space for selling their products. Also the e-materialization could reduce shelfspace in offices for all paperwork that is present today, all reports and p.m.s etc. could be delivered by electronic services, which means less cost in storage, purchasing of paper and waste maintenance. This does not necessarily stop at offices, but also newspapers have tended to use this as well, to create newspapers on the web, which do have the same positive effect as in offices.Therefore the is a secondary benefit to environment, since the waste produced by the economy could be reduced to new low-level. But as stated before, this is highly affected by the availability to the technology, thus the spread of broadband is taken to be a major part in the line of arguments in this paper.

An illustration from ACI regarding the use of paper for mail shows that internet by itself has changed the amount of paper used for mail purposes, where there is a declining trend from 2000-2001 to 2008. In a similar fashion one could predict that plastic used for making cds, dvds etc. would be likely to take on a similar trend, as the speed allows for larger digital objects to be sent in a time-window that makes it lucrative.

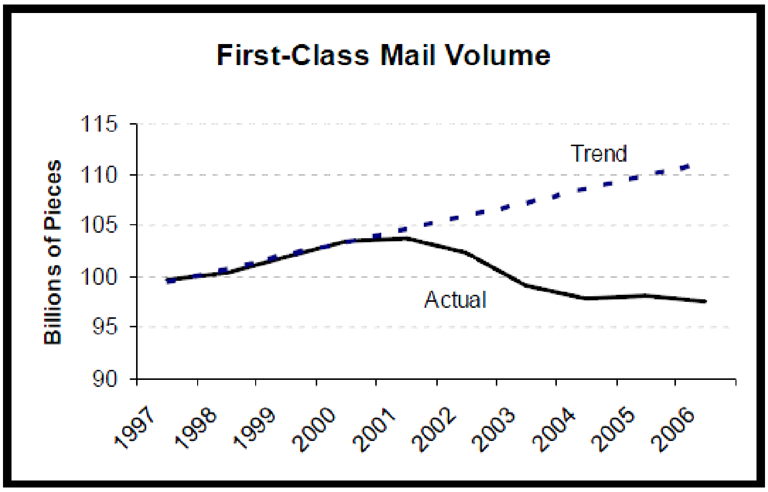

Figure 1 Showing decrease in the use of mail due to electronic mail, (Fuhr, Pociask, 2007, p 33)

Piracy on the internet may also have an effect on growth, directly from business in software-production, music and movie loosing profits and indirectly from the costs of legal pursuits of internet piracy. Thus, there are components that reduces small parts of economic growth.

Moreover, benefits would could occur to the society from programs in e-Government and e-Health whereas the spread of broadband would expand possibilities to allow remote locations to have a better respons possibility and improved sense of democracy in for instance being more influential to decisions. E-health programs could provide more services to those locations where people with expert knowledge could for instance guide procedures or give opinions on matters without needing to move either any of the involved between locations.

Based on that for any of these benefits to occur, there has to be a spread of broadband, the spread in itself makes it interesting to investigate. If it affects economic growth and if, how the spread then affects it.

To give a crude illustration of the broadband development, one can see that since 2000 and on there have been increases in the spread, that are in some cases quite substantial. This is another reason why it is interesting, because it is an contemporary technology in development and at high rate of spread. As one may see there is a vast spread in between how broadband spread growths between developed countries and developing countries is quite large, which will to some extent be discussed in the analysis.

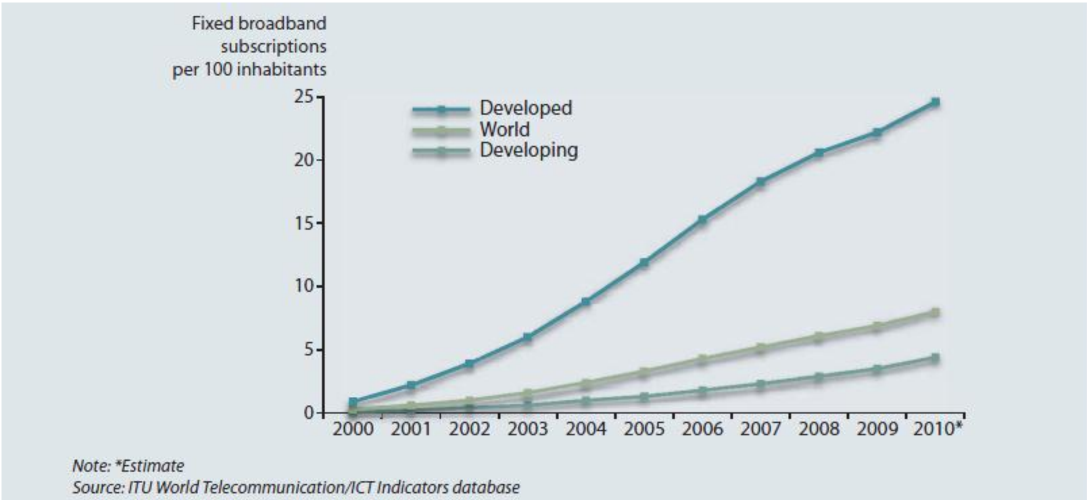

Figure 2 Showing development of fixed broadband between 2000 and 2010, ITU, The world in 2010: ICT facts and figures, p 6

Based on previous reasoning in the introduction to the thesis, one could state the question, do broadband truly contribute to the economy as a tool of expanding markets, improving information systems and benefit the infrastructure and environment? By extending the question into an economics territory and narrowing it slightly further one could ask it such as, does it benefit the economic growth as a means of increasing productivity within a country? The investigation therefore moves into the territory of questioning whether a piece of technology could possibly be significant to the production within a country and why would it be it and what possible factors would contradict or verify this answer in the quest for a truthfull answer. By investigating factors of economic growth and how broadband may relate to these and how it would affect economic growth, one could derive an indication of how to evaluate broadband in terms of whether one should include it in the economic growth policies in relation to other factors of economic growth. Furthermore, as it is a contemporary developing piece of technology, the studies of it tend in relation to economics tend to be scarce whereas the more general studies of ICT technique in relation to economics are more common.

1.1 Purpose and research question

The purpose of this paper is to investigate the connection between broadband use and growth of GDP per capita. Moreover, as the purpose of this thesis is to investigate the correlation between broadband and economic growth, there is also a need to investigate the factors promoting broadband use as well as the factors resulting from use of broadband to establish a logical causality. Hence, the investigation of causality between the economic factors is a part of the purpose in this thesis, as it will first be dealt with from a theoretical point of view, secondly it will be numerically confirmed or rejected by the use of econometric models.

From what is stated in the purpose of the thesis one can deduce a research question:

Is there a significant correlation between growth in GPD and the use of broadband?

1.2 Literature review

Koutroumpis (2009) found that for a critical mass of broadband there would be increasing returns to investment due to network phenomenon. By using 4 equations he calculated the growth in GDP contributed by broadband, the level of penetration of the technology which resulted in critical masses of broadband. This later was run as a regression, where the higher the critical mass was, the higher the percentage contributed to growth was. Thus, there are increasing returns to investment in broadband technology.

Kolko (2010), researched the effect of broadband use on local economic growth and related effects in California. He found a positive relationship and possible causality between broadband and economic growth, but the data did not definitely indicate the relationship. Though there was no significant relationship between employment rate and broadband, nor were average pay per employee, taking work home, home-based work or telecommuting correlated to broadband from what Kolko could find. As for the median household income there was even a negative relationship. The causes that Kolko lists for each variable was that business were eager to expand to broadband areas and working age population was also eager to move to an area with broadband. Though, in general people are mobile or willing to commute to work and the premium for know-how around broadband was very little on the salaries. Further, most broadband connections in the areas Kolko investigated were too slow to enable homebased work in any form as companies demanded a higher rate for work to be possible.

Gillet et al (2006)found in a research using zip code data over the USA that broadband increased the employment rate by 1%. Similarily to Kolko, Gillet et al did not find a significant relationship between wages and broadband. In addition, they found that in general business and especially IT firms expanded after the time of broadband deployment in an area. In contrast to this, they also found that small enterprises suffered after broadband was established in an area where there were less small enterprises after the introduction of broadband.

Thus, the literature present pertaining to broadband's effect on economic growth does not show a clear trajectory of the way that it would affect it, as some do say that it does not affect while others refer to a positive effect. Therefore it may be necessary to point out the expectations of a broadband variable may not be possible to predict in the econometric modeling.

2 Theory

2.1 The Solow Growth model

For the purpose of describing the matter at hand, it would be a proper beginning to explain one of the first theories around economic growth connected to the technological change.

The Solow growth model describes what contributes to economic growth by splitting up the growth in the significant parts output (Y), capital(K), labor(L) and technological progress (A) or what is also called the Solow residual in some studies.

$$Y=A(t)\ f(K,L,) \qquad (1)$$

As one differentiates the production function to show the change in production it gives:

$$\frac{\dot{Y}}{Y}=\frac{\dot{A}}{A}+A\frac{\partial f}{\partial K}\frac{\dot{K}}{Y}+A\frac{\partial f}{\partial L}\frac{\dot{L}}{Y} \qquad (2)$$

which is equal to

$$\frac{\dot{Y}}{Y}=\frac{\dot{A}}{A}+w_k\frac{\dot{K}}{K}+w_l\frac{\dot{L}}{L} \qquad (3)$$

given that

$$wk=\frac{\partial Y}{\partial K}\frac{K}{Y} \qquad wl=\frac{\partial Y}{\partial L}\frac{L}{Y} \qquad (4a, 4b)$$

Where $\dot{Y}$ denotes the derivative of Y with respect to time, as do the other "dotted" variables. By letting Y/L=y, K/L=k and $w_L=1-w_K$ gives

$$\frac{\dot{y}}{y}=\frac{\dot{A}}{A}+w_k\frac{\dot{k}}{k} \qquad (5)$$

which is the case when technical change is neutral. (Solow, 1957, p313)

What Solow found in 1957 while using this function for data from 1909-1949, was that technological change was in general constant with exception for the time around the great depression. According to Solow's findings technological change was also independent of the economic growth. A critique against Solow would be to not define A more narrowly or use another variable for technological progress alone, since in his equation A does not only represent technological progress, but also includes knowledge and other factors that may have an effect on the production called the Solow residual. Thus this equation for a growth model only suggests the initial ideas for relationships between growth in output and capital, labor and technological progress along with disturbances around it. For the purpose of this paper, only the initial relationships are of relevance for a theoretical basis.

What contribution one may find from Solow's model to this paper is the initial output growth correlation to disturbances from technology, along with capital and labor. Thus as a reminder for the empirical analysis, the model ought to include capital and unemployment as control variables. The control is evident from the previous equation, where one has to attempt to prevent the technology's significance in a model to be influenced by capital or unemployment as these will likely have a significance in explaining changes in output.

From the Solow growth model, what is called New Growth Theory by Romer 2006 is developed, which extends the more general growth theory to include research and development and human capital into the model.

2.2 Representation of technology

For any appearance of new technology there is a certain amount of factors for the technology's existence and spread through society. May it be the education of the general population as discussed later, or the creation of the technology by itself explained somewhat by the new growth theory.

According to Romer's new growth theory at basic perspective, the total production within a country is devided into two main sectors, first the goods and general service producing sector, then the knowledge producing sector. This generates an addition to the Solow growth model introduced previous section in forms of a_K and a_L which denotes fractions of input capital and labor devoted to R&D. In equation (6) one may see how this mathematically is formulated, where similarily to the Solow growth model, the output of the economy (Y) is equal to the factors capital and labor. The addition to the model comes in terms of how the production of knowledge and technology withdraws certain part of the production from both capital and labor, the mentioned a_K and a_L, where the remainder for production to output of the economy are (1- a_K) and (1- a_L).

$$Y(t) = [(1 - a_K)K(t)]^{\propto} [A(t)(1 - a_L)L(t)]^{1-\propto} \qquad (6)$$

R&D sector produces the knowledge (A) which has three distict characteristics, it is non-rival, non-excludable and its return to scale is not limited to be constant, but may be both diminishing or increasing given the nature of knowledge creation. In the R&D sector, the production of new knowledge and therefore technology is shown by equation (7). In equation (7) the difference in A is a function of a shift parameter B, the share of capital $a_K K$ which has elasticity β, $a_L L$ which has elasticity γ and at last the previous knowledge in form of A with its elasticity θ.

The ambiguous returns to scale are based on what is referred to as the replicative argument. In comparison to other productions where dubling inputs at constant returns to scale would double the output, producing the same knowledge again does not add up to the output. At the same time the joint resources of capital and human capital may interact and produce more output than input rendering in increasing returns to scale. Thus the returns to scale may be based more on previous knowledge and the human capital that creates new knowledge and range between diminishing to increasing returns to scale.

$$\dot{A}(t) = B[(a_K)K(t)]^{\beta} [a_L L(t)]^{\gamma} A(t)^{\theta} \qquad B>0,\ \beta\geq 0,\ \gamma\geq 0 \qquad (7)$$

(Romer, 2006, p 102)

An interesting feature regarding the process and the distribution of the technology for the advances within technology, is the more accessible it becomes, the less technology progresses. This is based on the concentration of labor with a specific skillset will rise as a technology with a very high density in one area, but low in the other geographical areas will attract labor with the specific skillset. "Initially, inventions increase the return to skills (by increasing the return to ability), but as technology becomes more accessible, the return to skills declines" (Galor, Tsidden, 1997, p 19). This implies that returns to education (enhancement of a skillset) is higher when technology has not been made available to labor with more general skillsets. Therefore, skill-intensive production will always promote education as it constantly raises the return which leads to an increased demand for education for the given area of expertise, conditioned on that the technology is not accessible to all skillsets. Furthermore, one may add the question whether this argument would imply that the technical convergence between advanced countries and less advanced countries would be the same as the economical convergence or if would be slower to non-existent. If it would be similar to the convergence of economical growth, it would be possible to see less developed countries catching up with advanced countries. Thus a technology introduced at $t=t_1$ by a few countries would be spread to other countries at $t=t_{1+a}$ and have a similar distribution as the forunners at $t=t_{1+b}$. If the convergence is unequal to that of economical growth, the event mentioned regarding the state at $t=t_{1+b}$ would not be visible as the distribution of technology would never become equal. One theoretical answer to this is “larger and richer regions have substantial static and dynamic advantages. The uptake process will begin sooner in these regions, the network will grow faster and the process of cumulative causation relating ICT to social and economic development will be more intenseve.” (Jensen-Butler et al, 2003, p 48) This theory also suggests that there is a greater likelihood for a technical divergence rather than a convergence, due to the network possibilities in denser metropolitan areas and the assumption that networking is more likely to be based on first-hand physical contact rather than internet contact. The limitations in this argument is the magnitude of the area discussed, this argument is so far mainly based on regions rather than countries also it is only a theoretical argument, not an empirical proofed research which makes it rather weak.

2.3 Importance of education in the use of technology

Based on the Solow growth model, the human capital theory complements the model by inducing human capital into the production function as follows in equation 8. The production function has similar features to that of the Solow growth model with respect to output and capital, but it adds the extension of H(t), human capital. Therefore the production function would be as follows, the output would be a function of capital, human capital and technology.

$$Y(t) = K(t)^{\alpha}[H(t), A(t)]^{1-\alpha} \tag{8}$$

While human capital H(t) “is the total amount of productive services supplied by workers” (Romer, 2006, p 134). The human capital H at point t is stated as the labor force L at t, times the years of education G(E) per worker as shown in equation (9).

$$H(t) = L(t)G(E) \tag{9}$$

In theory it should also capture experience as a function of learning-by-doing, but as that will be near impossible to show in a global dataset, it will be left out. An assumption which will be removed from this theory is that “each worker obtains the same amount of education, E.” This is because the more education a worker obtains, the better the skillset and the higher the human capital. In addition, primary school would give the individual the basic skillsets of reading, writing mathematics et.c. while secondary education and tertiary education would enhance these skills and form new skillsets.

Labor grows at nL(t) = $\dot{L}$(t) and technology grows in this case at gA(t) =$\dot{A}$(t) , sY(t)= $\dot{K}(t)$and are taken as exogenously growing variables, in contrast to H(t), which is treated as an endogenous variable. (Romer, 2006, p. 133-135)

The human capital theory suggest that it is the total stock of human capital that matters for growth rate of output and technology in a closed economy (Romer, 1989 , p 29). One reason is the production of scientists and related occupations, which are dependent on the the level of human capital introduced and formed in the economy. The higher the level of human capital becomes, the more an advanced technology is possible to be used by the labor force. This is may confirm the argument regarding the distribution of technology, that technological advanced regions or countries may have a higher propensity to use advanced technology closer to the time of invention than less advanced countries. Therefore one could see two patters forming out of this observation, 1) technologically and more educated countries will see a positive circle, whereas less advanced countries will see a vicious circle in technological progress since they will be less encouraged to invest in it. 2) By this theory, the income and possibly the growth gap between rich countries and poor countries would grow larger, which could lead to increased poverty and diminished welfare at a global perspective. By inducing trade to the argument, in the countries with low human capital growth**,** the incentives to acquire skills are reduced. The long run dynamics are then clear: the small economy falls ever farther behind the rest of the world in terms of human capital. (Stokey, 1991, p 605) With free trade the incentives to invest in human capital changes, when production technology is introduced.

The need of human capital, specifically education depends on the type of technology adopted in a firm. If the technology implemented in a firm is only a manufacturing technology with low need for skilled labor, the effect of human capital is low. Though when implementing more advanced technologies in manufacturing or management processes, human capital has a higher effect in production. What has been seen in implementations of advanced technology is that more skilled and higher paid workers are in general employed both before the technology has been implemented and afterwards. One explanation for the pre-employment of skilled labor to technology may be to instruct workers and to fulfill the proper preparation for installment of technology. Along with the pattern discussed, there have also been patterns of significantly increased wages for the workforce dealing with computer technology in industries, which could be taken as a sign of higher returns to a specified education or skillset in the industry. This is consistent with theory of labor supply, that more narrow fields of skillsets can use the leverage of specification to demand higher wages.

What should be noted from the human capital model is the negative impact on the labor force from a share of the labor supply increasing their education level instead of producing goods or services. This argument points therefore points out that there is a limited trade-off between standards in knowledge and economic growth. Even though the labor might become more effective, it may not always be in favour to the production in total if too much labor is missing from production.

Furthmore," as microeconomic reforms have helped ICT adoption, and that ICT diffusion is interacting with organisational and innovation factors in generating a positive impact on productivity" (Colecchia, Schreyer, 2001, p 19), one should elaborate this fact along with the human capital aspect as the effect of networking or social capital. Social capital may be considered as the time or action investment of one individual to another to maintain the relation between them or an organization. As both internet per se and broadband facilitates this one could argue that the cost of investment into social capital becomes lower with these technologies. For any economic purpose social capital may be seen as a foundation for making an organization or even just a group of investors to cooperate, either by a level of trust or the communication establishing knowledge of future gains. Thus the human capital model, ought to capture this at theory, empirically it is possible to find social capital at local network levels, but even at that point it is an abstract form of capital. It should be noted that empirical analysis of neighborhoods in the USA has come to the conclusion that it enhances contacts and communication for local issues as well as maintain communication even though the geographics changes.

2.4 Spread of broadband

For broadband to have an effect on GDP, a requirement would be that the broadband has enough spread (or penetration) in the population for giving the aggregate effect on the ICT market and for the spill-over effects to occur. Also, the spread is necessary for any other kind of communication as the more people who has the technology, the more effect it will have. This can be thought of having a similar pattern to a law of chemical reactions, the larger the area of interaction between two agents is, the larger the reaction caused by them will be. In economic terms, it would be translated to, the more consumers who would have access to a service, the larger the reaction would be due to the specific service.

Findings by Grosso, (2006) suggests that GDP was the largest contributor to broadband penetration in Grossos paper, other variables used by Grosso were Herfindahl-Hirschman Index, an unbundling local loop dummy, fixed internet penetration and previous year's penetration. This paper focuses solemnly of the market mechanisms, where HHI is and index of market shares of companies on a market and local loop was used to capture ease of entrance to the market. Therefore the national income has a part of increasing the spread of broadband, which may make the relationship symbiotic, being that they support each other at some point, or the possibility that the causality for growth may be reversed.

Wallsteen 2005, also discusses the importance of unbundling the broadband, while adding another component, rights of way. Wallsteen found that "rights of way" and "unbundling" were the two larger components in broadband penetration in the USA, while tax incentives by states was not significant. Rights of way in this case is a law regarding the right to use land for development in order encourage access to rural areas. The point from these two arguments is that the physical investment and process is contingent on the ability to an actor or actors on the market to acquire land from either government or population and how it is set to use. The unbundling regulation seen in the usa should theoretically force the actor first to the land to build, else the actor would effectively have to lease the property to the competition. The question though remains as to what prices the leases had to been supplied, if there are any regulations to those and how the competition could react to it. Despite that Wallsteen found the unbundling property in the USA to be a significant factor to increase the spread of broadband, it is mentioned that "broadband penetration in Canada is about 60% higher than in the U.S., and that Canada has less onerous unbundling requirements for telephone companies and virtually no network sharing for competitive network suppliers." (Wallsteen, 2005, p 8) Therefore one may question if the unbundling regulation is due to the U.S. legal system or any other reason that makes it typical for the US and atypical for other countries.

The spread may become more common in clustered firms where as "optimising the production-processes performance by redefining the relationships with customers and suppliers. In fact, shared databases, integrated information systems, and Internet-based applications supporting the marketing and logistic activities greatly improve the efficacy and efficiency of the key supply chain business processes" (Carbonara,2005 , p 221). Though the scenarios for how it will develop is still somewhat unclear, whether traditional relationships and communication will stay stable or if a less social culture will develop within the cluster in favor for technology. For this reason the spread may be affected by clustered firms and how a strategic development in the spread may occur, in order to get the best effect, it seems likely that the spread would occur to the it intensive industries to begin with and then if plausible stretch to low-tech industries.

The logical spread of broadband from a customer point of view, begins with having an internet connection at a slower rate as customers are unlikely to make the direct jump from no Internet use to broadband Internet access. Though as this describes the situation in a rural community, one could expect the situation in an urban community to be slightly different, the public access points in an urban community could be slightly different whereas contact with broadband could be introduced at institutions such as schools, libraries as well as companies. The motive for spreading broadband into rural areas by ICT companies, population density was more important than income in driving broadband deployment (Cromartie et al, 2009 , p 29), rendering in an income inelastic supply. If this is the case in more than just the USA, it means that the limitation to spread is defined as the number of dwellings clustered together. Also it brings to the thought that some rural areas are not going to be receiving any broadband availability unless government puts down infrastructure investment to ICT in the area as the providers would be reluctant to perform this action. The incentives for the government to invest into the broadband in these areas, could be the possilibity to induce e-Government and e-Health programs to the area. E-governance can be seen as a catalyst for change by demonstrating and taking the lead for other sectors to develop the local capacity for ICTs. (Sealy, 2003, p 353) Pointing out that a community far from the hub of a state can be helped to flourish if the government helps out the building of ICT to create stronger bonds between them. The way e-Governance may create bonds is that the voices of the community can communicate easier with the government, which enhances democracy by communication in the region. E-Health systems have similar population benefits as the e-Governance, whereas waiting times and transportation may be cut out from the costs in the system as long as the patients are somewhat educated in the how-to of ICT technology. There are though set-backs with e-Health since the use of ICTs has the potential to exacerbate inequalities (Gilbert et al, 2008 ,p.923) due to affordability to population in poverty and their possibility to invest to gain acces to ICT technology. Due to this reason, one could oppose the previous statement that the income may not be a driving force for the spread of broadband. As affordability to invest in any device (PC, laptop or cellphone) diminishes, this should in some way set the limit to where income dictates the spread of broadband even if an organization would provide the infrastructure leading to the population. By this argument it provides to some extent a limitation for how far an organization would go to provide the infrastructure and how it should be provided.

In order to fully exploit the possibilities for technology to improve how it can affect trade within countries and through this also the economic growth, it is necessary to build up the technology within the society. Innovation based growth is needed for countries which cannot compete with cheap labor, but have to come up with new or improved products to keep up their economic standards. Thus by increasing innovation and the production of technology, the more possibilities one would create within any country giving possibilities to lower unemployment and increasing economic growth in the given country. Therefore, if one would increase the broadband spread within a country, a theoretical inference would be that one would increase the possibilities to promote growth from this technology."Slow growth is mainly the result of failure to exploit the technological opportunities inherent in new and fast-growing technologies. This is not mainly a question of failing to be competitive in, say, the production of computers or other products embodying ICT, but embedding the new technology in society at large." (Fagerberg, 2000 , p 16)

2.5 Summation of theory

Technology and human capital are taken as endogenous variables, while capital and labor are seen as exogenous variables. While capital, labor and human capital do refer to relatively standard components to growth theory and in empirical analysis, technology as seen here does only limit itself to the spread of broadband and not the semi-residual connotation it has had in early growth theory. This may certainly have both advantages and disadvantages, for instance that broadband spread may take on a higher importance by strictly being a replacement to technology in the growth equation. On the other hand it may be one of the few viable options for discovering the impact.

3 Empirical analysis

3.1 Data collection

The data is collected from World Bank statistics and statistics from the International Telecommunications Union (ITU), where the latter is an agency in the United Nations which surveys all forms of telecommunication in the world. Based on the availability of data regarding specifically broadband, the data submitted for a regression will most likely be from 2001 until 2009 as prior to 2001 there were very few countries with broadband at all which will lead to a biased regression. The data for ICT will be collected from the ITU and data for economic growth, education and other data that is not directly ICT related is collected from the World Bank.

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3.2 Methodology

As a large numbers of the countries in the world do not have access to broadband technology, it would be a technical fallacy to include these countries into the model as the risk for bias in the regression from missing values would affect it to a large extent. Therefore, any country with lack of data on broadband spread for more than 6 years is excluded from the data set. In addition to this reduction of the dataset also the variables for human capital have been counted per country as to minimize the effect of missing values in the regressions. The dataset is thus unbalanced, since some countries lack input for other variables than fixed broadband subscription for the full period of time as shown in the descriptive statistics and in the appendix regarding missing values.

3.3 Defining variables and motivation for usage.

Variable	Type	Expected sign
GDP per capita	Dependent	
Fixed broadband subscriptions	Independent	Positive
Capital	Independent	Positive
Edu1, primary education	Independent	Positive
Edu2, secondary education	Independent	Positive
Edu3, tertiary education	Independent	Positive

GDP per capita - the annual GDP in a country, with aggregates based on year of 2000's value divided by the population at the time.

Education - education is counted as percentage of gdp per capita spent per student in three sectors of the educational program, primary, secondary and tertiary. Where primary is elementary school, secondary high school and tertiary university or college. It also includes the expenditure to both public and private education. As this is given in percentages of GDP per capita initially, it was necessary to multiply it by the GDP per capita values giving a monetary input to education. In the empirical study the different types of education will be stated as Edu1, Edu2 and Edu3 to point out the different types of education. The motivation for using the three stages of education is based on the argument presented at the end of page 8 regarding that higher education creates more refined skillsets and should thus affect the economy slightly differently.

Capital – annual addition of capital in the economy in terms of additions to tangible assets as well as inventories in the economy. The capital formation is based on US dollars fixed at year 2000's value. In order to retrieve a good measurement against the other variables this variable has been divided by the population of the country at t to render capital per capita.

Spread of Broadband – counted as fixed broadband-subscriptions per 100 people. What should be noted is that it is subscriptions and not total sum of users, which changes the desired interpretation of the result compared to a "real individual spread". But as the real spread is impossible to discover and only possible to estimate by an amount of hidden numbers, the subscription spread is the most easily attainable at the moment and to some extent the most realistic data on spread. Furthermore, it should be noted that this variable may have population overlaps since both individuals and institutions in society have subscriptions to broadband, by institutions it is meant companies, schools and government agencies may have broadband in many countries. Thus, some individuals may be subject to taking a share in several broadband subscriptions as they may receive it both at home and at work or similar occupation. This fact creates a standard deviation around the true mean of spread, whereas in some countries it could mean that the a person who has access at both home and at work due to education and wealth whilst being an exception to society regarding this status, can in fact create a bias in the data. The term fixed broadband refers to the type of broadband measured, that it is spread by wires in contrast to mobile broadband which is spread by antennas.

3.4 Descriptive statistics

By investigating the descriptive statistics given in the appendix, one may see several differences and noteworthy facts regarding the statistics. To comment the distribution of the variables one may see that there is excess kurtosis in several of the variables and the skewness of the distribution shows that the distribution within the variables tend to not be in the shape of a normal distribution. In all of the variables presented there is skewness and kurtosis, specifically almost all the variables as one may see from figure 12 to 17 in the appendix are leptokurtic and are positively skewed when comparing them to the normal curve in the histograms. This may affect the results as the variables used tend to not follow the normal curve, therefore test-statistics using normality assumptions could be affected. As a result of this the statistics used may not be seen as reliable as if the variables had followed a normal distribution. Also, a further notice to compliment the skewness and kurtosis, one may see that the medians and means for the variables differ from each other where the median is lower than the mean for all variables.

As if one would look at the count of the missing values in table 8 in the appendix, one may see that for the case of GDP per capita and Fixed broadband, the count of valid values is high enough to doubtly affect the regression statistics. While on the other hand, the Capital variable, Edu1 and Edu2 do have higher grade of missing values, where as count of ,missing values are at 31, 30 and 32 respectively and in the case of Edu3 the count of missing values is at 64 out of totally 322 observations. This accounts for that there is an imbalance in the dataset.

3.5 Model specification

Based on the theory presented, the regression would have components from each part of the theory. The overall construction is based on the classical Solow growth theory, using output and capital as stated in Solow's equation, but the labor is here changed to the human capital model and the broadband is included similarily as the technological difference. From the human capital model, investment into education per capita is added at three steps, primary, secondary and tertiary education.

The theory has thus given the basic production function with inclusion of broadband

$$\frac{GDP_{it}}{cap} = \beta_1 + \beta_2 \frac{K_{it}}{cap} + \beta_3 \frac{Edu_{it}}{cap} + \beta_4 \frac{FBroad_{it}}{100} + \varepsilon_{it}$$

Where subscript *i* and *t* denotes country and year in the equation.

By taking the logarithm of each variable the production function becomes the growth equation of GDP, which gives:

$$log(\frac{GDP_{it}}{cap}) = \beta_1 + \beta_2 log(\frac{K_{it}}{cap}) + \beta_3 log(\frac{Edu_{it}}{cap}) + \beta_4 log(\frac{FBroad_{it}}{100}) + \varepsilon_{it}$$

One of the implications of using panel data is that the pooled Ordinary Least Squares (OLS) model may not be consistent or it may be biased as the heterogeneity may likely be present within the dataset. Therefore were all three models run firstly with pooled OLS in order to run a panel diagnostics test to confirm an appropriate coefficient estimation model choosing between pooled OLS, the fixed effects model [the fixed effects in this case(the case of the test) is only pertinent to the one way groups fixed effects, not the two way group and time effects] and the random effects model. The panel diagnostics consist of three tests; test for differing group intercepts for distinguishing between OLS and fixed effects, Breusch-Pagan test for distinguishing between OLS and random effects and at last a Hausman test for distinguishing between random effects and fixed effects. Strictly through all the three models the panel diagnostics showed a favour of the fixed effects model since, the test for differing group intercepts gave a very low p-value in all models pointing to use fixed effects, the Breusch-Pagan test had as well very low p-values directing to use random effects. At last the Hausman test distinguished between using random effects or fixed, pointing to that fixed effects were to be used as the p-value was very low counting against the null hypothesis that the random effects would be correct. These tests are included in the secondary appendix labelled panel diagnostics for each regression. Based on the tests made the estimation has been done with fixed effects. Moreover, to control for time impacts between the years, time dummy varibables have been used, therefore modifying the fixed effects model to a two way fixed effects model. The significance of this has also been tested for as the joint significance test for the time dummy variables show that the null hypothesis of all dummy variables are equal to 0 is rejected.

Thus the change to the original model is as one adds α_{it} to the original model which is the capturing of omitted effects correcting, "the assumption that the omitted effects in the model are correlated with the included variables" (Greene, 2008, p193). What would happen if this was not done is that the error term would correlate with the variables, resulting in that the error term would not be indepent and identically distributed (IID) as the variance would else consist of $\varepsilon_{it} = u_i + v_{it}$ where u_i is the individual unobserved effects and v_{it} is the remaining disturbance

What should be noted is that the fixed effects do not fix any specific variable in anyway, it does only correct for differences between groups by capturing it in the alpha parameter, which is estimated in each regression. In the context of this thesis, groups are defined as countries.

The final regression thus has a form as:

$$\mathbf{Log}\left(\frac{GDP_{it}}{cap}\right) = \boldsymbol{\beta_1} + \boldsymbol{\beta_2 log}\left(\frac{K_{it}}{cap}\right) + \boldsymbol{\beta_3 log}\left(\frac{Edu_{it}}{cap}\right) + \boldsymbol{\beta_4 log}\left(\frac{FBroad_{it}}{100}\right) + \propto_i + \boldsymbol{D_2 \ldots D_7} + \boldsymbol{\varepsilon_{it}}$$

3.6 Results from investigating broadband effects.

Regression 1 uses primary education labelled Edu1

Table 1 Regression 1

Dependent: Log(GDP per capita)					
	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	6.894	0.454	15.185	<0.00001	***
Log(Fixed Broadband)	0.017	0.008	2.164	0.031	**
Log(capitalpercapita)	0.185	0.035	5.280	<0.00001	***
Log(Edu1)	0.141	0.047	2.977	0.003	***
dt_2	-0.005	0.007	-0.819	0.413	
dt_3	0.004	0.011	0.402	0.687	
dt_4	0.009	0.014	0.637	0.524	
dt_5	0.021	0.017	1.182	0.238	
dt_6	0.043	0.019	2.213	0.027	**
dt_7	0.039	0.020	1.881	0.061	*

Table 2 Regression statistics for Regression 1

Mean dependent var	9.422		S.D. dependent var	0.982
Sum squared resid	0.203		S.E. of regression	0.031
R-squared	0.999		Adjusted R-squared	0.998
F(49, 210)	5274.312		P-value(F)	9.9e-300
Log-likelihood	561.231		Akaike criterion	-1022.464
Schwarz criterion	-844.429		Hannan-Quinn	-950.891
rho	0.544		Durbin-Watson	0.553

Regression 2 uses secondary education labelled Edu2

Table 3 Regression 2

Dependent: Log(GDP per capita)					
	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	7.087	0.586	12.081	<0.00001	***
Log(Fixed Broadband)	0.018	0.008	2.063	0.040	**
Log(capitalpercapita)	0.213	0.041	5.077	<0.00001	***
Log(Edu2)	0.087	0.056	1.555	0.121	
dt_2	-0.003	0.007	-0.431	0.666	
dt_3	0.003	0.013	0.257	0.797	
dt_4	0.010	0.017	0.623	0.533	
dt_5	0.024	0.019	1.248	0.213	
dt_6	0.046	0.022	2.025	0.044	**
dt_7	0.042	0.024	1.745	0.082	*

Table 4 Regression statistics for Regression 2

Mean dependent var	9.445		S.D. dependent var	0.982
Sum squared resid	0.230		S.E. of regression	0.033
R-squared	0.999		Adjusted R-squared	0.998
F(48, 211)	4765.747		P-value(F)	8.5e-296
Log-likelihood	544.716		Akaike criterion	-991.432
Schwarz criterion	-816.959		Hannan-Quinn	-921.291
rho	0.576		Durbin-Watson	0.508

Regression 3 uses tertiary education labelled Edu3

Table 5 Regression 3

Dependent: Log(GDP per capita)					
	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	6.974	0.654	10.654	<0.00001	***
Log(Fixed Broadband)	0.020	0.008	2.372	0.018	**
Log(capitalpercapita)	0.256	0.060	4.206	0.000	***
Log(Edu3)	0.060	0.039	1.528	0.128	
dt_2	0.001	0.006	0.162	0.871	
dt_3	0.009	0.012	0.765	0.444	
dt_4	0.016	0.015	1.073	0.284	
dt_5	0.022	0.018	1.231	0.219	
dt_6	0.042	0.022	1.906	0.058	*
dt_7	0.043	0.022	1.930	0.054	*

Table 6 Regression statistics for Regression 3

Mean dependent var	9.494		S.D. dependent var	0.927
Sum squared resid	0.228		S.E. of regression	0.034

R-squared	0.998		Adjusted R-squared	0.998
F(46, 193)	3767.407		P-value(F)	4.2e-262
Log-likelihood	494.178		Akaike criterion	-894.356
Schwarz criterion	-730.7660		Hannan-Quinn	-828.441
rho	0.600		Durbin-Watson	0.487

In the first regression an one percent increase in; capital would increase growth in GDP by 0.185%, broadband would increase growth in GDP by 0.017%, primary education would increase growth in GDP by 0.141%. Regarding significance, all of the explanatory variables are significant. The fit of the variables to the model show that in explaining variance, it explains 99% of the variance in growth in GDP.

In similarity to regression 1, the capital and broadband variable are significant, while the secondary education variable is not. If one would make an increase by 1%; in capital, growth in GDP would increase by 0.213%, in broadband growth in GDP would increase by 0.018% and in secondary education it would have been an increase by 0.087%. Regarding the models power to explain variance it is at 99% , similarily to regression 1.

As in regression 2, only capital and broadband were significant while tertiary education was insignificant. The effect of an 1% increase in; capital gives a 0.256 % increase in growth of GDP, broadband gives a 0.020% increase in growth of GDP, tertiary education would have increased growth in GDP by 0.060%. In the third regression the explanatory power of the model is at 99% explanation of variance in growth of GDP.

Regarding the test statistics run in each regression for each of the fixed effects, group and time, they showed that fixing the effects did have a significance in the regressions. The test for differing alphas rejected the null hypothesis in each regression regarding if the alphas were significantly different from each other or not. Also the joint significance test for the time dummies proofed that at least one was significantly different from 0 which can also be seen in the coefficient statistics. Thus the two-way fixed effects model could be seen as a true model of estimation and an pooled OLS would have been inconsistent and along with a one way fixed effects it would also suffer from omission bias (Baltagi, 2008 , p 36).

By inspecting the qq-plots of the residuals in the appendix one may see some similar features of the residuals in the regression that over all the residuals fit closely to the 45-degree line except for in the first percentiles of the plots where the residuals seem to be fitting below what is to be expected from the residuals. There are also streaks of a likely secondary function closely to the median of the qq-plots, though the streaks are fitting closely to the 45-degree line. Therefore the residuals seem to be well fitted overall in all three regressions. Though, as a limitation to the examination of the residuals, no histograms have been available after using fixed effects as a model of estimation, which could have been more usefull than qq-plots in the regressionwise examination of the residuals.

3.7 Limitations in the results and in dataset

One flaw that should be pointed out is that the dataset although fixed, is unbalanced, it does not contain the same amount of observations for all groups and variables, which may cause some disturbance to the result. Mainly the unbalance would lay in the variables for education or possibly rarely in capital as the values for broadband spread and gdp growth have been the priorities of having a complete set of values for any country and year.

By reviewing a plot of Log(capital) against log(GDP) from figure 2 in the appendix one can see that for this variable there are very few possibilities to detect an outlier and the fitline going through the plot has a high fit-value of 0.95. it seems to be a well fitted in general and no need of removal of observations.

On the other hand in observing the plot of Log(broadband) against Log(GDP) in figure 3 one can see several patterns. For instance at the bottom one may follow India as well as at the top Liechtenstein, where one may see a trend pattern, most likely from time series. Also it is possible to detect two other trends in terms of viewing the scatter as two major clusters and India at the bottom. If one looks closely one can detect that the clusters are located on either side of the line which would create different constants and possibly also estimates. Thus this variable by itself may be the very reason to why the statistics showed that the fixed effects model was the correct model. The pattern stemming from time series may be corrected by the time effects in terms of dummy-variables for each year except 2002. The second pattern regarding the two loosely figured clusters may be the reason to why there is a significant one way fixed effects, since it captures unobserved differences in this case the differences in the broadband variable and adjusts for individual constants α_i. This should theoretically shift the distances in residuals from this variable to give a closer fit of residuals.

As for an outlier analysis in primary education growth against GDP it is hard to point out any clearcut outliers as most of the observations lie closely to the fit line. Only Liechtenstein and the United Arab Emirates may be considered outliers in some opinions, but it is doubtful if removal of either would affect the econometry.

As for the plot of secondary education it has a similar pattern to the plot of primary education against growth in GDP. There is some spread of the observations on each side of the line, the only countries coming close to possibly be considered outliers would be the United Arab Emirates and India though neither are far from the fit line.

In the plot for tertiary education growth visavis growth in GDP the situation is slightly different as the variance around the fit line is substantially larger and one could point out India to be a clear outlier along with Liechtenstein and probably Korea Republic as their observations are grouped noticeably far from the rest of the observations and fit line.

For any regression with more than 100 observations and including three variables the lower limit from the Durbin-Watson table is 1.61 and the upper limit is 1.74, for seven variables the lower limit is 1.5279 and the upper 1.8262. Comparing the Durbin Watson values of the regressions to the statistical table show that all three of the regressions do test positive for autocorrelation with a rho between 0.54 and 0.60. As the absolute value of rho is definitely smaller than 1 the effect of the autocorrelation will hopefully be limited.

Regarding multicollinearity, by examining the collinearity matrix in the appendix one can see that there are severe multicollinearity problems between capital and any of the education variables. There is some multicollinearity as well between broadband and the other variables, although not as severe. Therefore the results of the regression should be seen with causion based on the possible outcomes of multicollinearity such as the fact that coefficients may be strongly affected by the observations.

As the data is a panel type, the heteroskedastic behavior that might appear in the data would be in between groups, or countries in this case. Thus by running a modified Wald test for differing individual variances, it was detected that heteroskedasticity is indeed present in the dataset as the null hypothesis of all individual variances being equal was rejected. To remedy the heteroskedasticity, the heteroskedastic and autocorrelation consistent (HAC) estimation was used, which differs from the White robust standard errors (heteroskedasticity consistent covariance matrix estimation, HCCME) estimation as it accounts for autoregressive heteroskedasticity. The standard errors did increase, leading to the rejection of the estimates for Log(Edu2) and Log(Edu3) after the HAC robust standard errors where introduced.

4 Analysis

In all of the three regressions one can point out that most of the explanatory variables are significant, there are some small differences in between the regressions which one may compare. It is statistically confirmed here that by inducing fixed broadband subscriptions as a percentage coverage per person instead of using the more general A(t) one can see that technology does make a difference in the production function, as well as in the growth equation. Also it gives a statistical confirmation of that specific technologies may be subject to improve the economic welfare. If comparing this version of the production function to the original one can see that the major contribution comes from capital independently of the amount of human capital. Though as an interesting fact, the contribution from capital differs as one changes the type of human capital in the input. As the level of education becomes higher, the contribution from human capital has a steady decline, where as the opposite happens to capital, at least by judging from the beta-parameters in each regression. From regression 1 to 3 the estimated parameter for capital are 0.185, 0.213 and 0.256 compared to the estimates for education 0.141, 0.087 and 0.060 which do present opposite trends to each other. There is also an increasing trend for the estimated parameter for broadbands spread although the difference may not be as large as for the other variables, 0.017, 0.018 and 0.020. To say that the differences in broadband and the effect thereof may be directly caused by differences in human capital may be erroneous, though it may be a possibility.

If one compares the results in between each the variables, for each regression one can see that largest contribution to economic growth is capital, followed by human capital and at last the spread of broadband in the population. Therefore one may draw the conclusion of what factor matters the most, capital, followed by human capital and at last technology. This brings forth the priority to what one should satisfy first as well to a basic economic growth, thus it could explain why for instance less developed countries may have lower standards of the technology as shown later. The resources in the economy to stimulate economic growth are better put in the capital or human capital than in broadband technology even though there would be possibilities to improve human capital by using broadband technology.

By continuing the spread of broadband, there are still possibilities to increase the economic growth in most part of the world. Where one would be able to see the highest possibility to increase growth, would be most of the less developed countries, but on the other hand one would most likely see the causality in this that just because they have a low income per capita this is an infrastructural improvement that is not likely to occur before other more necessary improvements. An interesting fact around this is according to ITU the broadbandtype that increases the most in African countries is the mobile type of broadband which would mean less needs for physical infrastructure in and between metropolitan areas. This could reduce the cost in terms of the physical capital as well as the cost of maintenance and cost of installing the physical infrastructure.

Also, possible hidden effects are for instance the technology being a tool to academic jobs, where as human capital will be the major factor to the job getting done, while broadband could have the effect of enforcing the effect of human capital. Furthermore, the service sector in the economy benefits largely from the broadband technology by improving communications or giving means of operation for certain companies. To draw this argument further, if more people would be educated about the possibilities for use of broadband in their business there exist a chance that it could increase the demand for broadband. This would in turn increase the spread and the economy with it.

The problematic aspect with doing a change in spread analysis, is that at the end, change would become negatively related or insignificant as the spread has been saturated, where the changes would not occur at any larger extent in the same type of broadband, similarily as to in a cumulative distribution, one would in the end not see any larger changes. Therefore this is one of the major limitations along with availability to continuous data on the global scale regarding several of the variables. With more observations one could derive regional differences as well as retrieving a higher likelihood of coming closer to a true estimation of the beta-coefficient. Gillet discusses this obstruction as well seeing that the level and number of observations are not as in depth as what is desirable. One of the theoretical solutions to the problem was "if data were available to identify the local cable franchise and/or ILEC in 1998, and this data predicted well the availability of broadband by 1999, such a variable could provide a control for early broadband availability that is not itself also related to economic growth." (Gillet et al, 2006, p 16) This could have been a solution if it was not as problematic as it is, thus the true early base for broadband is not likely to be found, resulting in that it is very hard to predict what the original change to the economy was for approximately the first five-year-period.

A further limitation in comparing broadband's spread and its effect is how one may differ between generations of broadband types. A first class is already defined as one can define between fixed broadband a mobile broadband, but what the classification misses is the possibility to define differences in quality of the technology. If one could measure these differences one could narrow down further the effect of changes in this type of technology. Examples of the global differences can be made by pointing out the differences between Japan, Korea Republic, Sweden and the USA. By Meaning one could measure spread and quality effects unisonly and thus show what offers the greater contribution. A graphic illustration (albeit somewhat rough) demonstrate the global differences in quality

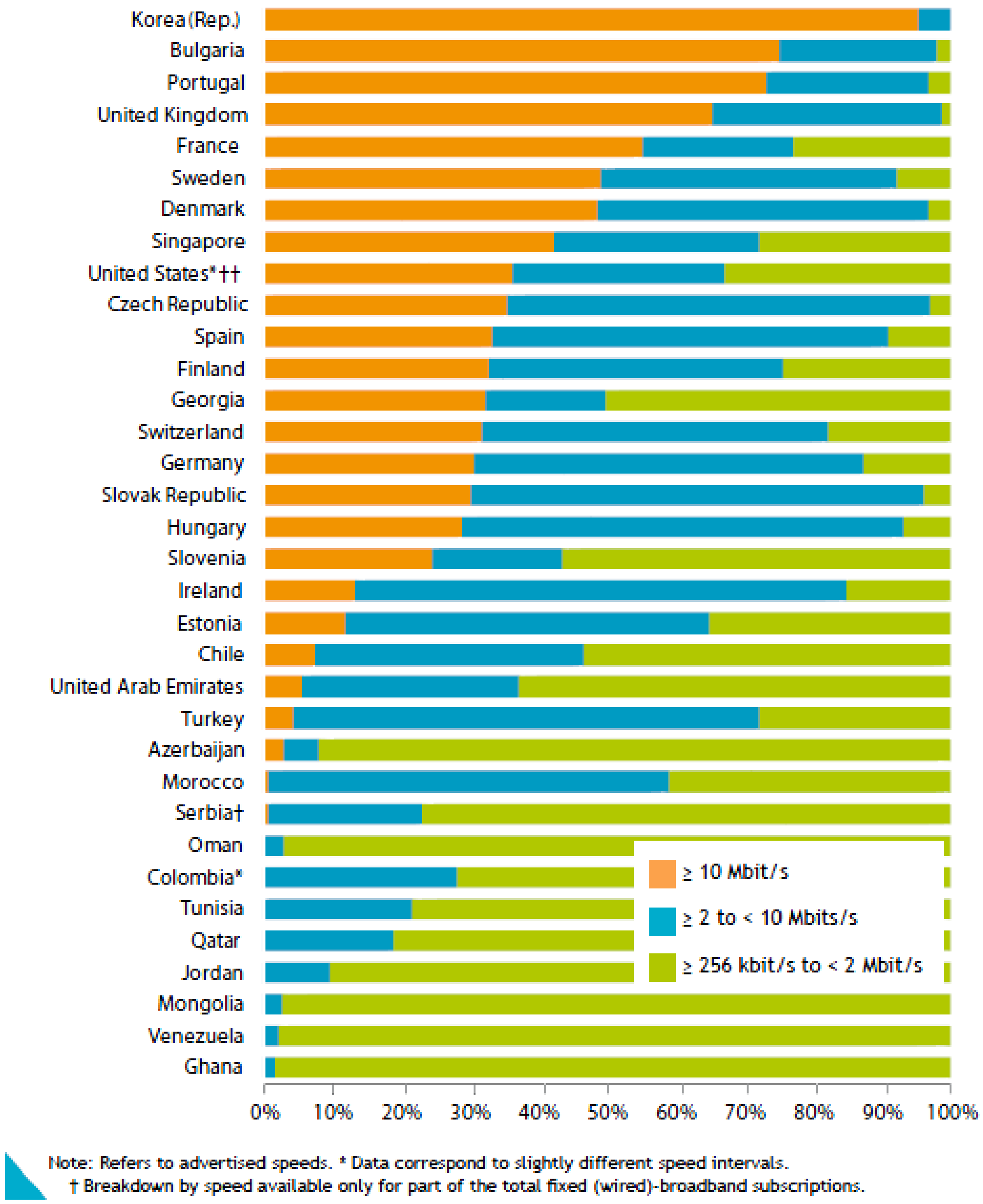

Figure 3 Showing difference in speed and spread thereof in the technology, ITU, The world in 2011: ICT facts and figures, source itu.org, p.6

Even in between the developed countries the differences in the technology is substantial, where though the different local classes of options for broadband may certainly be in between the limits for what is described here as the ITU collects the data simplifies it. Therefore, the heterogeneity between the countries in terms of speed and its spread dictates a problem to how to statistically measure them. The point for this paper of this is that the basic technology may be statistically significant to alter the economic status, but to narrow it down further and to find a clearer causality it would be necessary to use either weighting techniques or dummy variables for each year and status to perfectly concentrate the effect. The question to this is if it is possible or economically feasible with respect to resources.

In addition, an argument that should be included to the discussion regarding broadband is the fact that ICT in general may be what one refers to as general purpose technology (GCT). Why ICT and thus broadband can be categorized as GCTs is because ICT may take place in any production or application, similarily to electricity in the beginning of the 20th century (David and Wright, 1999) that could be included as an technological improvement in any production. The characteristics of GCT may also include some bias while measuring the technology and how it may affect the production and the economy. The arguments for the bias may include reasons as for instance the lag of time between the introduction of the technology and the time it takes for adjusting the production to the new technology before it may be increasing the productivity in the production. Also the reason that on occasion the complementary investments into the application to the production or developments during time, may not be captured by the spread of the technology and therefore leading to bias in measurement in the productivity. The bias in measurement would also include unmeasured intangible capital that have been created in adjustment processes or development processes may not have been captured in the empirical analysis. (Basu and Fernald, 2007) Another argument explaining why GPT would not increase economic growth is the fact of loss of resources devoted to change the production for the new technology. The production would be lower due to the resources changing the production would not be productive to output, thus total output would diminish for the time and then increase when installments are completed and resources are once again devoted to produce to output. (Jacobs, Nahuis, 2002, p 248) Thus GPT could possibly as well affect economic growth negatively for a period of time.

Moreover, the factor stated in theory regarding the income elasticity to broadband could possibly show why broadband may advance faster in some countries than others, as mentioned in some regions it may not be affordable resulting in that the spread growth is lower compared to what it could have been otherwise. An estimate made by the ITU for the price difference for a fixed broadband subscription between developed countries and developing countries is that by purchase power parity dollar (PPP$) a subscription "cost on average 190 PPP$ per month in developing countries compared to only 28 PPP$ per month in developed countries." (ITU, 2011, p7)Due to this problem there is another problem as well that may occur, the exacerbation of the poor as being poor and not affording a technology that could possibly improve the situation. This leads to a conclusion that while broadband may be deployed in an area, there is a need to apply measures to not let a social divide because of broadband drain people further into poverty as the chances for improvement else would be diminishing.

To furthermore explain possibilities for low spread, the demand for broadband may be low due to low or none information as to what benefits broadband could provide or even how computers may aid business and personal life. Thus more information could increase the demand, making the market more profitable for more broadband providers. Better regulations for the rights-of-way argument or the unbundling argument could also provide to the increase in the broadband spread, which would in turn increase economic growth and activity contingent on that broadband would in fact stimulate growth.

What implication the growth factor spread of broadband has, contra the affordability along with intangible possibilities for development do comprise a problem. Perhaps not for the developed countries in the world, but for the LDCs in the world where broadband probably could do have a greater effect of improving standards of economy, health and education by saving resources in inputs and creating new jobs. In some sense it is a possibility to restrain urbanization as well, by aiding the incentives to stay in rural areas. Given the problems that may occur with extreme urbanization such as unemployment, congestion and poverty, this could be a mean against those problems by giving a chance for a higher population distribution to the rural areas instead of in urban are.

A critique against broadband could improve economical standards is that computer systems require both literacy and electricity, as if these infrastructures are low, the possibilities to stimulate a country's growth with ICT would likely be very low. Neither would ICT be the more important investment in these cases, but education to how to reach the standard for increasing ICT would likely be a better goal. This argument could relate to the statistics from the regressions, where as primary education stimulates economic growth more than broadband spread could do, while secondary and tertiary education turned out to be insignificant after HAC robust errors were applied.

As to where one would place the importance of broadband spread to economic growth would be a secondary level of development, because the effect will not fully come through before any primary development of infrastructure has taken place. Nor would it likely be the most rewarding investment as the coeffients point to that the more rewarding factors are capital and education, which also serve as basis for the whole society. Though as a secondary development along with secondary and tertiary education it will most likely have its best effect since the necessary skillset is in place and it may aid developing more skillsets. In addition, primary skillsets and capital may be what broadband needs to have an effect on business, in both trade and production, where broadband could serve as an efficiency increasing factor to the other factors of production, for instance in minimizing storage and office space. Moreover, continuing education around broadband would increase the demand for it which would improve the economy. Moreover, to apply the argument presented by Fagerberg to the analysis made, the contribution of broadband as a factor that would "give an edge" in the international perspective of economic growth, may be significant in hindsight of the econometric analysis. As an application to growth theory and connecting the argument to export based growth, the addition of broadband to a nation, that may be within the range in terms of development, would probably enhance the nation's performance. As one interprets the results in the empirical analysis, it could confirm the trade argument of technology and its effect on economic growth. Therefore, the more spread the broadband would be in the population, the better its basis for performance would be.

Another explanation to the correlations in the result are also the either reversed causality or the bi-directional causality, whereas either the magnitude of GDP may be the factor increasing broadband or they may have increasing impact on each other. For instance (Grosso, 2006, p.21) mentions that GDP was the strongest force to increase broadband, means there is at least a reversed causality to this. Possibly it may also point to that high income countries may afford to invest more into ICT compared to low income countries, which is why it may not even exist in some countries until the latest years. From the statistic from ITU one can read that the difference between poor and rich is already high at the global view, 4.4% in LDCs have broadband while in developed countries the figure is 24.6%, which might support this argument. Therefore the results in the empirical analysis may show the results of the reversed causality, rather than the causality that this paper has undertaken to investigate. In some cases the direction of causality have been hard to point, in previous research (Gillet et al, 2006 p. 10). Due to these reasoning, one should let the conclusion to the causality, whether broadband causes economic growth or vice versa, and hense the outcome of the paper be put in careful terms as there are evidence pointing to other directions.

The result discussed are similar to other articles within the broadband area, Kotroumpis estimated that there was a positive relationship between GDP and broadband spread in a production function. Kolko's findings did not entirely state that there was a positive effect on economic growth, Gillet found positive correlations between broadband and growth, though none were deemed to be a proof of it. In comparison to the findings, one may see that there is a statistical significance here, using logged variables and fixed effects in the estimation, which could contribute to a statistical point of view that broadband is significant to growth. Given an argument by Gillet et al regarding that their estimates were larger in magnitude than expected, it does seem fit to show a 95% confidence interval instead of a point estimate. A true estimate for the coefficient for broadband could lie in between 0.0015 and 0.0337 using estimate and standard errors from the first regression as it has the lowest coefficient for broadband spread. Taking into account the arguments contradicting that broadband spread could affect growth, the lower bound of the confidence interval may seem more realistic as an estimate for the possible effect.

5 Conclusion

As a summarization of the paper, it would be logical to suggest that the effect of broadband on the economy and the economic growth, is positive and significant, though it is relatively small compared to the other factors that promote growth in the economy.

What is necessary around this kind of technology is the establishment of costs and income for networkproducers, what kind of product they offer in both terms of speed and reliability of signal. Without this kind of information it is hard to establish the exact effect, since if the product differs substantially between countries or regions, there is a need of weighting between the individuals for a reasonable comparison. Also the price of the product towards consumers relative to their income would be an interesting factor to count in as it determines the reach of broadband, if only a certain social class in the region sees the product as affordable or if it is affordable to all demographics makes a great difference.

The term affordability comes into use when one would discuss projects such as e-government and e-healthcare, which are projects under the international telecommunications union. Both discuss how it would be possible to broadband in order to let physically immobile resources become mobile through broadband connections, where the need for the resources is allocated to remote places for instance in agricultural areas. If these kinds of programs could be evaluated by performance one could possible take the discussion of the value of broadband spread to another level from the purely economical to the discussion where it affects the living standard of a wider population. It could also be a means of slowing down the urbanization in many areas, if higher living standards could be provided in countrysides with features from urban areas through networks.

The factors that may make this paper weaker is the short time span of the data, the unbalance in the panel, the heteroskedasticity and the low knowledge of global difference in for instance definitions of broadband and product quality. Moreover, the fact that the area is somewhat new has both its strengths and weaknesses, it has a strength in that it is an area that is contemporary and may have an affect now, it has a weakness in that the foundations for research are smaller. Even though there are similar areas, the area for broadband technology has some characteristics that are not covered in for instance telephone technology nor internet, an example would be the rate at which information may pass through it compared to the previous that changes the market for it.

The future possilibities for the paper are numerous but for mentioning a few that are pertinent from economical perspectives and from development perspectives, e-Health, e-Government and market characteristics do come in mind when discussing spread broadband. To investigate e-Health's and e-Government's possibilities to improve rural life and a key for geographical stretch of resources, where distances may be too costly for any agent on the market to provide transport, may have significant improvement of communication of power reinforcing a dialogue as well as improving security of people in health issues. The market characteristics for ICT technology on the global scale may further be another topic to investigate as it does hold a key to how vast the spread is, if it takes income elastticities into consideration or if there are barriers to improvement in regions.Also the quest for improved security and enforcement of laws may be a field for investigation related to what extent the spread affects the economy. If more agents on the market could see a higher security, would one then see a further increase in the effect on the economy?

Based on the facts presented, policy implications from the paper would incline that increases in spread of broadband could theoretically improve regional and national income and standards. Moreover, it has advantages to both business and pure infrastructure which would be beneficial to the living standards in any given region, as well as possible gains to the environment. For example less congestion that causes less exhaust and lost hours in traffic, another example is the possibility of remote interactive education which may have beneficial implications for areas with low density in population. Though any inferences should also refer back to the reverse causality argument and the GPT argument as there may be other factors affecting the results.

6 Appendix

6.1 Graphs

Plots of independent variables against the dependent

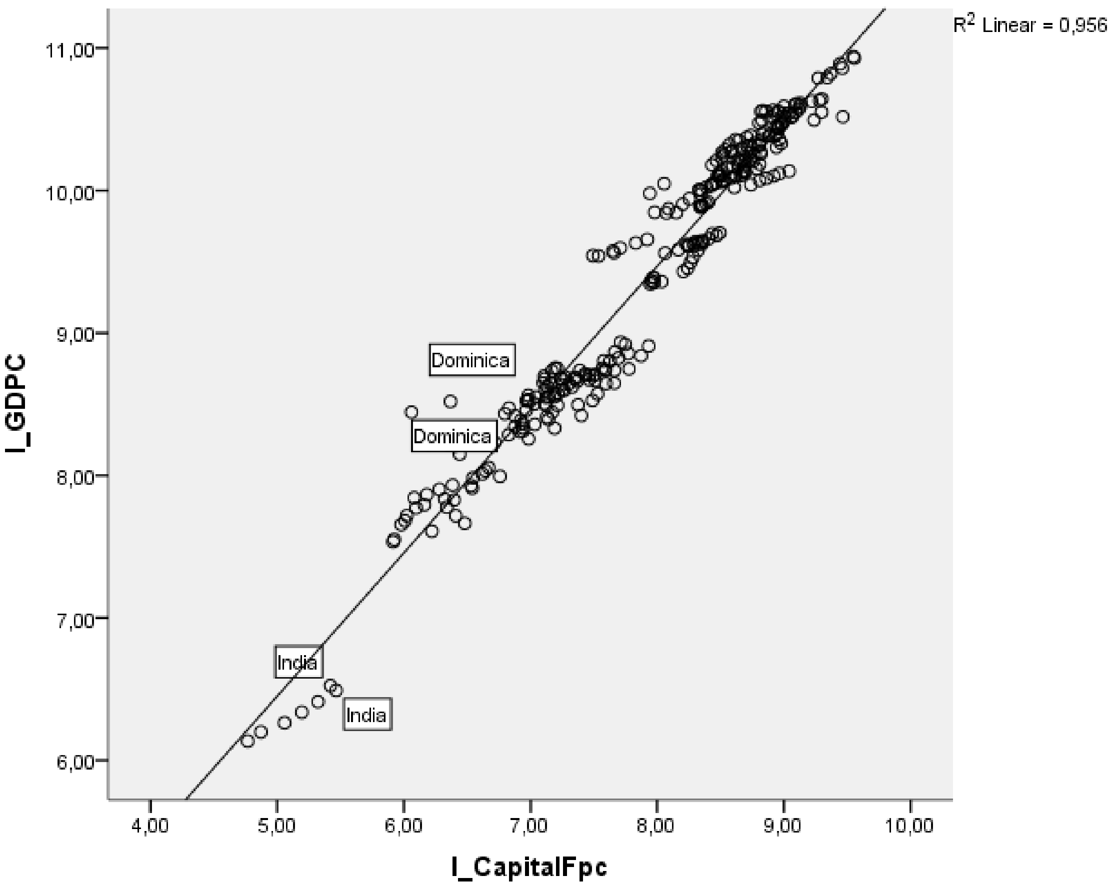

Figure 4 Scatter plot of Log(capital) against log(GDP)

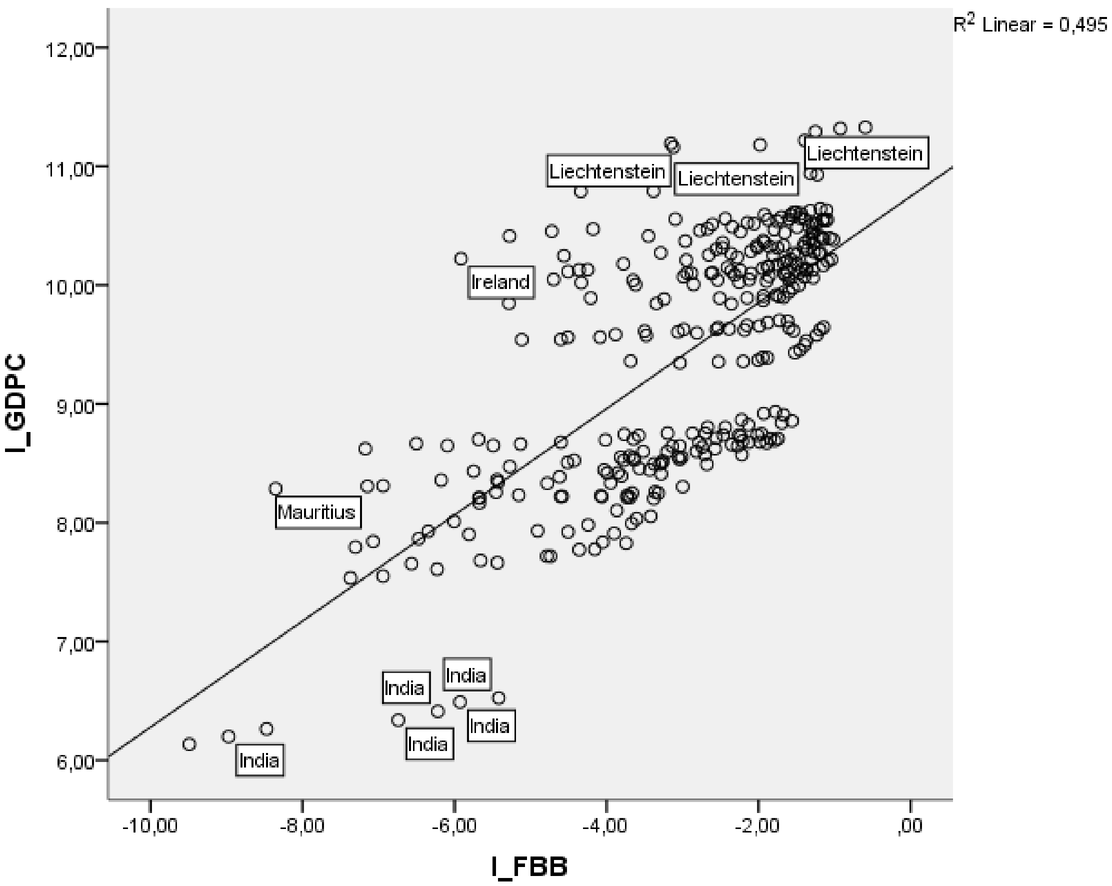

Figure 5 Scatterplot of Log(Broadband) against log(GDP)

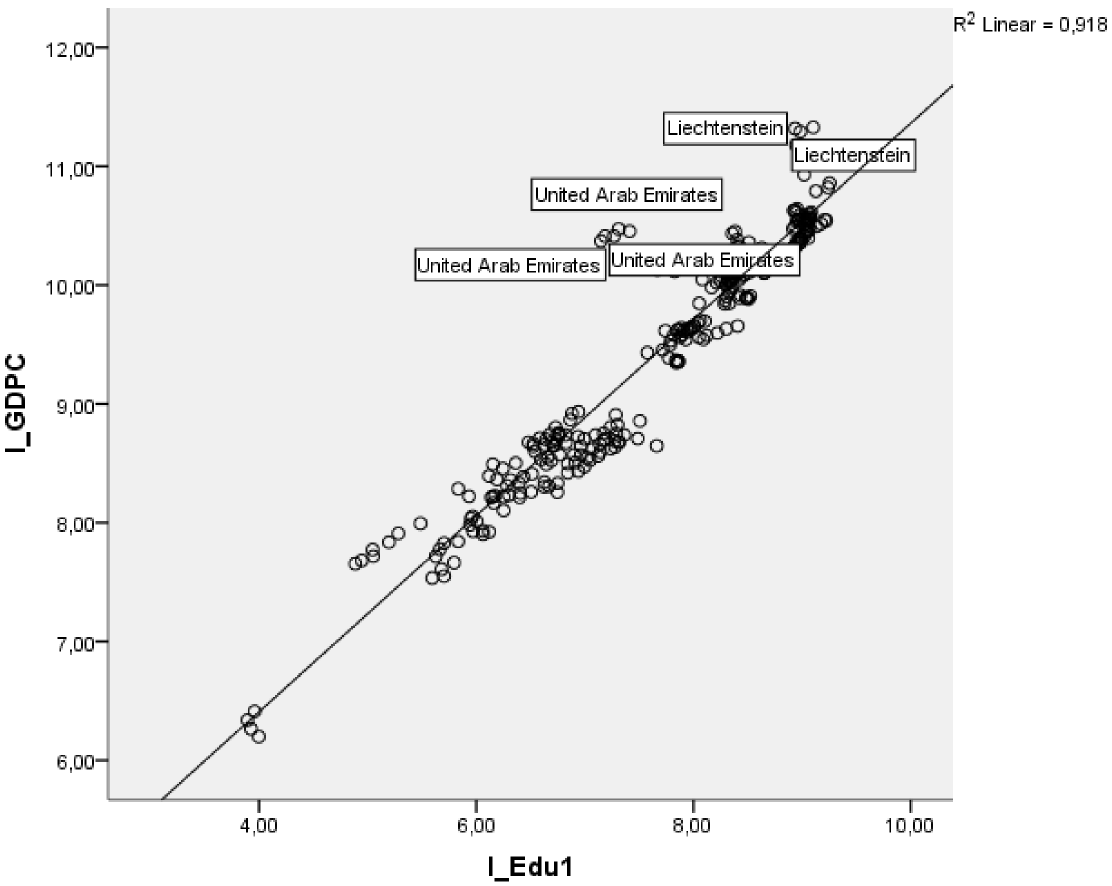

Figure 6 Scatterplot of Log(Edu1) against Log(GDP)

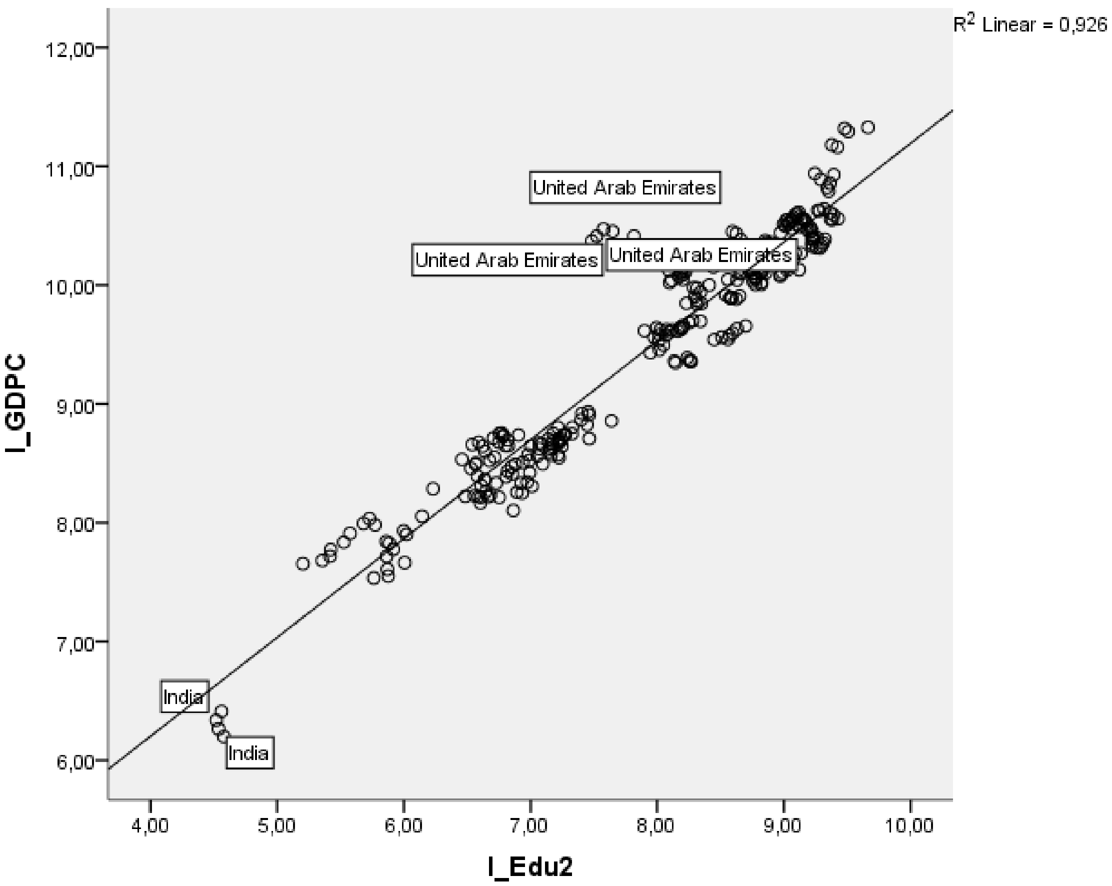

Figure 7 Scatterplog of Log(Edu2) against Log(GDP)

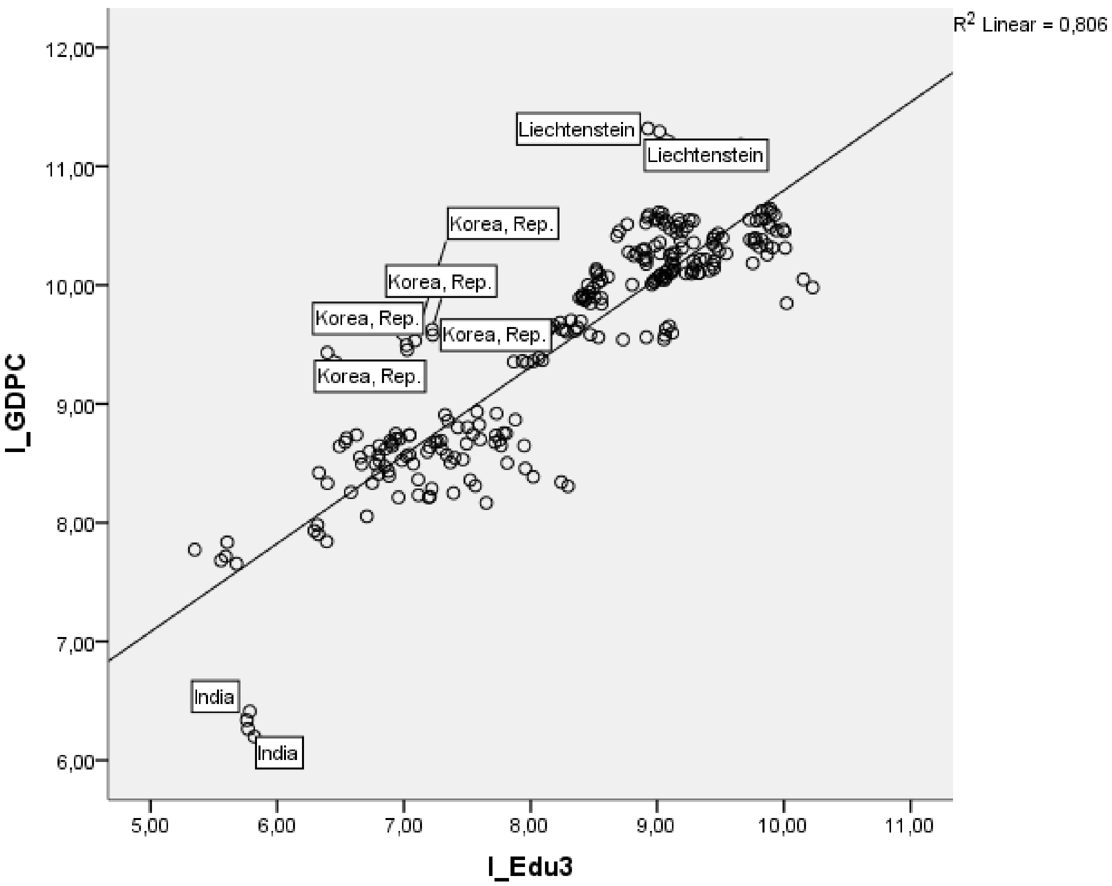

Figure 8 Scatterplot of Log(Edu3) against Log(GDP)

Grahps from regressions

QQ-plots

Regression 1

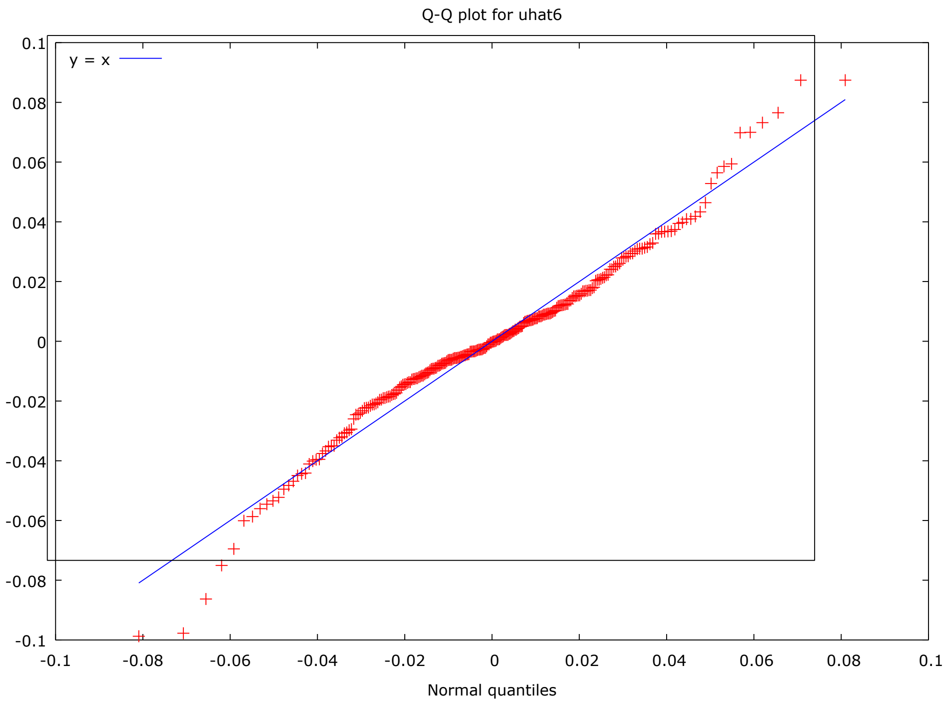

Figure 9 QQ plot for Regression 1

Regression 2

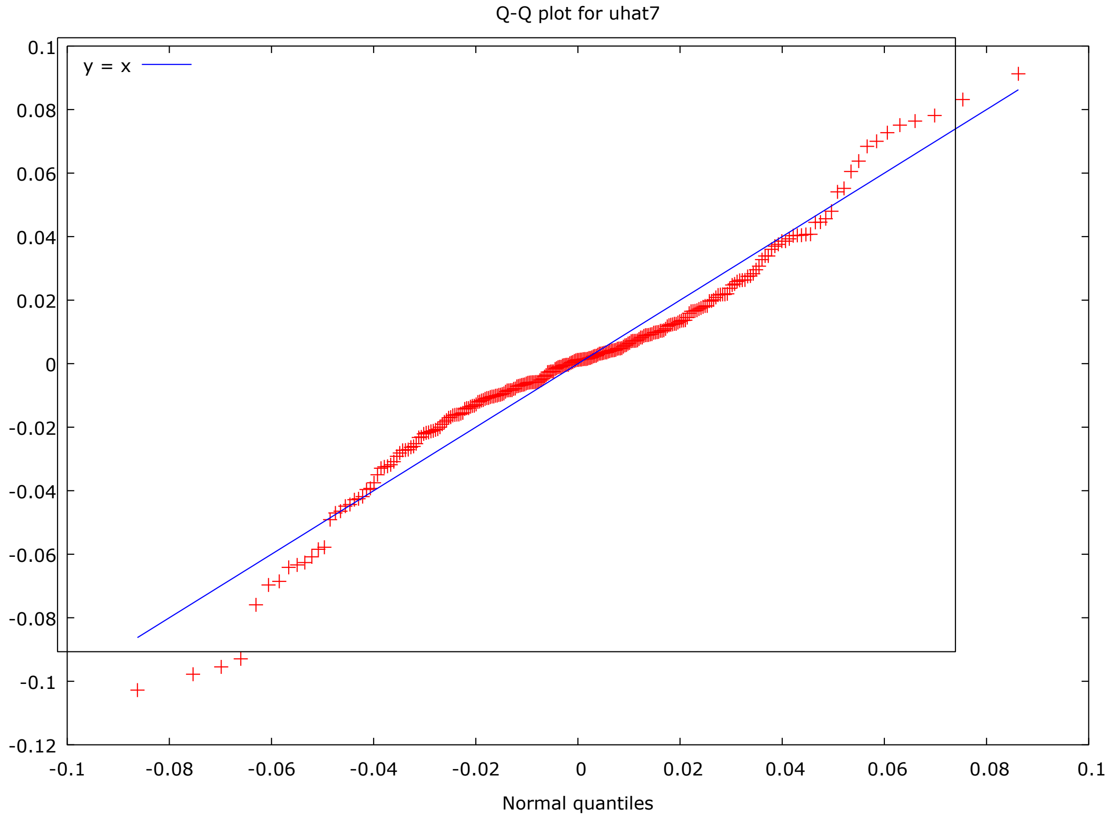

Figure 10 QQ-plot for Regression 2

Regression 3

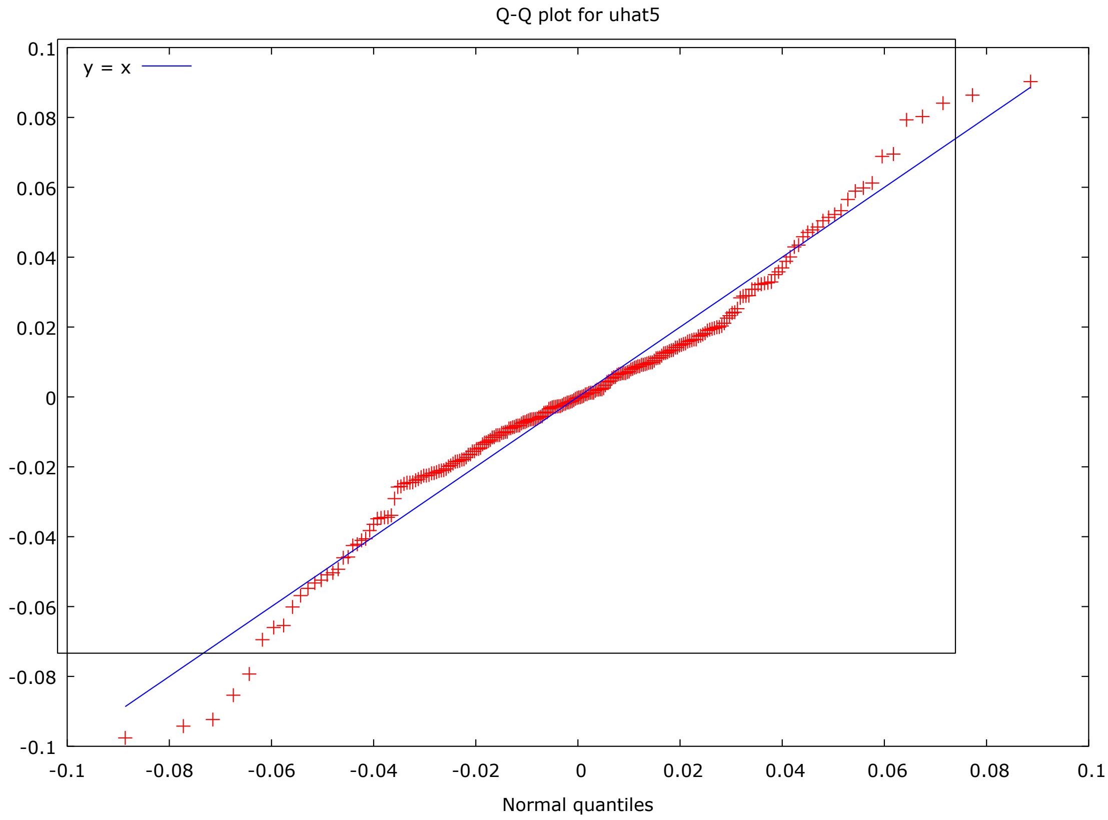

Figure 11 QQ-plot for Regression 3

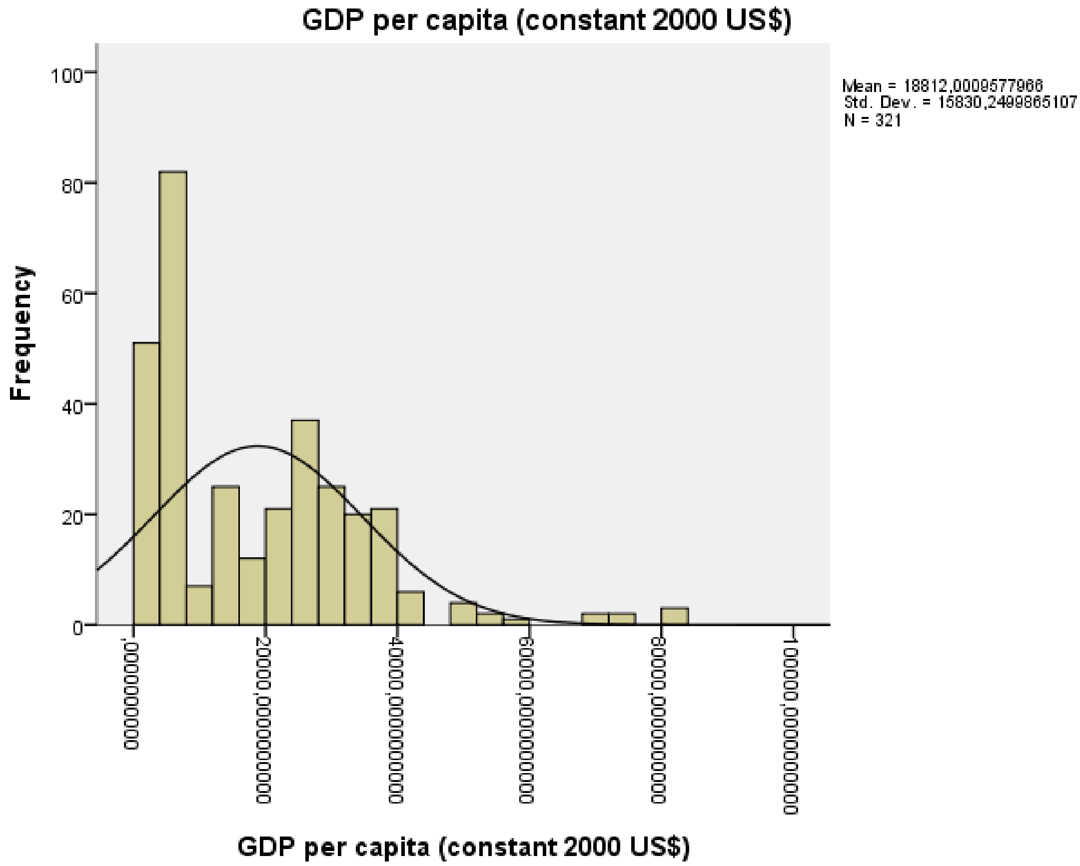

Figure 12 Histogram and normality curve for GDP per capita

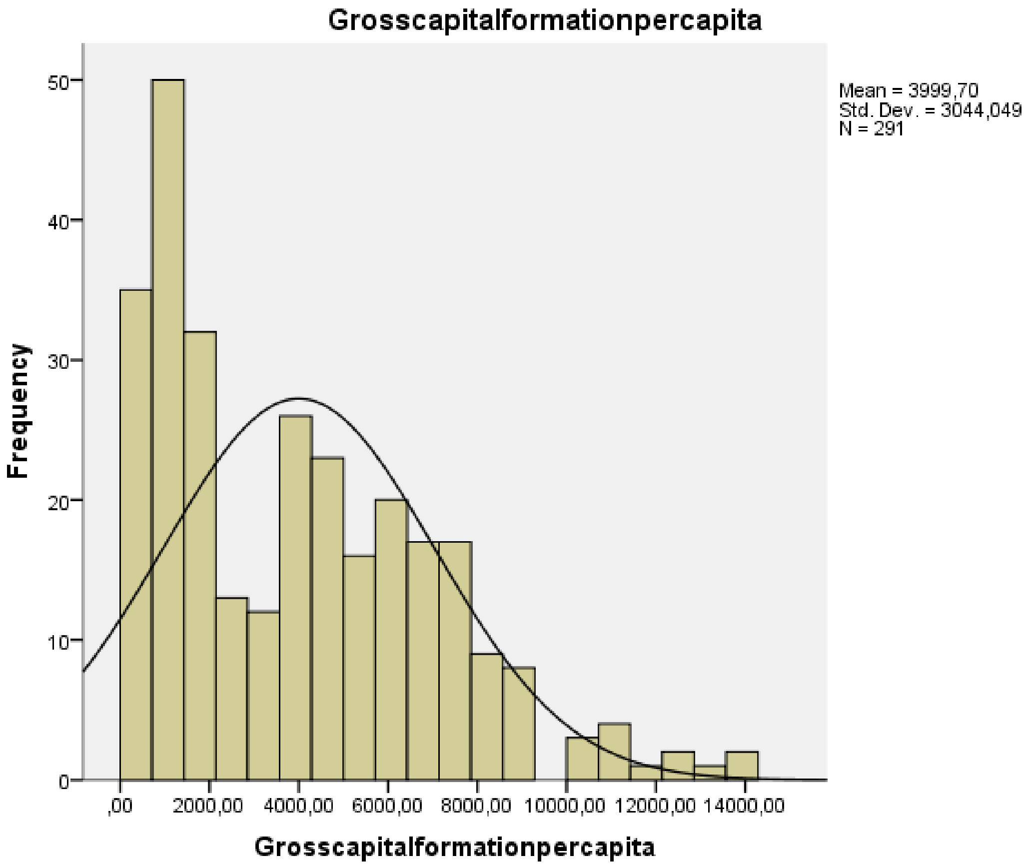

Figure 13 Histogram and normality curve for Capital per capita

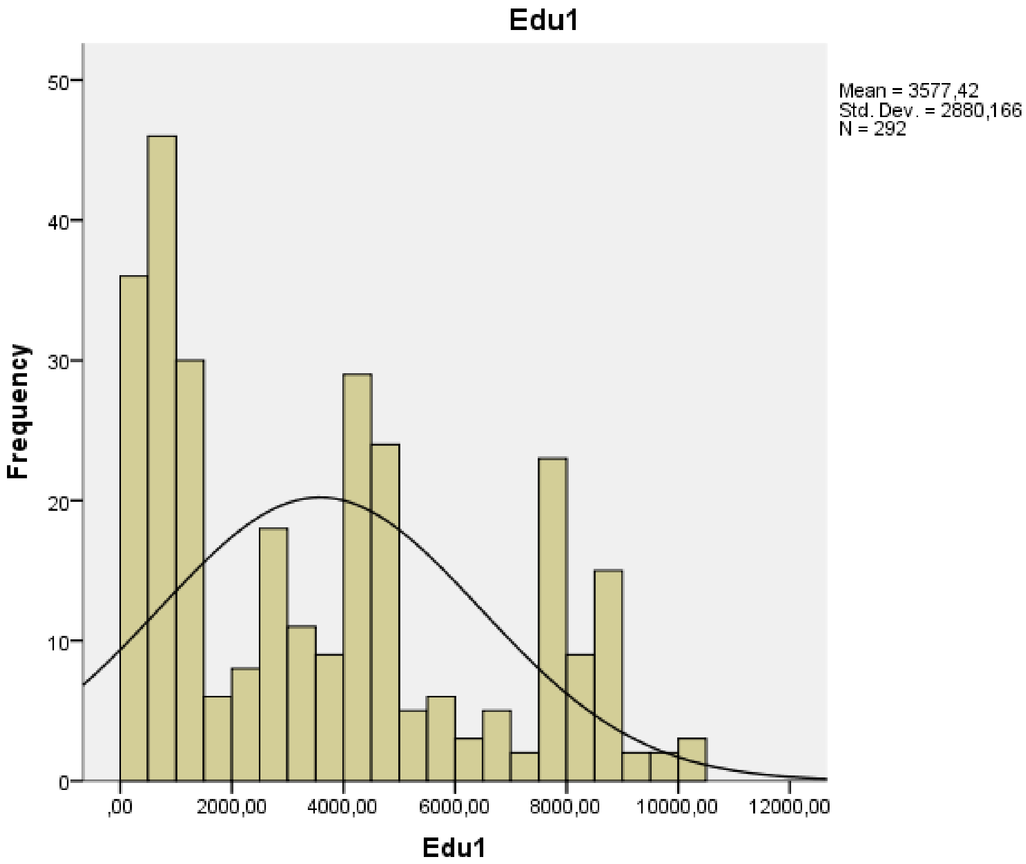

Figure 14 Histogram and normality curve for Edu1

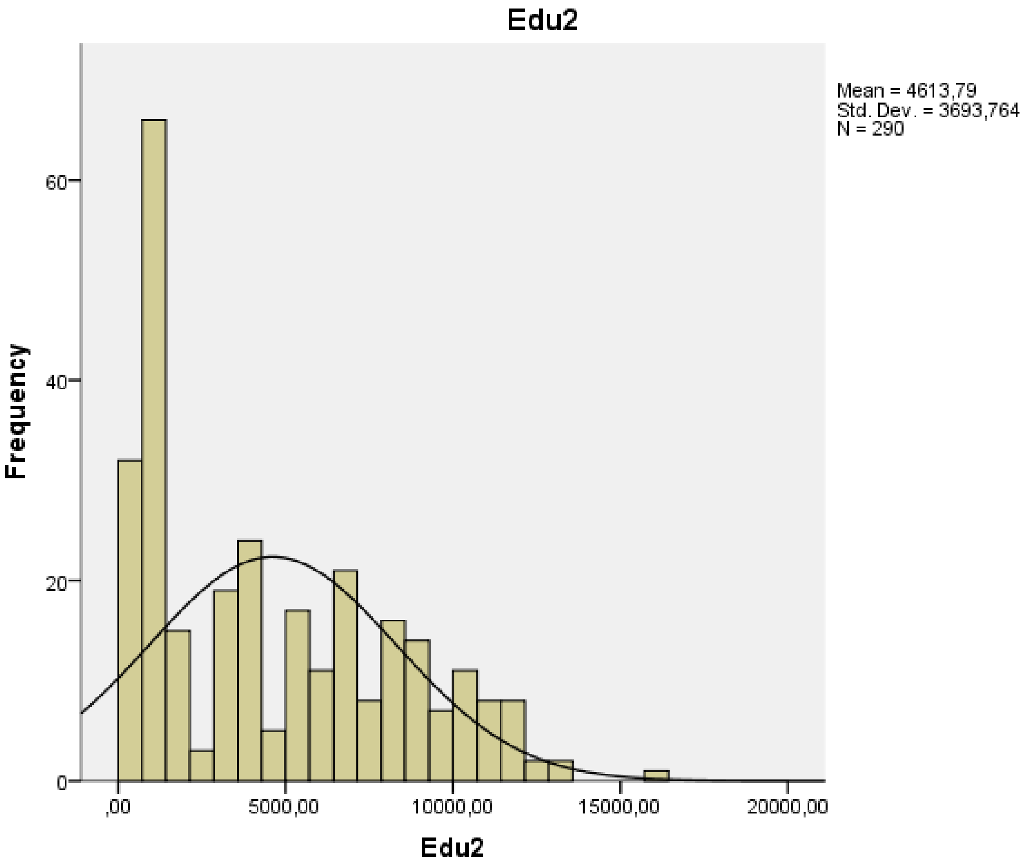

Figure 15 Histogram and normality curve for Edu 2

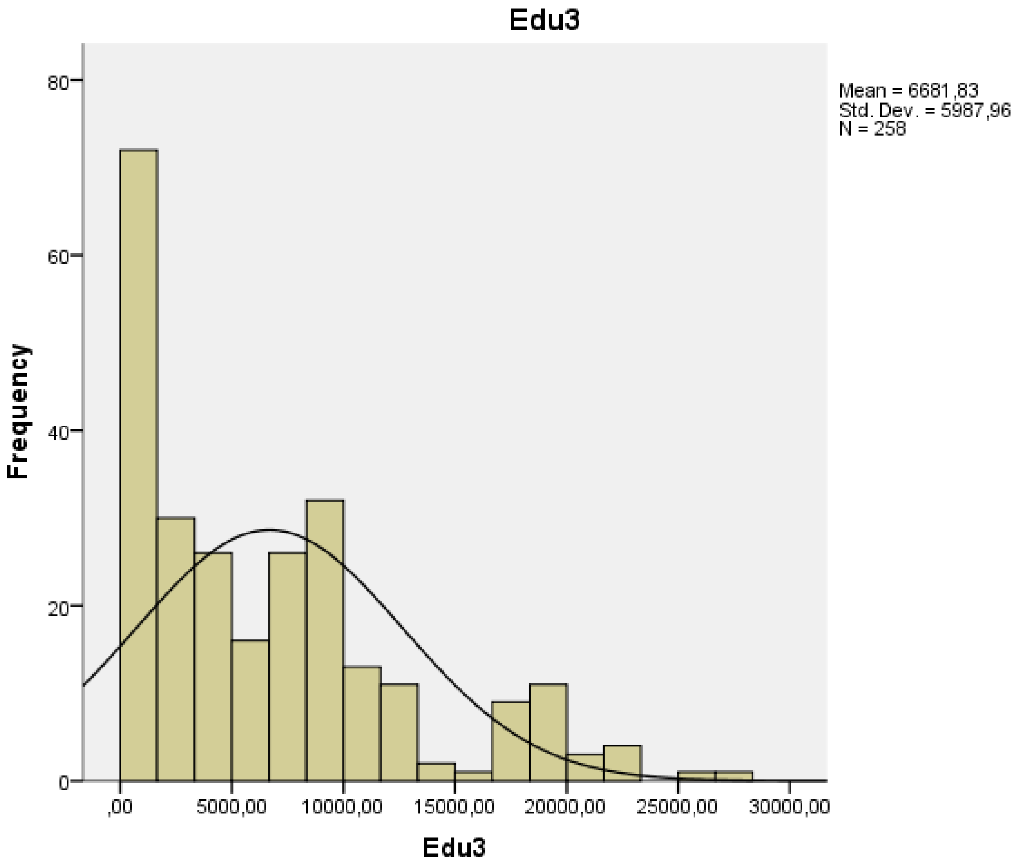

Figure 16 Histogram and normality curve for Edu3

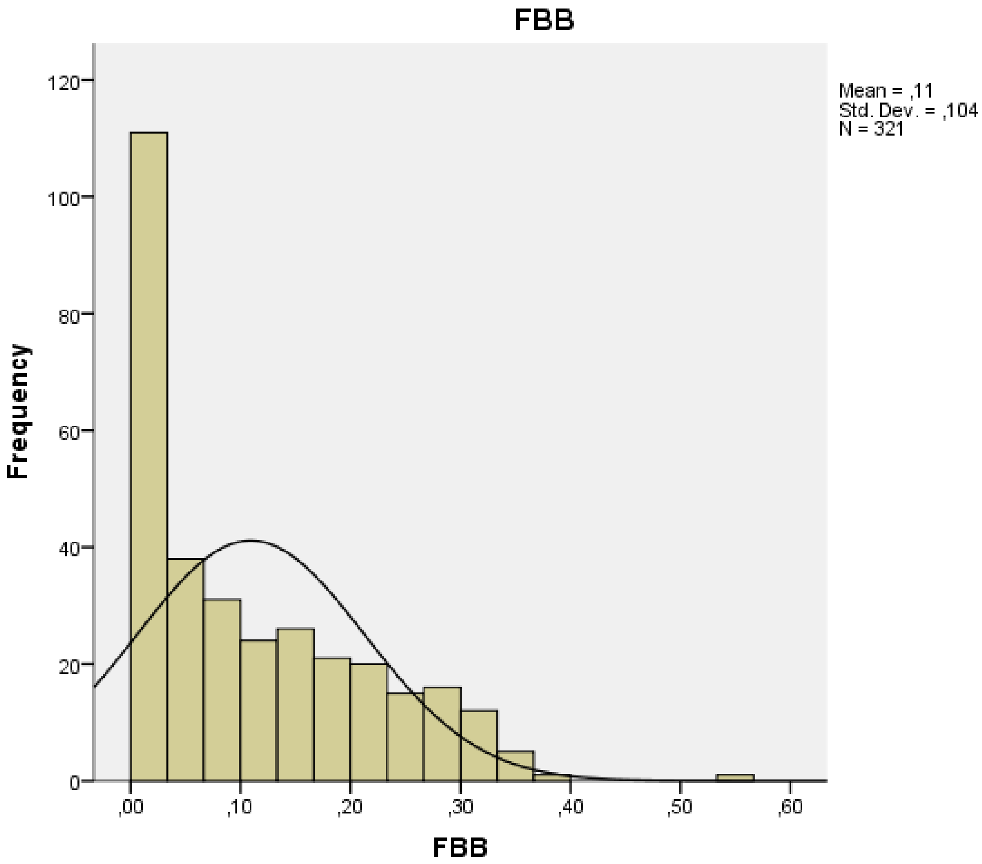

Figure 17 Histogram and normality curve for Fixed broadband subscriptions

6.2 Statistical tables and tests

Panel diagnostics for Regression 1

```
Fixed effects estimator
allows for differing intercepts by cross-sectional unit
slope standard errors in parentheses, p-values in brackets

           const:        6.5589       (0.19987)       [0.00000]
   l_capitalperc:       0.22597       (0.02292)       [0.00000]
           l_FBB:      0.026996     (0.0030967)       [0.00000]
         l_Edu1b:       0.14852      (0.021848)       [0.00000]

41 group means were subtracted from the data

Residual variance: 0.22952/(260 - 44) = 0.00106259
Joint significance of differing group means:
 F(40, 216) = 125.611 with p-value 2.27434e-128
(A low p-value counts against the null hypothesis that the pooled OLS model
is adequate, in favor of the fixed effects alternative.)


Breusch-Pagan test statistic:
 LM = 424.542 with p-value = prob(chi-square(1) > 424.542) = 2.50549e-094
(A low p-value counts against the null hypothesis that the pooled OLS model
is adequate, in favor of the random effects alternative.)

Variance estimators:
 between = 0.0207782
 within = 0.00106259
Panel is unbalanced: theta varies across units

                         Random effects estimator
           allows for a unit-specific component to the error term
           (standard errors in parentheses, p-values in brackets)

           const:        4.0509       (0.20857)       [0.00000]
   l_capitalperc:       0.34195      (0.031883)       [0.00000]
           l_FBB:     0.0048603     (0.0041718)       [0.24509]
         l_Edu1b:       0.34383       (0.02718)       [0.00000]

Hausman test statistic:
 H = 316.065 with p-value = prob(chi-square(3) > 316.065) = 3.3163e-068
(A low p-value counts against the null hypothesis that the random effects
model is consistent, in favor of the fixed effects model.)
```

Panel Diagnostics for Regression 2

```
Fixed effects estimator
allows for differing intercepts by cross-sectional unit
slope standard errors in parentheses, p-values in brackets

          const:         6.7369        (0.2285)       [0.00000]
   l_capitalperc:        0.25784      (0.023637)       [0.00000]
          l_FBB:       0.028584      (0.0032819)       [0.00000]
        l_Edu2b:       0.092387       (0.024208)       [0.00018]

40 group means were subtracted from the data

Residual variance: 0.260762/(260 - 43) = 0.00120167
Joint significance of differing group means:
 F(39, 217) = 103.972 with p-value 1.15902e-119
(A low p-value counts against the null hypothesis that the pooled OLS model
is adequate, in favor of the fixed effects alternative.)


Breusch-Pagan test statistic:
 LM = 378.081 with p-value = prob(chi-square(1) > 378.081) = 3.25591e-084
(A low p-value counts against the null hypothesis that the pooled OLS model
is adequate, in favor of the random effects alternative.)

Variance estimators:
 between = 0.0198249
 within = 0.00120167
Panel is unbalanced: theta varies across units

                         Random effects estimator
           allows for a unit-specific component to the error term
           (standard errors in parentheses, p-values in brackets)

          const:          3.717        (0.21815)       [0.00000]
   l_capitalperc:        0.38581        (0.03224)       [0.00000]
          l_FBB:      0.0053289      (0.0043801)       [0.22487]
        l_Edu2b:        0.33413       (0.028215)       [0.00000]

Hausman test statistic:
 H = 308.048 with p-value = prob(chi-square(3) > 308.048) = 1.80295e-066
(A low p-value counts against the null hypothesis that the random effects
model is consistent, in favor of the fixed effects model.)
```

Panel Diagnostics for Regression 3

```
Fixed effects estimator

allows for differing intercepts by cross-sectional unit

slope standard errors in parentheses, p-values in brackets


          const:         6.6458       (0.24286)       [0.00000]

   l_capitalperc:        0.29177      (0.025041)      [0.00000]

          l_FBB:       0.030164     (0.0034782)       [0.00000]

        l_Edu3b:       0.071777      (0.018463)       [0.00014]


38 group means were subtracted from the data


Residual variance: 0.247354/(240 - 41) = 0.00124299

Joint significance of differing group means:

 F(37, 199) = 116.669 with p-value 1.60327e-115

(A low p-value counts against the null hypothesis that the pooled OLS model

is adequate, in favor of the fixed effects alternative.)



Breusch-Pagan test statistic:

 LM = 330.046 with p-value = prob(chi-square(1) > 330.046) = 9.39154e-074

(A low p-value counts against the null hypothesis that the pooled OLS model

is adequate, in favor of the random effects alternative.)


Variance estimators:

 between = 0.0234785

 within = 0.00124299

Panel is unbalanced: theta varies across units


                         Random effects estimator

           allows for a unit-specific component to the error term

           (standard errors in parentheses, p-values in brackets)


          const:         3.8246       (0.24344)       [0.00000]

   l_capitalperc:        0.49214      (0.030899)      [0.00000]

          l_FBB:       0.013204     (0.0047549)       [0.00593]
```

```
        l_Edu3b:        0.20939      (0.022114)       [0.00000]


Hausman test statistic:
 H = 268.593 with p-value = prob(chi-square(3) > 268.593) = 6.22143e-058
(A low p-value counts against the null hypothesis that the random effects
model is consistent, in favor of the fixed effects model.)
```

Test for joint dummies, differing alpha and heteroskedasticity

Regression 1

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(40, 210) = 138.514
with p-value = P(F(40, 210) > 138.514) = 6.58148e-130

Wald test for joint significance of time dummies
Asymptotic test statistic: Chi-square(6) = 27.3903
with p-value = 0.000122345

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
H_0: sigma(i)^2 = sigma^2 for all i
chi2 (42) = 1.1e+05
Prob>chi2 = 0.0000

Regression 2

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: F(39, 211) = 114.799
with p-value = P(F(39, 211) > 114.799) = 1.75116e-121

Wald test for joint significance of time dummies
Asymptotic test statistic: Chi-square(6) = 27.6581
with p-value = 0.000108964

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
H_0: sigma(i)^2 = sigma^2 for all i
chi2 (41) = 1.5e+05
Prob>chi2 = 0.0000

Regression 3

Test for differing group intercepts -
Null hypothesis: The groups have a common intercept
Test statistic: $F(37, 193) = 112.899$
with p-value = $P(F(37, 193) > 112.899) = 1.40723e-111$

Wald test for joint significance of time dummies
Asymptotic test statistic: Chi-square(6) = 15.7515
with p-value = 0.0151519
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
H_0: sigma(i)^2 = sigma^2 for all i
chi2 (39) = 1.7e+27
Prob>chi2 = 0.0000

Coefficient correlation matrix

Table 7 Coefficient Correlation matrix

Fixed Broadband	Edu1	Edu2	Edu3	Capital per capita	
1.0000	0.7302	0.7116	0.5075	0.7658	Fixed Broadband
	1.0000	0.9841	0.8819	0.9599	Edu1
		1.0000	0.9065	0.9544	Edu2
			1.0000	0.8495	Edu3
				1.0000	Capital per capita

Descriptive statistics

Table 8 Descriptive statistics for variables used in the regressions

	GDP per capita (constant 2000 US$)	Grosscapital formation percapita	Edu1	Edu2	Edu3	FBB
N Valid	321	291	292	290	258	321
Missing	1	31	30	32	64	1
Mean	18812,000957796600	3999,6955	3577,4205	4613,7918	6681,8252	,1093
Std. Error of Mean	883,5583936567606	178,44529	168,54898	216,90528	372,79411	,00579
Median	15392,502713562679	3789,2099	3124,2642	3765,8127	5012,8676	,0775
Mode	461,4958820344[a]	117,67[a]	49,05[a]	91,70[a]	,00[a]	,00
Std. Deviation	15830,2499865107000	3044,04865	2880,16617	3693,76385	5987,96009	,10378
Variance	250596814,635	9266232,155	8295357,152	13643891,400	35855666,080	,011
Skewness	1,228	,804	,584	,549	1,103	,907
Std. Error of Skewness	,136	,143	,143	,143	,152	,136
Kurtosis	2,131	,180	-,888	-,831	,623	,174
Std. Error of Kurtosis	,271	,285	,284	,285	,302	,271
Range	82725,4156398259	14006,57	10397,53	15637,79	27652,89	,55
Minimum	461,4958820344	117,67	49,05	91,70	,00	,00
Maximum	83186,9115218603	14124,24	10446,58	15729,49	27652,89	,55
Sum	6038652,3074527085	1163911,40	1044606,79	1337999,63	1723910,90	35,08

Countries in the dataset

Australia
Austria
Belgium
Belize
Chile
Colombia
Croatia
Cyprus
Czech Republic
Denmark
Dominica
Estonia
Finland
France
Hong Kong SAR, China
Hungary
Iceland
India
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Korea, Rep.
Kuwait
Latvia
Liechtenstein
Lithuania
Luxembourg
Malaysia
Maldives
Mauritius
Mexico
Netherlands
New Zealand
Norway
Peru
Poland
Portugal
Spain
Sweden
Switzerland
United Arab Emirates
United Kingdom
UnitedStates

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