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Impact of broadband speed on household income: Comparing OECD and BIC[1]

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Presented at 24th European Regional Conference of the International Telecommunications Society, Florence

Preliminary draft

Abstract

This paper aims to measure the impact of broadband speed access and upgrades on the household income based on a survey comprising 20,000 respondents in eight OECD and three BRIC countries in 2010 (Brazil, India and China). The study is novel, as most previous studies on broadband emphasize the penetration rate as the variable of interest. Moreover, by digging deeper on broadband speed (rather than broadband penetration rate), the problem concerning "broadband definition" that varies between countries can also be avoided. To investigate the impacts, a treatment effect model is employed using the Propensity Score Matching (PSM). Two aspects are being investigated: the impact of broadband access and the impact of varying broadband speeds on income. For access impact analysis, the samples are one with broadband access at a particular speed level against the other without the broadband access. Moreover, for the speed upgrades, the comparisons are carried out at various speed levels, e.g. users with 2 Mbps compared with the ones with 512 kbps. The results reveal that obtaining access to 0.5 Mbps in the OECD countries would not be expected to yield an increased income. The study suggests a minimum speed requirement where the households are expected to benefit from broadband lies somewhere between 2 Mbps and 4 Mbps. For BIC countries, however, the impact is already visible at 0.5 Mbps. At this speed, broadband users have a greater likelihood to gain 800 USD compared with the unconnected ones which is equivalent to 70 USD per month per household. For speed upgrades, the speed level giving the highest benefit to income in BIC and OECD countries is the same (4 to 8 Mbps), even though higher speed levels (8 to 24 Mbps) seems to contribute more in OECD than BIC countries. Note that the survey was carried out in 2010 when the sample average speed level in OECD countries was only about 4-5 Mbps and 2 Mbps in BIC countries. The analysis is supported by a reasonably strong statistical significance in OECD but not for the BIC countries due to sample limitation.

Keywords: broadband, speed, household income, OECD, BICs, propensity score matching, treatment effect

JEL Classification: O11, O14, O32, O33, N84

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Introduction

The impact of Information and Communication Technologies (ICTs) products on economic progress, especially in terms of the Gross Domestic Product (GDP) and employment usually faces the problem concerning *"chicken and egg"*. Two possible causations can be seen - that the development of ICT (i.e. infrastructure and penetration rate) generates further increments on GDP and employment, and on the other hand, GDP and income is an important determinant on adoption and diffusion of the ICT devices (Dutta, 2009). The broadband is not an exception in this case where the pervasive use of broadband technology in a wide range of sectors generalizes productivity gains transferred to the rest of economy, but at the same time, the economic indicators, such as GDP, is a common factor affecting the stages of broadband adoption.

Previous studies investigating the impact of broadband on socio-economic development can be found, for instance in Crandall et al (2003), Katz and Sutter (2008) on the US national economy and Kelly (2004) on the US regional economy level. Majumdar (2008) identifies the impact of broadband on wages improvement; Van Gaasbeck (2008) and Grimes et al., (2012) on employment and productivity gains; Savage et al., (1997), Sivakumar and Robertson (2004), Sooryamoorthy and Shrum (2007), Mbarika and Byrd (2009),Lindsay et al. (2008) and McKague et al (2009) on health and education; Goodman (2000) and Mariussen and Ndlovu (2012) on the emerging of the Small and Medium Enterprises (SMEs). Beyond that, Joseph and Andrew (2007) identify the contribution made by the Internet to empower women in rural areas. These studies generally conclude that the broadband is embedded with the general purpose technology (GPT) capabilities where other sectors and activities can greatly benefit from.

On the other direction, income level/GDP is one of important determinants affecting the diffusion of the Internet and broadband as shown in in the studies, for instance, by Billon et al (2009) and Mocnik and Sirec (2010). Billon et al (2009) found that in countries with higher levels of ICT adoption, the digitization pattern is explained by GDP together with other variables; the size of the service sector, education, and governmental effectiveness. In addition, at the household level, Martin and Robinson (2007) employ multiple logistic regressions based on the data in the United States from 1997 to 2003 found that the broadband access increased most rapidly for individuals at highest family income levels and most slowly for individuals with the lowest income levels.

Apart from causation direction, another problem concerning the broadband impact studies is related to *"the broadband definition" (*Middleton, 2013). Providing citizens to the access of broadband will allow them to connect with the information society but all broadband networks are not the same which means that the potential benefits vary between users. Middleton (2013) accentuates the problem mainly due to *"various definition of broadband connection"*. To exemplify, the telecommunication survey launched by the Canadian telecommunication regulator (CRTC) in 2008 defined a high speed broadband access as a broadband connection with a 1.5 Mbps download speed capabilities. Following this definition, only 50 % of population has a high-speed broadband access. Later, the Canadian Internet Use Survey (CIUS) was carried out by the Statistics Canada in 2009 to identify the characteristics of broadband access in the country. In this survey, the respondents were asked whether their internet access is considered as "a high-speed broadband". However, without a clear limitation in this later survey, the respondents were then self-answering their connection as a "high speed broadband" wherever it is connected by any means other than a dial-up connection. As a

result, 92 % of respondents reveal that they have a high speed internet access (or equal to 70% of total population). Based on these two surveys, the way the terminology of broadband is defined may lead to a 20% discrepancy of the broadband penetration rate data. Therefore, studies emphasize on the broadband penetration rate as the point of interest (or a dependent variable) can be embedded with this typical data inaccuracy.

Having identified these complexities on causality issues and definition problem, this paper fills the gap from what the exiting studies have found in measuring the impact of broadband. The paper answers a research question on *"How much will the broadband access and broadband upgrades increase the household income in OECD and BIC countries".* In addition to that, the paper also answers on *"How much the broadband speed should be offered to ensure positive benefits for the users (threshold of speed)? Are the thresholds the same for OECD and BIC?"*

The novelties of this study are supported by the fact that most of broadband impact analysis put "penetration rate" as the variable of interest whereas as Middleton (2013) stated the access is not similar and hence a deeper investigation on speed is required. This study is moreover based on survey at household level, involving a large and comparative sample. On the causality issue, the study employs the treatment effect model to be able to isolate the impact of access and upgrades of broadband speed. In doing so, two samples are being compared with different broadband speed level subscriptions to measure the impact of speed upgrades. The basic idea behind the method is to estimate the counterfactual outcome of income that people who are connected to broadband at particular speed would have achieved had they not been connected to that level and instead subscribed to the lower speed. By employing the treatment effect model, one can estimate the impact of treatment variables (broadband speed and upgrades) on a response variable (household income) in a one-way direction. At the end, the policy can be designed based on the impact of treatment variable on the response variable as it is generally done in the impact analysis/policy studies employing the treatment effect model.

The paper is structured as follows; after the introduction section, literature reviews on broadband development especially concerning the broadband speed is presented. The methodology section discusses the treatment effect model employed in this study. The data analysis is elaborated afterwards followed by the treatment effect statistical results. Some conclusions and policy implications are discussed at the end. Though the study is able to estimate the impact of broadband access and upgrades on the households income, it has to be taken into consideration that employing the treatment effect method is actually similar to assigning the dummy variable. Instead of the actual impact, the results should be seen as the likelihood that users with the access to the broadband (subscribes to a higher speed broadband) gain additional income compared with the unconnected ones (subscribers with lower speed levels). In the other words, the the interpretation of the results is more about the likelihood which means that households subscribing to XX Mbps have a greater likelihood for earning YY USD annual income compared to those subscribing ZZ Mbps (where XX > ZZ). Another caveat of this study is that the results that are reasonably robust for OECD but not for BIC countries.

Literature review

The availability of broadband between countries becomes more similar as the benefits of the device are more apparent and, hence, the broadband development is put a part of an important national agenda. An early study by Marcus (2005) found that among OECD countries, penetration rates of broadband varies considerably ranging from 15% or more (Korea, Canada, Iceland) to 1% or below (New Zeeland, Ireland, Poland, Czech Republic, Mexico, Slovak Republic, Greece, and Turkey). A later study by Wallsten (2009) shows the more similarities of broadband attainment between OECD countries, though, Korea is still leading with a penetration level at 80% whilst Greece is still lagging behind at a level of 14%. Narrowed down to the fixed broadband connection, Rohman and Bohlin (2012) based on OECD databases found the gap became smaller in 2010. The countries achieving the highest fixed broadband penetration rate in 2010 are the Netherlands, Denmark, Switzerland, Norway, Korea and Iceland with the average fixed broadband penetration rate around 35%. On the other hand, the countries that had the lowest penetration rate in 2010 were Chile, Mexico and Turkey with penetration rates around 10%.

There are two different perspectives on broadband development; the availability (coverage), and actual usage (penetration). *Availability* is determined by among others, technologies for deploying broadband (DSL, fibre, cable or satellite). Figure 1 shows different technologies for broadband connection.

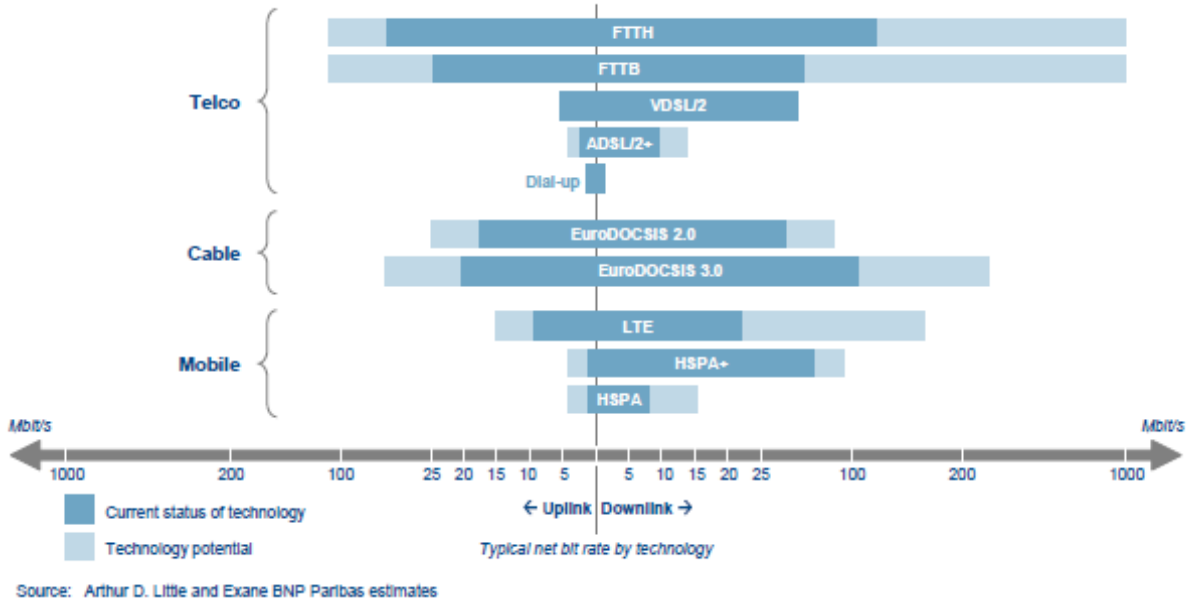

Figure 1 *Speed level and broadband technologies*

From Figure 1, it can be seen that fibre and cable have the greatest potential to avail the users with a high speed broadband connection. With fibre, up to 1 Gbps speed can be generated in the future even though the present technology is only able to serve up 100 Mbps at maximum capacity. Connecting with cable has similar speed availability up to 100 Mbps in current state of technology with the potential somewhat lower than fibre. Mobile broadband, while it is seen as alternative technologies to close the digital gap especially in developing regions (Reynolds and Samuels, 2004;

Galperin, 2004; Proenza, 2006; ITU, 2011), has a lower potential to serve a higher speed connection especially those requiring more than 200 Mbps.

Many recent studies also support the importance for having higher speed broadband capabilities. Howell and Grimes (2010) accentuate the fact that a faster Internet access is widely considered to be a productivity-enhancing factor; while Stenberg and Morehar (2010) mention that the Internet will be more useful to businesses, households and governments via high-speed technology. In the case of Australia, Atapattu (2010) argues that a high-speed broadband internet access is widely recognised as a catalyst for social and economic development. Additionally, Lennett and Meinrath (2009) discussed that the broadband and telecom infrastructures that facilitate high-speed connectivity can no longer be seen as a luxury but as a critical element.

Several social effects will also follow the increased broadband speed. For example, in healthcare, an increase in broadband speeds makes it possible to conduct real-time doctor-to-patient communication. Thus, there are additional advantages arising as some applications require especially high speeds (up to 1Gbps). For emergency medicine, for instance, the transmission speed is crucial if images need to be analysed by someone who is not present where the patient is. The report *Bringing America up to speed* (PEW, 2010) reports on a case in which a woman injured in a car crash died as a result of low broadband speed – the images were not transferred in time and could therefore not be analysed before it was too late. Figure 2 below shows a range of features of health care services at different broadband speed availability.

Application	Application technology	Broadband speed			
		1Mbit/s	10Mbit/s	100Mbit/s	1Gbit/s
High-quality non-real-time video-imaging for diagnosis	File transfer	High quality	High quality	High quality	High quality
Cardiology neurology and emergency room consultations	H.323 video	Low/ Medium quality[1)]	High quality	High quality	High quality
Cineo-angiography and Echocardiograms	H.323 video	Low/ Medium quality[1)]	High quality	High quality	High quality
3D interactive brain imaging	SGI Vizserver	Unsupportable	Unsupportable	Medium quality	High quality
Clinical decision support systems	Web browsing	Medium quality	High quality	High quality	High quality
Advanced clinical decision support system	Image transfer	Unsupportable	Low quality	Medium quality	High quality
Professional tele-education	MPEG 1 video	Low quality[2)]	High quality	High quality	High quality

Source: Network Developments in Support of Innovation and User Needs, OECD (2009), Arthur D. Little analysis
Note: 1) At least 10Mbit/s is normally recommended for H.323 video. 2) MPEG 1 video typically required 1,5Mbit/s without excessive quality loss.

Figure 2 *Healthcare applications and corresponding qualities in relation to speed*

Comparing the variety of broadband technologies that generates different speed levels also brings about a new idea to understand digital divide phenomenon (Whitacre & Mills, 2010). Based on the data obtained from the *Population Survey Supplemental Questionnaires on Household Computer and Internet Use* in the United States, which represent about 50,000 people, it is reported that by the

year 2000, the internet connected by the dial-up access in rural households lagged behind their urban counterparts by 11 percentage points. By 2003, however, dial-up access rates were equal in rural and urban areas, but high-speed access rates were 14 percentage points higher in urban areas. In the other words, promoting access in rural areas, as usually set as a policy instrument to close digital divide, fails to address the root of problem of digital divide unless the speed capabilities are also taken into consideration into the policy.

Methodology

The methodology employed in this study is seen as a complementary effort to existing studies that investigate the impact of education on earning. The impact of schooling (education) on income at micro-level has been addressed by several economists, for instance by analysing different impacts across individuals with different education levels (Guison-Dowdy, 2012). To operationalize this aim, a variety of models and estimations has been employed to identify the return to schooling. These models capture the difference in schooling quality and a gap between socio-demographic factors, e.g. between males and females, and ethnicities. However, as stated by Hanushek and Welch (2006), it is a challenge to approach the impact of education precisely, as, for instance, people have different skills (e.g., ability, initial human capital, motivation, etc.), especially when individuals have multiple skills. Guison-Dowdy (2012) mentioned that these multiple skills may also relate to knowledge acquisition from the ability to absorb information from different content areas, whereas, cognitive competencies are concerned with the ability to learn, process and apply knowledge. Both factors have been found to influence individual achievement.

Therefore, the present study introduced some additional variables concerned with 'additional skills and experiences' possessed by individuals and accumulated as a result of the ubiquity of ICT in the recent information society. The analysis is conducted after controlling all other possible factors affecting household income level; primarily education and skills (managerial competencies), together with other socio-economic variables (age, gender, type of occupation, marital status, geographical area and type of housing). This study conceives that ICT variables are important as the proxy of *'skills and experience'* in order to predict the return to education. The ICT variables include the usability of the Internet and telephony for working purposes and the access and type of speed level subscribed to by the respondent. This access and use are believed to play important roles in increasing knowledge and skills, as shown in many previous studies (James, 2011; van Deursen and van Dijk, 2011; Hargittai, 2010).

Treatment effect

To identify the impact of broadband access and speed upgrades, a treatment effect model is employed. In this case, two samples are being compared, one with broadband access and the other without, to investigate the impact of broadband access. The later investigation compares samples with different broadband speed level subscriptions to measure the impact of speed. The basic idea behind the method is to estimate the counterfactual outcome of income that people who are connected to broadband would have achieved had they not been connected to broadband. For speed upgrades impact, the analysis is carried out by comparing the one with a particular broadband speed subscription against another with different speed levels (higher or lower). Assuming there are

two potential outcomes (Y_0, Y_1) representing the states of being without and with treatment. An individual can only be in one state at a time, so only one outcome is observed. The unobserved outcome is then called a counterfactual outcome. The treatment effect for an individual is:

$$\Delta = Y_1 - Y_0 \quad (1)$$

which is not observable directly. If $D = 1$ represents the person who participates and $D = 0$ otherwise, the observed outcome is then denoted by: $Y = DY_1 + (1 - D)Y_0$. From this, the conditional distribution of $F(Y_1|X, D = 1)$ and $F(Y_0|X, D = 0)$can be recovered from the data. However, the joint distribution $F(Y_0, Y_1|X, D = 1)$ or $F(Y_0, Y_1|X)$ and the impact $F(\Delta|X, D = 1)$ are not observed. The focus of the study is then to calculate the average impact of treatment on the treated (ATT), denoted by $TT = E(Y_1 - Y_0|D = 1)$. The treatment and matching should also make the assumption that treatment assignment is strictly ignorable given any covariates (observed characteristics, Z, e.g. all socio-demographic and economic variables), such that: $(Y_0, Y_1) \perp\!\!\!\perp D|Z)$ which can also be represented as $E(D|Y_0, Y_1, Z) = E\ (D|Z)$ or $Pr\ (D = 1|Y_0, Y_1, Z) = Prob\ (D = 1|Z)$.

Propensity score is defined as the conditional probability of treatment given the covariates. It means that, if treatment group (T) and control group (C) differ hugely for many observed variables (x), e.g., socio demographic aspects (age, gender, education, geographical area, etc.), the difference in outcome (Y) cannot be associated with the difference in treatment. The solution is possible only by comparing the member of C and T with a similar member in X (propensity matching estimators). Matching by the propensity score can be done by choosing propensity score p(x) at random and, suppose we select two individuals with the same propensity score, the first individual receives treatment and the second does not. Todd (2010) mentioned that the main advantage of the matching estimator is that it does not require any functional form of outcome equation and thus is not susceptible to misspecification bias along with the dimension (which usually arises when econometric tastings are employed). In other words, when an econometric model is used, one needs to iterate the best functional forms of the equation to best represent the sample.

Additionally, the treatment effect is also distinctive with regards to the concept of causality. Lee (2005, p.9) explains the extensive description on how the causality is defined in the treatment effect discourse. Define $y_{1i} - y_{0i}$ as the treatment (or causal) effect of subject i; the causal effect from two-potential responses in this case is ***a counter-factual causality.*** The definition has a sharp contrast to "probabilistic causality" –regression methods—that investigates the cause of the response/dependent variable instead of the counter-factual. The concept is also different to correlation and covariance as shown in the following equation. Let the observed treatment be d_i and the observed response be y_i, the relationship can be shown in the following equation (2)

$$y_i = (1 - d_i).y_{0i} + d_i.y_{1i}, \qquad i = 1, \ldots\ldots, N. \quad (2)$$

Correlation between observe treatment and observe treatment variable only require the data on d_i and y_i , whereas regression analysis require $\beta_i = \frac{Cov\ (d_i y_i)}{Var\ d_i}$. Contrary to this, in the counterfactual causality on treatment effect requires all information on y_{0i}, y_{1i}, d_i to be taken into consideration.

Return on education model and broadband

The relationship between the common return on education model and the broadband impact is supported the fact that the outcome equation in this study is based on the return models that have been extensively discussed. Card (1993) for instance identified that the impact of schooling on wages is controlled by some socio-demographic factors (ages, skills, geographical area, household backgrounds, etc.). However, different to Card study which mainly elaborates some exercises to control endogeneity of education (using for example: school proximity), this paper takes simple regression analysis on the outcome equation giving more emphasize on the treatment equation. The operationalization of the model can be presented in the following Eq (3):

$$y_i = \beta_1 + \beta_2 d_i + \beta_3 x_i + u_i \text{ where } d_i = \alpha_1 + \alpha_2 z_i + \varepsilon_i \quad (3)$$

The left hand side of equation (3) is a return on education where income y_i is influenced by education and other covariates (x_i) and treatment variable d_i . In addition, d_i is estimated using the standard probit model putting 1 = if respondent has the broadband access, 0 =otherwise for access equation and step-wise speed for broadband speed upgrades model.

To illustrate, the treatment effect and PSM method are applied as shown in Figure 3.

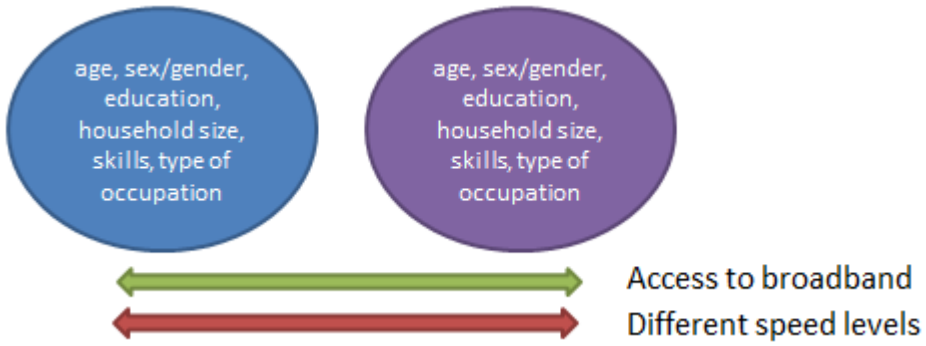

Figure 3 *Operationalization of the methodology*

As illustrated in Figure 3, the treatment effect controls the possible factors that contribute to income. Therefore, the only difference between the two samples is (i) the access to broadband, for access impact, and (ii) the different level of broadband speed, for speed impact assessment. The flow of the analysis in this study is presented in Figure 4.

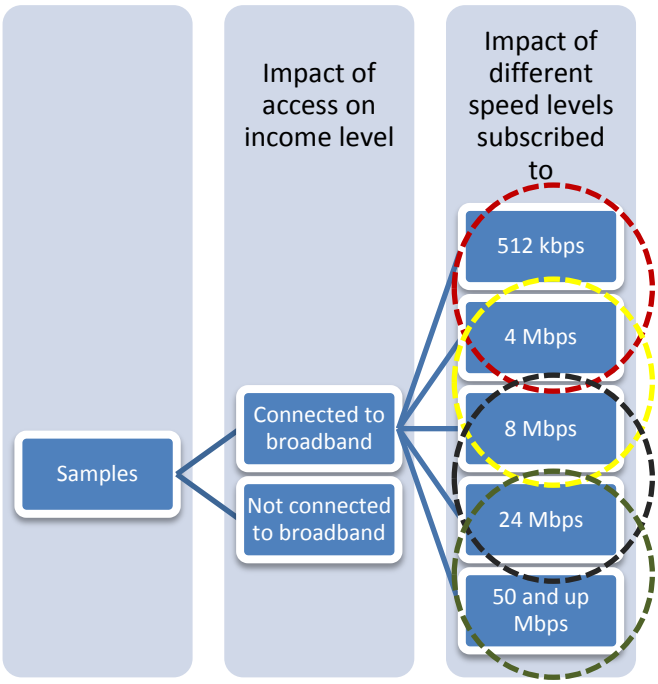

Figure 4 *Flow of the analysis*

As indicated in Figure 4, the flow of the analysis is divided into two main aspects. The first analysis on the broadband access impact is conducted by comparing the respondents who have connected to broadband with those who have not. The second stage analysis deals with the speed investigation when the respondents are divided into some speed categories. The study then compares respondents with different speed subscriptions to see the impact of varying speed levels on income. As shown in Figure 4, the comparison is carried out, for instance, between 8 Mbps and 4 Mbps and between 24 Mbps and 12 Mbps.

Some recent studies have adopted the treatment effect model and the use of propensity score matching, in particular in many areas of ICT. Beard, Ford, Saba and Seals (2012) estimate the effect of Internet use on job searching. The study indicates that broadband use at home or in public locations reduces the probability of unemployed persons stopping their job search by over 50% relative to unemployed persons who do not use the Internet at all. As a policy implication, even public connections (e.g. at libraries) in unserved and underserved areas may produce substantial social benefits. Grimes, Ren, and Stevens (2012) investigate whether broadband access can be considered a productivity-enhancing factor which shows that the level productivity is influenced by a firm's Internet access choice. The study indicates that broadband adoption boosts firm productivity by 7-10%.

Data

The investigation into the impact of broadband access and speed was based on the Ericsson Consumer Lab's web-based survey in 2010 with 22,000 respondents worldwide (1000-2000 per country)[2].

Table 1 List of countries in the 2010 survey

Country	Number of respondents	Per cent of total sample
UK	2,001	8.98
France	2,026	9.10
Germany	2,019	9.06
Italy	2,040	9.16
Spain	2,026	9.10
Sweden	2,003	8.99
China-urban	1,014	4.55
Japan	2,046	9.19
Brazil	1,018	4.57
US	2,013	9.04
India	1,000	4.49
Russia	1,058	4.75
Mexico	1,007	4.52
South Africa	1,003	4.50
Total	22,274	100.00

From Table 1, the list of countries investigated in this study consisting mainly OECD countries and some emerging countries labelled as BRIC (Brazil, Russia, India and China). The number of respondents is not equally distributed giving a greater sample for developed countries. From the total sample in the survey, this paper left out Russia, Mexico and South Africa from the analysis. Some socio-demographic information is added in the following Table2 and Figure 5.

[2] Other sources used include the World Bank, IMF and Ookla Net Index for deriving correction factors. As some countries have their own currencies, all the investigations in this study were performed by converting the local currencies of households into PPP USD income (with the index released by the International Monetary Fund [IMF]); hence, it has taken into account the different purchasing power of the currencies.

Table 2 Socio demographic variables

Country	Age	Household size
UK	39	2.9
France	40	2.8
Germany	41	2.5
Italy	37	3.3
Spain	35	3.1
Sweden	46	2.5
China	31	3.6
Japan	39	3.0
Brazil	30	3.6
US	41	2.8
India	28	4.2
Russia	32	3.1
Mexico	32	4.1
South Africa	37	3.5
All countries	**38**	**3.1**

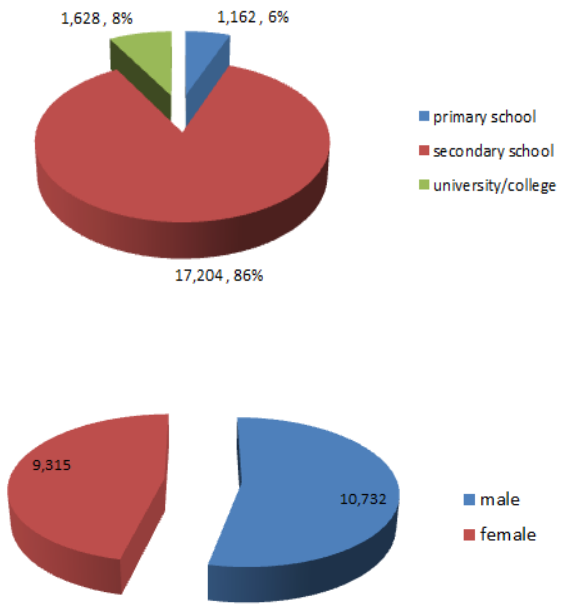

Figure5 Socio demographic variables

It can be inferred from Table 2 that the survey has captured the respondents that fall into the category of 'the productive population'. The average age of the sample is 38 years, with the exceptions of 28 years in India and 46 years in Sweden. By classifying the education level into three groups (primary, secondary and some colleges/universities), the average level of education attained by the respondents is 'secondary education'. In terms of gender, the sample is roughly equally distributed between male and female. The average household size in the sample is about 3, with extremes of 2 in Sweden and 4 in Mexico.

Figure 5 scatters the countries and their achievements on both household income level and the broadband speed. It can be seen that four countries lead in both variables: the US, Japan, the UK and Sweden. The majority of other European countries are located somewhere in the middle (France, Germany, Spain and Italy) whereas all the BIC countries together with Mexico and South Africa are placed on the bottom left of the figure noting that both speed and income levels are still emerging in these countries. These descriptive results can lead one to hypothesize *that a higher speed level contributes to a higher income level or a higher income level household tends to subscribe a higher speed broadband access*. However, bearing in mind that correlation does not say anything about the direction of the relationship, thus, the analysis is then more formally investigated using the treatment effect model on access and speed upgrades.

The other aspect worth addressing in this study concerns with the income data. The data on household income was converted from an ordinal to a continuous scale. As is customary in survey studies, respondents had stated their annual household income corresponding to a set of predefined ranges (e.g. 30k-50k USD). This is typically a preferable way for data to be collected from the

respondent who may not know the exact figure or be reluctant to provide an exact figure. Naturally, these ranges were provided in local currency and different ranges depending on the country. However, to estimate the magnitude of the marginal income impact from broadband speed it is necessary to use continuous variables. This type of challenge is common when using survey data and the applied method is based on scientific best-practice.

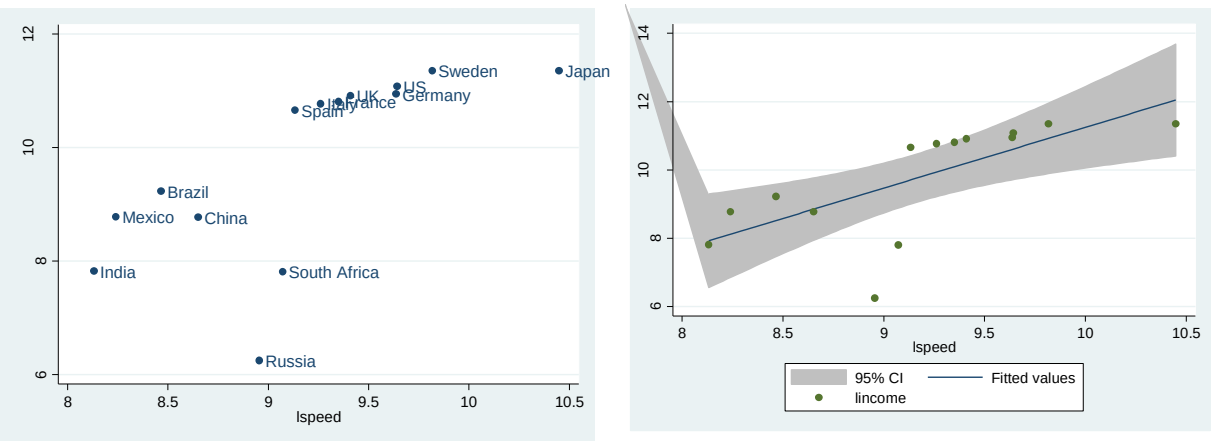

Figure 5 *Relationship between broadband speed level and household income*

As discussed previously, income varies between countries and between broadband developments, namely speed levels. With regards to the countries investigated in this study, the following Figure 6 shows variety of income levels by country.

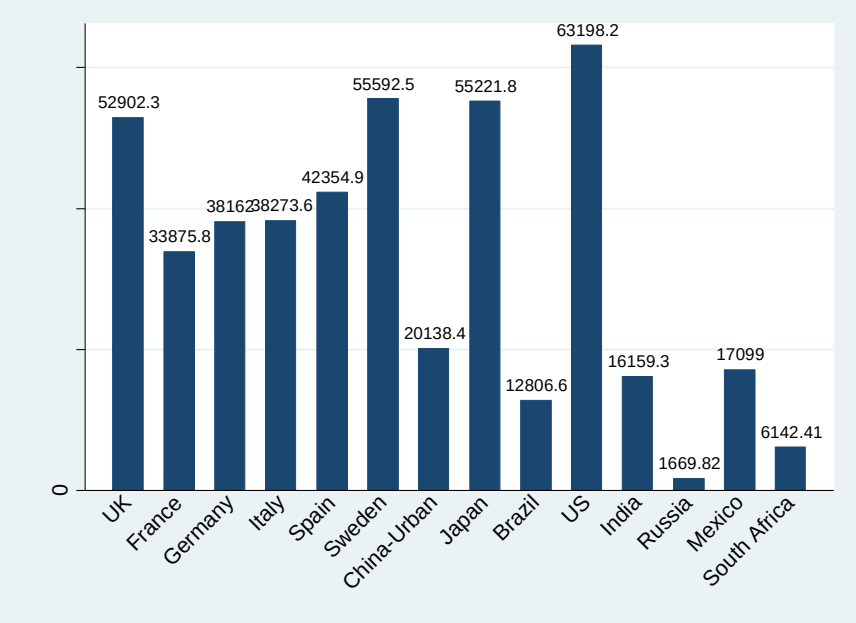

Figure 6. Distribution of income between countries

Figure 6 shows the income level in the country based on the survey in 2010. The US, Sweden, Japan and the UK record the highest household income compared with other countries in this study with the range of income 50k – 65k USD. Other European countries like France, Germany, Italy and Spain follow in the second group with the ranges of income between 35k- 41k USD. Whereas, emerging nations like India, China, Russia and Brazil achieve lower income level. Mexico, amid being categorized as member OECD countries, has a lower income to be only comparable to other emerging countries which become another reason why the country is left out in the analysis. The next Figure 7 shows the distribution of income levels between speeds.

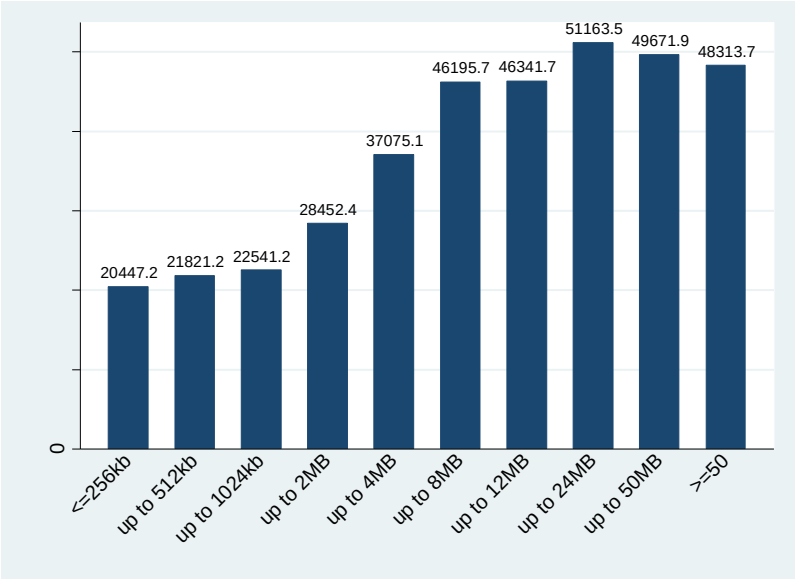

Figure 7 *Distribution of income between countries*

Figure 7 illustrates that income level increase following the pattern of speeds. A massive incremental income can be seen at three peaks, especially when the speed is moving from 1 Mbps to 2 Mpbs, 2 Mbps to 4 Mbps and from 4 Mbps to 8 Mbps. The flatter association between income and speed can be seen from the transition from lower speed level (e.g. going from 256 kbps to 1 Mbps). Similarly the income level tends to be even lower when speed level is reaching more than 24 Mbps which might indicate the saturation of income with speed level. In addition, the fact that the income increases disproportionately by going to a higher speed level (from 1 Mbps to 8 Mbps) might indicate that the relationship between speed and income is not linear. Based on the survey carried out in 2010, average speed level in OECD countries was about 4-5 Mbps and 2 Mbps in BIC countries.

As discussed earlier, the speed available to the users is also affected by different of internet technologies, particularly by contrasting the dial-up and the broadband. The following Figure 8 compares the relationship between income levels and broadband technologies both in OECD and BIC countries.

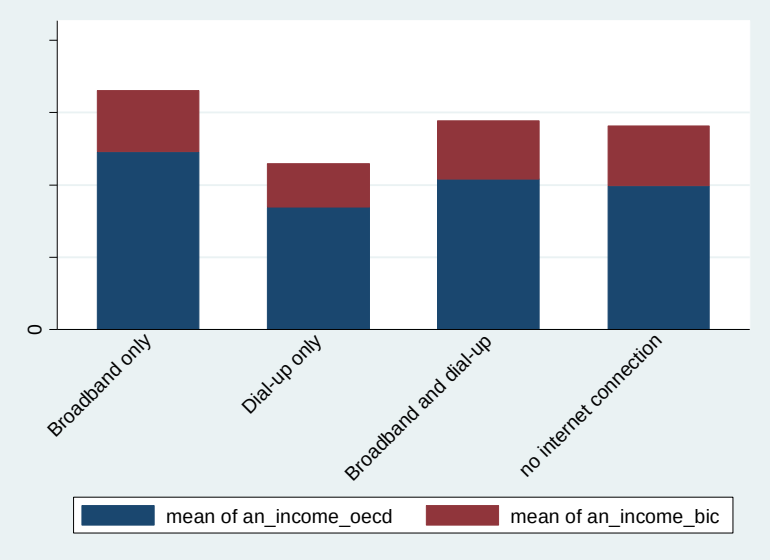

Figure 8 *Distribution of income and broadband technologies*

In addition to the fact that income might vary in association with the broadband speed, there is also a tendency that income level can differ in relation to the broadband technology accessed by a household. Figure 8 shows variety of broadband technologies that can be accessed in the household. The Figure distinguishes the connection between broadband technology and income level in both OECD and BIC countries. It can be inferred that the more advanced internet technology accessed by households can be associated with a higher income compared with traditional dial-up Internet. In OECD countries; the left hand side graph shows broadband subscribers who, on average, have around 50 k USD annually are connected to the Internet via broadband, whereas the second left shows dial-up only subscribers who earn around 30k USD. The difference is, however, not really apparent for BIC countries.

Results

As discussed, the treatment effect model is used as the methodology to compare the households with the access and without the access for the access impact and between households varying their speed levels for speed upgrade impacts. The summary of the output is presented in the following Table 3.

Table 3 *Summary results*

No	Speed	Access			
		OECD		BIC	
		Untreated/treated	Difference (Annual HH income, USD)	Untreated/treated	Difference (Annual HH income, USD)
1.	512 kbps	1715/764	-475	279/262	1567
2.	1 Mbps	1715/1256	2077*	279/406	2246
3.	4 Mbps	1715/886	3520**	276/158	2536
		Speed upgrades			
1.	512 kbps → 4 Mbps	842/884	6179***	294/180	1014
2.	4 Mbps → 8 Mbps	912/1619	2342*	168/44	230
3.	8 Mbps → 12Mbps	1621/742	670		
4.	8 Mbps → 24 Mbps	1621/657	1080		
5.	8 Mbps → 12 ups			119/56	-67

*, **, *** denote the statistical significance at 1%, 5% and 10% respectively. The results are presented before the adjustment process (see appendix 1)

Table 3 presents the summary findings of the study dividing the analysis into two parts (access and speed upgrades) in both OECD and BIC countries. Generally, the access impact is significant in OECD countries (except at the lowest speed level) whereas the speed upgrades is significant up to 8 Mbps. The fact that all investigations in BIC countries are not statistically significant might be as the results of a lower sample size (e.g. only 44 households are subscribing to 8 Mbps). The explanation of the table can be exemplified as follows: investigating the impact of broadband access at 1 Mbps speed level, there are 1256 respondents with a 1 Mbps broadband connection being compared with 1715 households without the broadband access. The PSM approach will then select samples that are comparable in terms of other covariates (socio-demographic factors). By comparing both samples, the respondents accessing broadband at 1 Mbps has a 2077 USD annual household income more than those of the unconnected ones. A similar conclusion can also be drawn that households accessing 8 Mbps has 2342 USD annual income more than those subscribing at 4 Mbps. However, the results for the BIC countries can only be used as an indicative analysis without necessarily showing definitive impacts of both broadband access and upgrades as the results are not statistically significant.

The results from PSM in Table 3 are adjusted using two adjustment factors. Firstly, the results are adjusted by the actual/advertised speed ratio, as seemingly respondents answered the speed level with the advertised speed[3]. In addition, as the survey is conducted based only on the online survey,, there is a strong tendency that the household income data to be skewed towards higher income levels. The results from the first step adjustment are therefore further adjusted by the ratio of sample to actual average pre-tax household income in both OECD and BIC. The adjustment factor is 0.78 for OECD and 0.58 for BIC after comparing the actual data in both groups of countries with the data from the survey. With the lower ratio, this adjustment factors tell us that the sample in BIC countries are more skewed than in OECD. Bringing the results after adjustments, which explained in a more detail analysis in the Appendix, the following Figure 9 pictures a different threshold level at which broadband access is expected to yield a positive impact on household income.

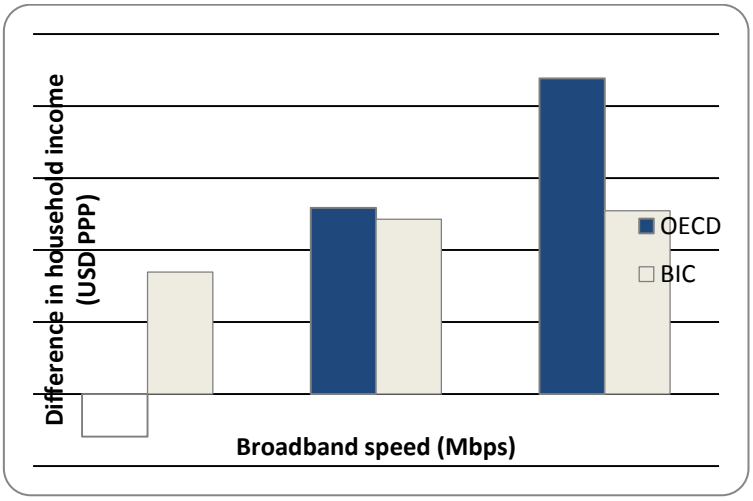

Figure 9 *Estimates differences in income from access to broadband by speed*

From Figure 9, gaining access to 0.5 Mbps in an OECD country, for instance, would not be expected to yield an increased income. It seems that for OECD, the threshold is somewhere between 0.5 Mbps and 2 Mbps on average. For OECD countries, it seems that on average, the greatest expected increase in income is for going from not having broadband to 4 Mbps, the difference being about 2100 USD per household per year. This is equivalent to 182 USD per month. This result is also statistically significant (p=<0.01). For BIC countries, the threshold level already seems to be at, or below, 0.5 Mbps. About 800 USD additional annual household income is expected to be gained by introducing 0.5 Mbps broadband connection in BIC countries. This is equivalent to 70 USD per month per household. However, the sample size is relatively small so the results should be interpreted with care.

The impact of a different broadband speed level has also been investigated in both regions. Figure 10 (below) portrays the different impacts between OECD and BIC. From Figure 10, the impact of speed is clearly not linear, nor is it the same between the regions.

[3] The index for all countries is available in http://www.netindex.com/promise/allcountries/.

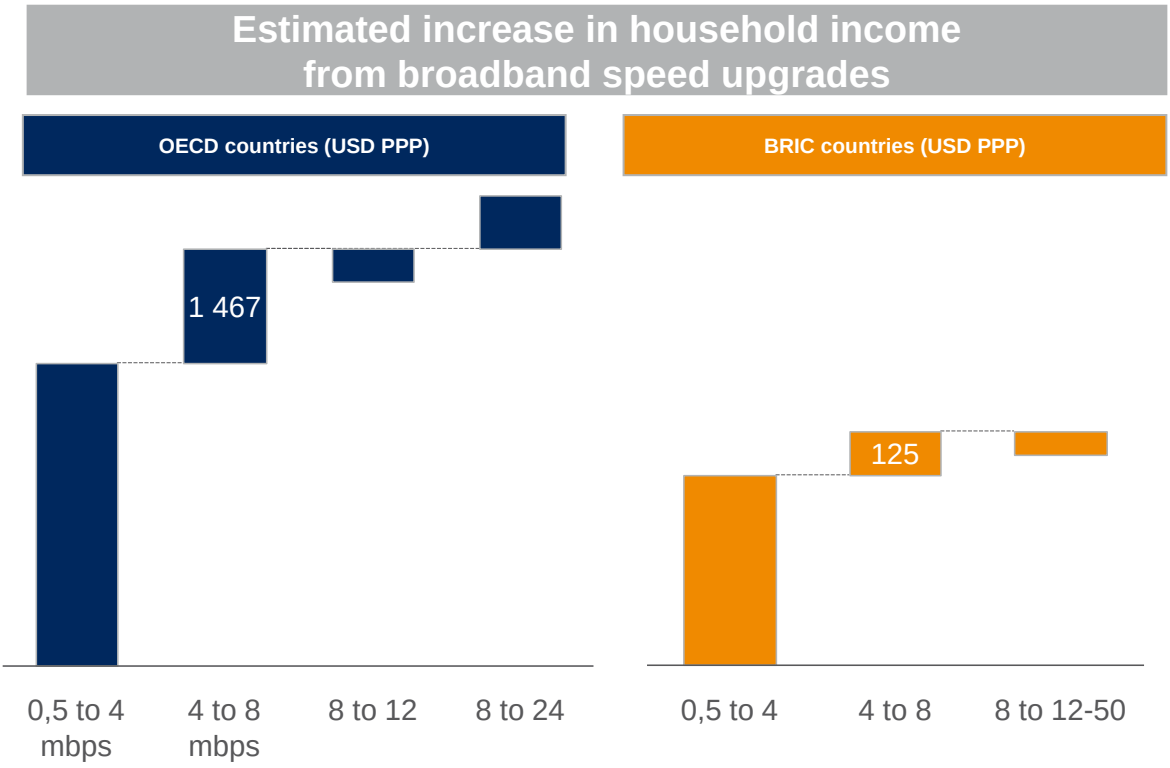

Figure 10. Estimated differences in income from upgrading broadband speed

The speed estimated to give the highest benefit to income in BIC and OECD countries is the same (0.5 to 4 Mbps), but higher speed levels (8 to 24) contribute more in OECD than in BIC countries. With this impact, the incremental income generated in OECD countries was about 4% (with an average income in this class of 37000 USD) and about 1.5% in BIC countries (with the average income in the class 10000 and 12000 USD for China and Brazil respectively). However, BIC countries can obtain a higher impact by upgrading the speed from just 0.5 to 4 Mbps. On this scale, the countries would gain an additional household income of 2.2% for China and 4.7% for Brazil.

Rationale

The statitical procedures employed in this study has been able to present the hyphotetical impacts from gaining the broadband access and upgrading the broadband speeds on the household income. However, this statistical results need to be further investigated, particularly, on how households with a greater speed levels are able to earn additional income due to the broadband connection and broadband speed upgrades. The rationale for this question can be supported by looking at the descriptive statistics on the broadband usages shown in Table 4. The Table is obtained by looking at the survey data asking about the usage of broadband in each group of countries. The frequency of the usages is calculated in terms of how many times per week the housholeds utilize the internet for some purposes: information, emails (for both personal and works), entertainment, and specific contents (e.g. internet banking). The following Table only contrasts the greatest and the lowest

portion of the usage between high speed and low speed broadband subcribers where a higher speed is indicated by at least 8 Mbps broadbans subscription.

Table 4 Broadband usages

Factors	OECD		BIC	
	Low speed	**High speed**	**Low speed**	**High speed**
Broadband usages	Lowest use for email and browsing for both personal matters and work. Highest portion in instant messaging (chatting) Highest portion for entertainment (streaming and listening to music)	Greatest portion for email and browsing for both personal matters and works Lowest portion for instance messaging Lowest portion on entertainment	Lowest portion for email and browsing both for personal matters and work. Lowest portion for entertainment Lowest portion for internet banking transaction Lowest portion for medical search information	Greatest portion for email and browsing for both personal matters and works Greatest portion for entertainment Highest portion for internet banking transaction Highest portion for medical serach information.

Source : Ericsson survey 2010

Table 4 presents the characteristics the broadband usages in OECD and BIC countries. The intensity of broadband usages in OECD is generally higher than that in BIC countries. Moreover, in BIC, the users with higher broadband speeds have a higher usage frequency than users with lower broadband speeds. In OECD countries, there are five purposes where usage increases with higher speeds; *accessing news and other up-to-the-minute information, personal and work related e-mail and internet browsing*. The users also use less the broadband for entertainment purposes. In BIC countries, the characteristics are rather inconclusive as high speed broadband users are also using many entertainment functionalities in addition to work-related purposes. Therefore, particularly in OECD countries, the pattern of usages supports the positive link between broadband connection and broadband speed upgrades and earning as the broadband usages are more productivity related purposes.

Another rationale might relate to the *service advancement effect* that explains why benefits increase with speed. Gaining access to more advanced services (e.g. HD videoconferencing) enables both *more effective, productive ways of working*, and *more advanced types of businesses*. Increased broadband speed boosts personal productivity and allows for more flexible work arrangements, such as teleworking and telecommuting. This allows an individual to get more out of the available 24 hours per day. It also enables an iincreased number of productive hours through decreased time taken for non-work obligations (e.g. via online bill payment). Increased broadband speed opens up possibilities for more advanced home based businesses as a replacement or complement to an ordinary job. This impact has been shown in several previous studies such as Dutz (2009), Lehr (2005) and Quiang (2009).

Additionally, it has to be kept in mind that using the treatment effect estimation also has similarities to assigning dummy variables in a common econometric analysis. To exemplify, being a male (in the

standard wages model) will increase the likelihood to earn a higher income--in comparison to female. Similarly, people living in urban area have the higher likelihood to earn more income as well due availability of job compared with the rural one. Of course, there are female in rural area yet get a higher income than a male in urban area. Therefore, the interpretation of the results is more about the likelihood which means that households subscribing to XX Mbps have a greater likelihood for earning YY USD annual income compared to those subscribing ZZ Mbps (where XX > ZZ).

Conclusion

This study aims to investigate the impact of broadband access and speed upgrades on the household income in OECD and BIC countries. The study answers the question on: *"How much will the broadband access and broadband upgrades increase the household income in OECD and BIC countries?.* As the group of countries differ significantly on the stage of broadband development and economic progress, the study also answers a question on *"How much the broadband speed should be offered to ensure positive benefits for the users (threshold of speed)? Are the thresholds the same for OECD and BIC?"* The results support the view that the impacts of both accesses to broadband and speed upgrades are positive and statistically significant in OECD countries but not in BIC countries. In addition, three key characteristics of ICT benefits are detected:

- There is a required minimum level of broadband speed needed to gain benefits that varies between economic regions

This conclusion can be accentuated from the finding that the impact from introducing the broadband access at 512 kbps is not visible in OECD but is still visible in BIC countries.

- The benefits from broadband are not linear and continuous, but nonlinear and stepwise

The results do not show a significant positive effect for particular speed interval, for instance going from 8 to 12 Mbps in OECD countries, it supports that it is not a continuous S-curve but rather a staircase. Simply having 8 or 12 Mbps does not make a substantial difference in terms of the services used.

- Households in advanced economies gain more leverage from broadband upgrades

The conclusion can be supported by the results that gaining the same increment of speed levels (e.g. 4 Mbps t0 8 Mbps) bringing a greater benefit in OECD than BIC economies. The study sheds lights on the possible reasoning that the users in the less emerged broadband economy only acquire devices they can access, whereas in the more developed broadband countries, users perceive that value-added services are useful and also available hence it is reflected by more productivity related services used from their broadband connection.

The policy recommendation from this study can be derived in terms of bringing forward the longer term aggregate spill over effects of broadband as the device is believed to improve the productivity of the whole economy and to enhance a longer term growth and development (Qiang, 2010). For the OECD countries, the policy can be guided, particularly to give incentives to broadband suppliers to invest in network upgrades that extend service and improve quality and speed (Crandall et al., 2004).

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Appendix

The data in this study is gathered from the households survey which needs some adjustment due to the limitation of the survey procedure. The fact that the survey is conducted on online basis brings the tendency that the responsent skewed to the “more active IT respondents” which might lead to a higher income status. The skewness on income is corrected by looking at the actual income in each country. Moreover, it is a greater tendency that respondent answers the speed data by looking at the adverstised speed rather than the actual speed. The more elaborated adjustment process is presented below:

1. Exchange rate and purchasing power parity
    a. The combined annual household income data for each country was collected from the survey as a categorical data set in each national currency.
    b. The annual household income in USD was calculated from the median of each category/groups divided by average exchange rate in 2010 when the data is conducted. The data on exchange rate was from the World Bank dataset.
    c. Then, household income in USD PPP is obtained by using PPP data from the World Bank.
2. Adjusting for difference between advertised and actual speed in different countries
    a. The results are adjusted with actual/advertised speed ratio as seemingly respondents answered the speed level with advertised speed. The ratio can be found here:http://www.netindex.com/promise/allcountries/.
3. Adjusting for skewed sample income
    a. The more challenging adjustment concerns with the fact that the survey is conducted based on online survey only. Hence there is a strong tendency for having skewed respondent in terms of income.
    b. The results from (3a) is then adjusted with the "actual average pre-tax household income".
    c. For reasons of data availability, income adjustment for BIC countries is only for Brazil and China
    d. Income adjustment index
        i. The average household net-adjusted disposable income in OECD is 22 387USD[4].
        ii. The average income tax (aggregated from tax rate difference with respect to type occupation, size of family, etc.) is 35.3%[5]

[4] http://www.oecdbetterlifeindex.org/countries/sweden/

iii. By combining (i) and (ii) yielding the average pre-tax annual household income for OECD around 30.289 USD. The average household income from the survey is 37.721 USD hence the adjustment ratio is 0.802

iv. For BIC countries, the actual pre-tax annual household income in China is 7773 USD[6], the survey recorded 20.138 USD (note than the survey is only conducted in China-Urban). In Brazil, the actual household income is 10.000 USD [7] where the survey recorded 12.000 USD. Therefore the weighted average for BIC countries only basing on the data from Brazil and China is 0.78.

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5 http://www.oecd.org/newsroom/taxtheaveragetaxburdenonearningsinoecdcountriescontinuestorise.htm

6 http://www.stats.gov.cn/english/statisticaldata/Quarterlydata/t20100817_402665698.htm

7 http://www.slideshare.net/vameyer/BIC-middle-class#btnNext

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