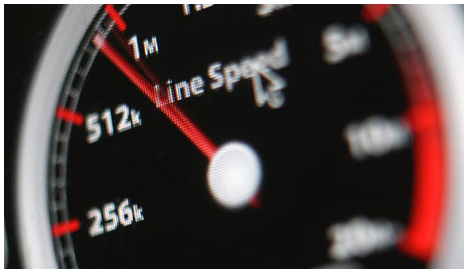
CHALMERS
UNIVERSITY OF TECHNOLOGY

Broadband speed impact on GDP growth and household income:

Comparing OECD and BRIC



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Presented for the ITU Workshop:
New Trends for Building and Financing Broadband: Policies and Economies
24-25 September 2013
Manama, Bahrain

Two studies: Macro and Micro

- Collaboration between LM Ericsson, Arthur D. Little and Chalmers University of Technology
- Macro study released in 2011 – scientific publication: Rohman, I.K., and Bohlin.E. (2012). Does broadband speed really matter as a driver of economic growth? Investigating OECD countries. *Int. J. of Management and Network Economics, 2*(4), 336-356
- Micro study released in 2013 – scientific paper: Rohman, I.K., and Bohlin.E. (2013). Impact of broadband speed on household income: Comparing OECD and BRIC, paper to be presented at 41st Annual TPRC, Washington D.C, Sept 27-29, 2013

The GDP study: Press clips

YAHOO! FIN

HOME INVESTING

optionshouse $3.95 FLAT-RATE STOCKS

New study quant… GDP

THOMSON REUTERS

Topics: Economy, Government &…

Press Release Source: Ericsson On T…

- Doubling the broadband s…
- Research conducted by E… increased broadband speed cont…
- Positive effects come from… access to basic services such as…

A new report, conducted jointly b… Technology in 33 OECD countries, qu… the broadband speed for an economy…

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Speech at the launch of the Australian Broadband Applications Laboratory,

Allowing us to do old things better, and to do new things not even yet imagined.

A Deloitte-Access Economics Report released in August estimates that the Internet contributes around $50 billion a year or 3.6 per cent of Australia's GDP.

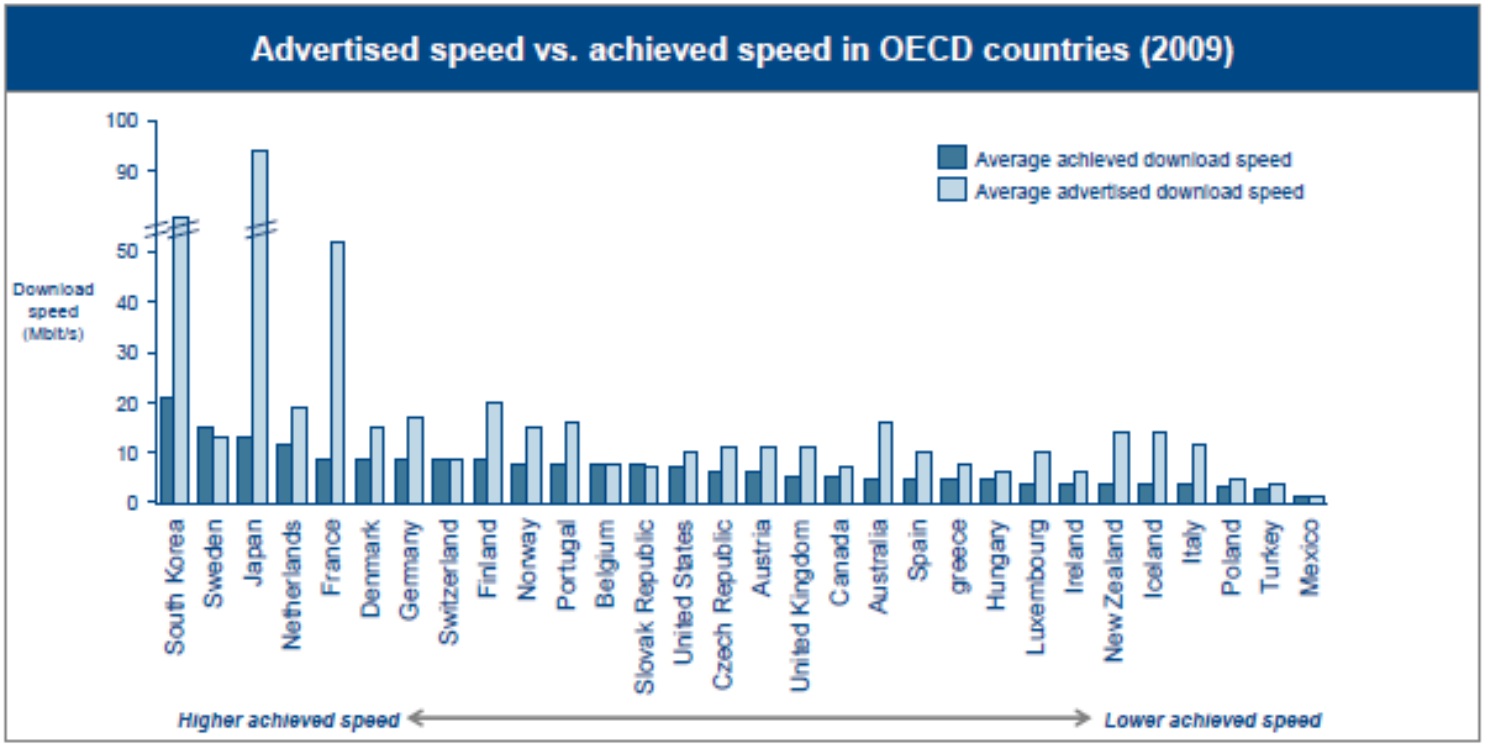
That's the same size as our agriculture industry.

And it's set to grow by around 7 per cent a year by 2016.

Further, research being released yesterday in Europe by Ericsson and Arthur D. Little finds that every doubling of broadband speed increases GDP by 0.3%

To put this into perspective; the basic service offered under the NBN has a speed of 12 mega bits per second - significantly faster than the 1 to 5 mbps speeds most Australians experience today.

What speed should be measured?



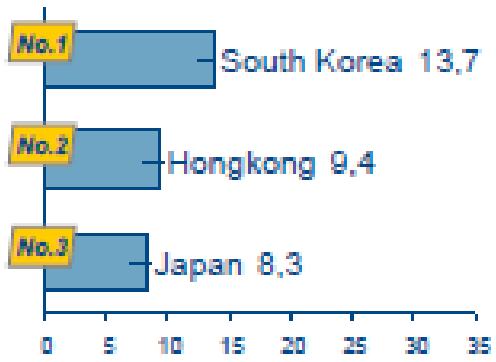
Source: OECD, Ookla speedtest.net

Significant variation in measuring achieved speed

Akamai

Top 3 countries with highest achieved broadband speed

(Mbit/s)

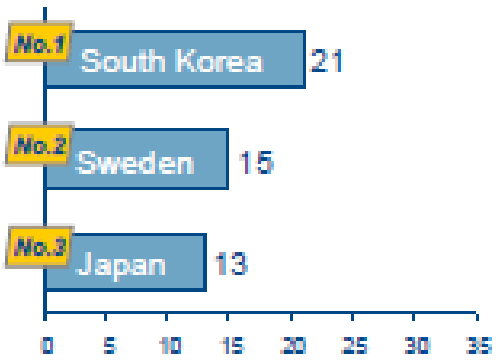


Akamai has servers placed world-wide in order to speed up downloads from the Internet. They also measure the download speed from these servers, which forms the data on which these figures are based.

OECD

Top 3 countries with highest achieved broadband speed

(Mbit/s)

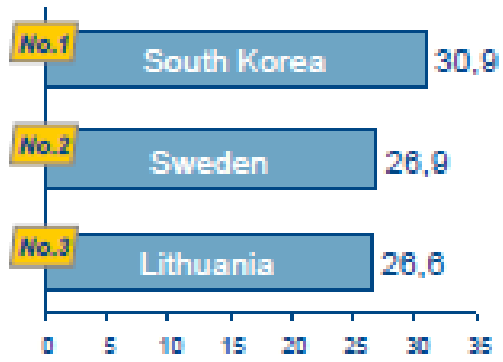


The statistics are based on data from speedtest.net, which is a service provided by Ookla. The measurements were done in 2009. The figures are indicative – OECD does not provide exact numbers.

Ookla

Top 3 countries with highest achieved broadband speed

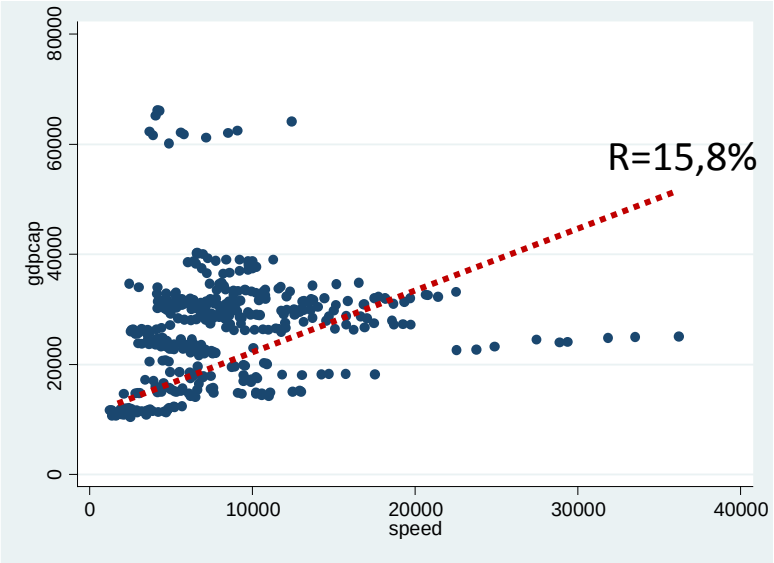
(Mbit/s)



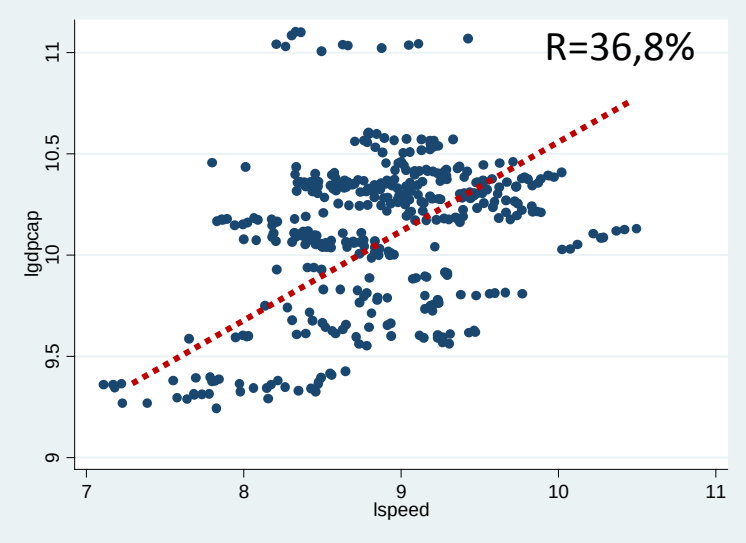
The statistics are based on millions of recent test results from Speedtest.net. Top 10 countries require at least 100,000 unique IP addresses for a given country. Speed measured over Nov 3, 2008 – May 5, 2011.

Source: State of the Internet, Akamai. Next Generation Connectivity, OECD. Ookla's netindex.com, accessed on May 6, 2011.

Descriptive statistics : correlation between speed and GDP per capita



(1) Level (correlation = **0.158**)



(2) Growth rate-in the log forms (correlation = **0.368**)

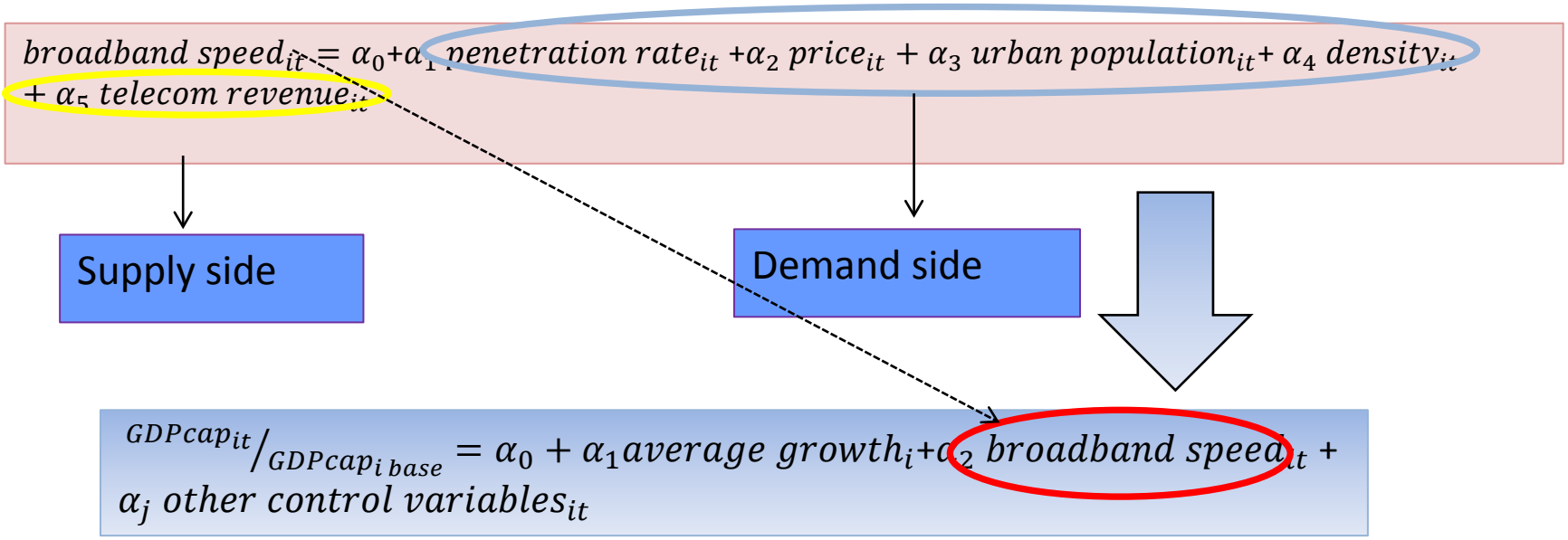
The relationship between GDP per capita and broadband speed is more visible in the log forms (growth) in the right hand figure, with higher correlation between two variables.

Description of the model

	Model for estimating GDP effect of broadband speed upgrades
Model type	Static panel data regression
Source of framework	Lehr et. al. (2005), Koutrompis (2005), Shiu and Lam (2008)
Empirical framework	Two stage fixed effect panel data
Number of observations	33 OECD countries
Time series	3 years (12 quarters)
Dependent variable	■ GDP/capita (OECD)
Independent variables	■ Quarterly data on average achieved broadband downlink speed (Ookla)
Control variables (independent)	■ Fixed broadband penetration rate ■ Average broadband subscription price (USD PPP) ■ Graduates from upper secondary education or higher ■ Telecommunication revenue in millions of US dollars (PPP) ■ Population density

The impact of speed to GDP

(model adopted from Lehr, 2005)



- Both equations are in the log forms, the coefficient reflects the elasticity.
  - Control variables in equation 1 –broadband speed equation- (broadband penetration rate, broadband subscription price, urban density, proportion of urban population, and telecom revenue)
  - Control variables in equation 2 –main equation-(urban density, proportion of urban population, labor force, proportion of tertiary education, population),

Results

Model 1 (Macro level) – Impact on percentage GDP growth compared to base year (2008)		
Independent variables	**Coefficient**	
Average GDP growth (2008-2010)	0,577	*
Population density	-0,0441	*
Urban population	-0,0103	**
Labour force growth (%)	0,483	*
Telecom revenue growth (%)	0,0492	*
Population growth (%)	-0,630	**
Average achieved downlink speed	-0,00214	
Average achieved downlink speed squared	**0,00142**	*
Notes		
*	*p-value < 0.01*	
**	*p-value < 0.05*	

Interpretation of macro results (1)

- The estimated coefficient is the **squared average achieved downlink speed**, with the value of 0,0014
  - The result is highly significant ($p<0.01$) and the model is robust to changes in control variables.
  - Hausman test confirms the fixed effects regression as the best model (in comparison to the random effect)
  - Durbin-Wu-Hausman (DWH) test confirms the successful isolation of the independent impact from speed to GDP (not influenced by reversed causality), hence no endogeneity in the result on most levels of significance.
- The coefficient can be translated into an elasticity measurement, with elasticity values evaluated at the sample mean.
  Such an elasticity measurement is on the form:
  2*coefficient=2*0.00142%=0.00284%
  ≈0,003% additional GDP mean growth from base year (2008)
  by 1% higher mean speed
  (the result is significant at log x square and derived accordingly)

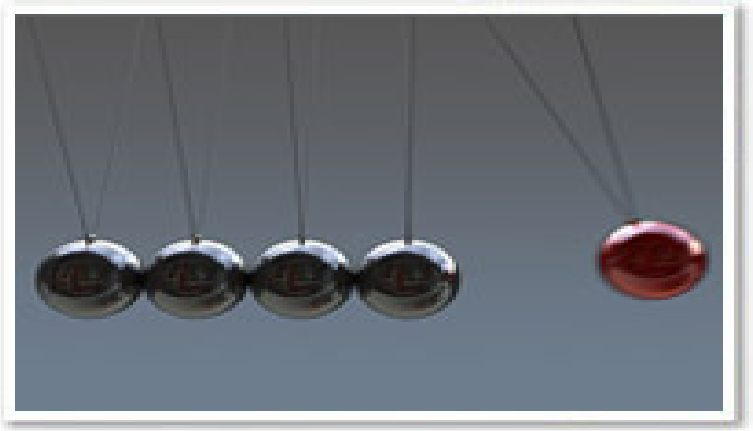
Interpretation of macro results (2)

- The size of the coefficient is more readily understood in the context of a doubling of the average speed, i.e. an increase by 100%
- The sample mean is **8.3 mbps,** hence **16.6 mbps** for 100% increase
- If the speed level is doubled, the impact to GDP growth is 100*0.003= 0.3% (relative to the growth in 2008)
- As an example, if the overall economic growth in 2008 is 2%, then the hypothetical ***isolated*** impact from doubling the speed level on growth would be: 2%+0,3%=2.3%.
- The hypothetical impact will depend on:
  - The size of beta (coefficient of speed)
  - The existing economic growth in each country
  - As the impact is modeled as linear, it needs to be judiciously applied when a hypothetical country growth is far away from sample means
- The hypothetical impact is based on an elasticity measurement and any forward-looking simulation should be applied with care

The household study

Method
Treatment effect

- In many areas there are interests to investigate the effect of treatment/cause in a model called ***treatment effect.***
  - Drug → illness
  - Educational program→ academic achievement
  - Economic policy → GDP
- Once the effect is found, policy makers can adjust and intervene the treatment to obtain a desired level of response.



Starting point

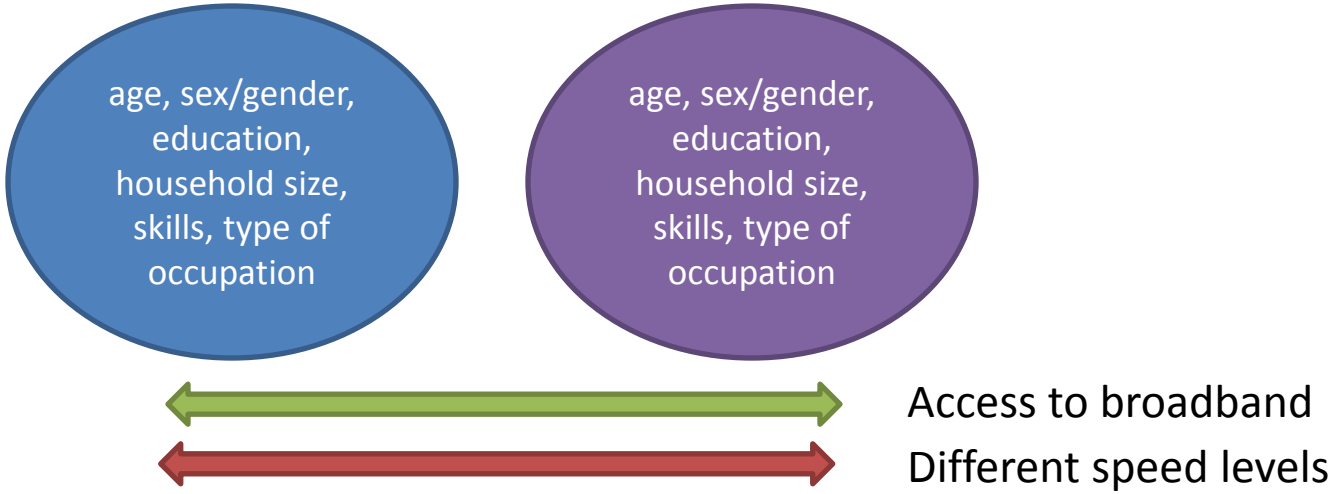
What might influence the level of **personal/ household income ?**

- Gender
- Ages
- Education
- Geographical location
- Type of occupation

- Number of households member
- Skills
- Prior assets ownership

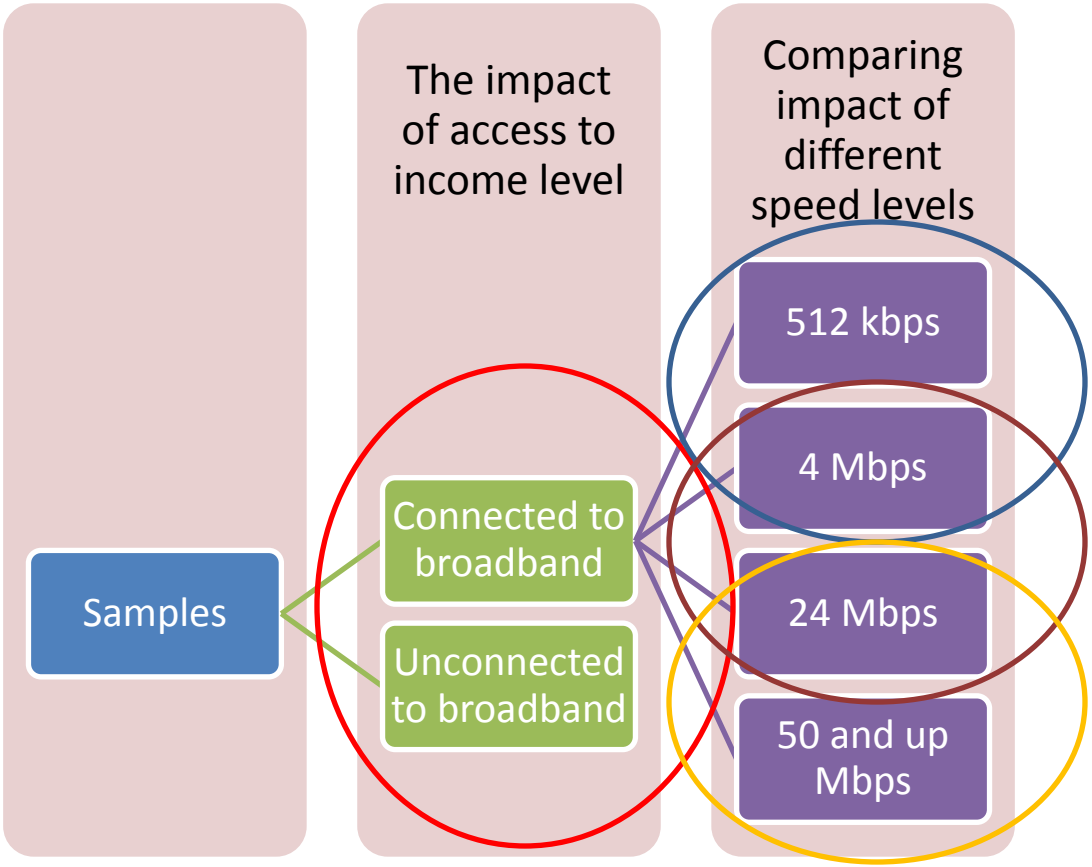
Propensity Score matching

The method controls for the possible factors that contribute to income (age, sex/gender, education, household size, skills, type of occupation, etc)



The only difference between the two samples is (i) the access to the broadband , for access impact, and (ii) the different level of broadband speed, for speed impact assessment.

Access and speed investigation



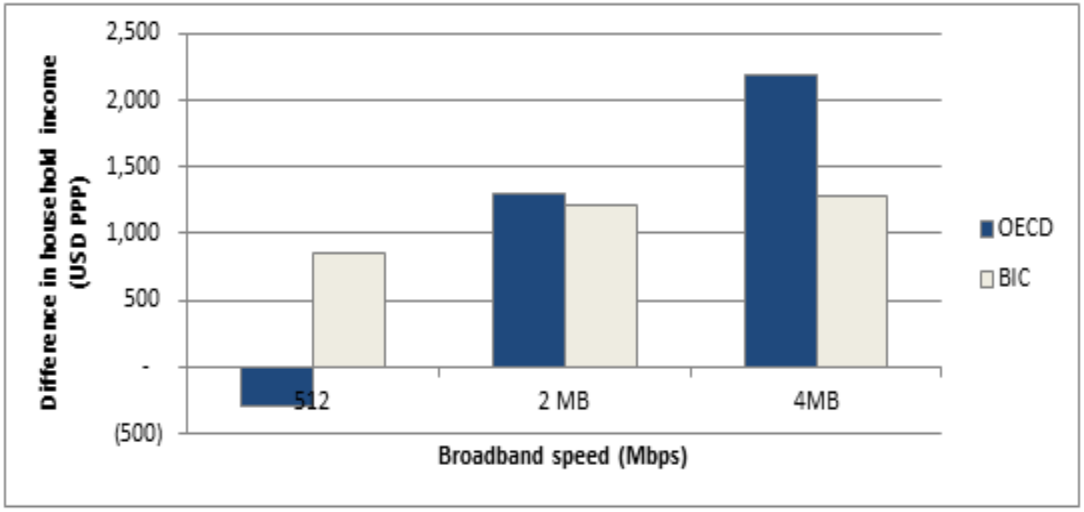
Propensity score matching between speed level except for the lowest one which is compared to unconnected respondents (similar to access)

Propensity score matching between connected and unconnected **households** to broadband

Framework of the model

Source	Type	Data	Description
Ericsson Consumer Lab	Dependent variable	Household Income (USD PPP)	Median of income class, the span of class varies between countries. The currencies have been standardized into PPP USD based on the World Economic Outlook databases October 2012 released by the International Monetary Fund (IMF)[14].
	Investigated variable	Access to broadband	Only for fixed broadband
		Reported broadband speed	Based on some category (up to 256, 512, 1024, 2 MB, 4 MB, 8 MB, 12 MB, 24 MB, 50 MB and beyond)
	Control variable	Level of education	Based on three global education standards (primary, secondary, some colleges/universities).
		Type of occupation	Different type of occupation
		Gender	Male and female
		Age	Continuous variable
		Geographical area	Urban and non-Urban
		Marital status	Married and other marital status
		Household size	Continuous variable
		Type of housing	Different type of housing and dwelling (rented and owned)
		Managerial competencies	Different level and degree of participation into decision making.
		Prior ICT access	Adoption to telephony, computer, laptop and notebook
		Prior ICT usage	Behavior towards ICT usage—telephony and internet for work)
		Country dummy	

Results : Access



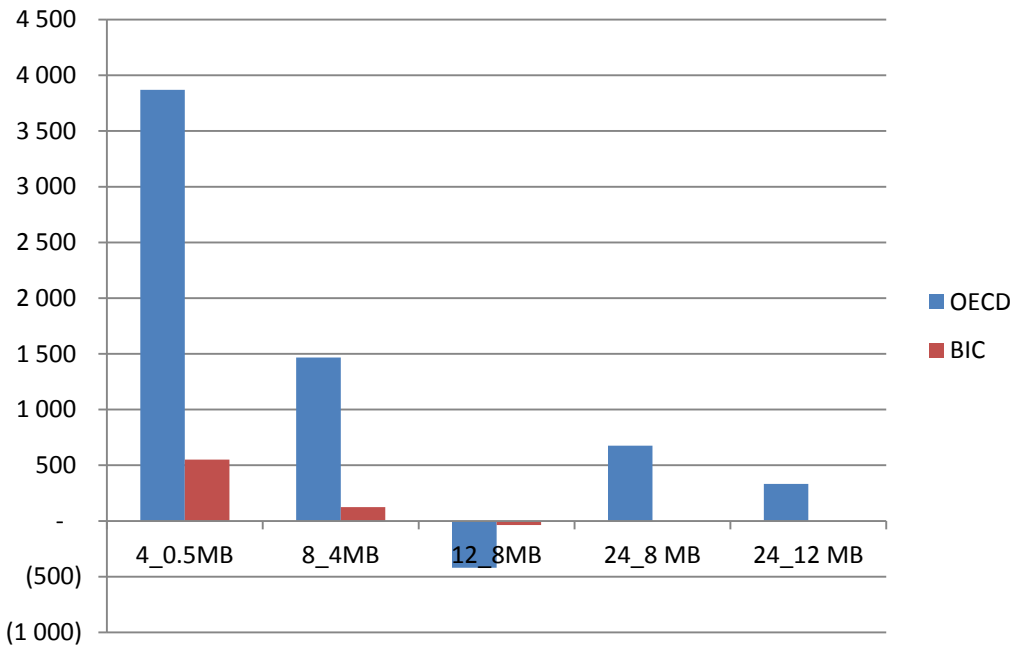
Estimated difference in income from access to broadband, per speed.

Interpretation

- In OECD countries, gaining access to 0.5 Mbps would not be expected to yield an increased income. It seems for OECD, the threshold is somewhere between 2 Mbps and 4 Mbps.
- For BRIC countries, on the contrary, the threshold level is already visible at 0.5 Mbps.
  - Around 800 USD additional annual household income is expected to be gained by introducing 0.5 Mbps broadband connection in BRIC countries which is equivalent to 70 USD per month per household.

Results : Speed

Estimated increase on household income from speed upgrades



Interpretation

- The speed upgrades giving the highest benefit to income in BRIC and OECD are the same (0.5 to 4 Mbps)
  - A higher speed levels (8 to 24) contributes more in OECD than in BRIC.
  - The incremental income generated in OECD country is around 4% (with average income in this class 37000 USD)
  - However, BRIC countries can obtain higher impact by upgrading the speed only from 0.5 to 4 Mbps. At this scale, the countries will gain an additional household income of 2.2% for China and 4.7% for Brazil

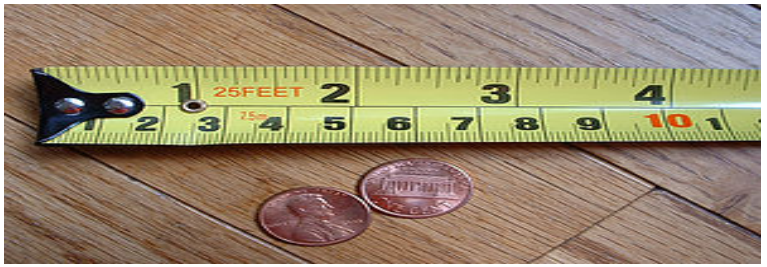
Conclusions of the household study

- In OECD countries, gaining access to 0.5 Mbps would not be expected to yield an increased income. It seems for OECD, the threshold is somewhere between 2 Mbps and 4 Mbps.
  - For BRIC countries, on the contrary, the threshold level is already visible at 0.5 Mbps.
- The impact of broadband speed to households income
  - Is not linear between countries and regions
  - There are moving targets concerning the best speed level giving an impact to incomes:
    - In the OECD, the unconnected users will only benefit from broadband if the speed level is at least 2Mbps whilst in BRIC 0.5 Mbps would give additional benefit
    - Concerning the speed upgrade, both countries have similarities for having a greater impact moving from 4-8 Mbps. However, OECD will benefit more as speed increases up to 24 Mbps.

Annex: Descriptive analysis and variables of interest

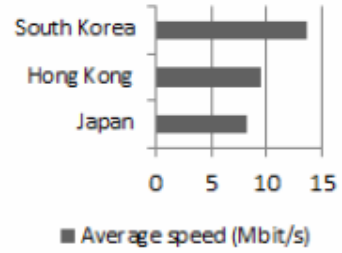
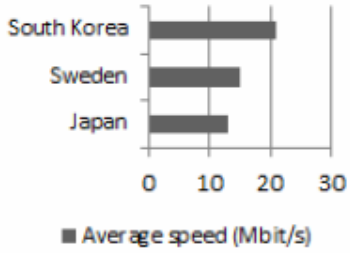
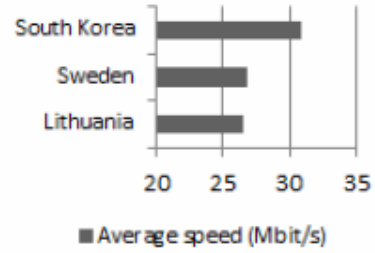
Broadband speed: various way to measure

Term	Definition	Pros	Cons
Advertised speed	Typically the theoretically highest possible downlink net bit rate that may be obtainable on a subscribed to connection in a broadband access network	■ If correctly cited, the advertised speed gives an indication of the theoretically highest possible downlink speed	■ Not real measured data
Achieved speed	The average (downlink) net bit rate (or data transfer rate) that is obtained over a connection in a broadband access network, caused by capacity limitations in the total end-to-end broadband network. This is the data rate typically measured by end users doing self-initiated speed tests	■ Measured data ■ Takes into account the entire connection line; end-to-end ■ A speed measurement that is easily interpreted by the general public	■ Few reliable sources ■ There are several ways to measure speed over a connection, different methods giving different results (Akamai uses mirror servers, which may – but are not aimed to – bias the outcome)
Peak speed	The average highest achieved downlink net bit rate for a population of broadband users measured from the server end in a broadband network over a defined time span	■ Measured data ■ Takes into account the entire connection line; end-to-end	■ Depends on the user's Internet behavior, and does not always correspond to the maximum possible speed ■ Few reliable sources ■ There are several ways to measure speed over a connection, different methods giving different results
Capacity consumption rate	The average amount of downloaded bytes over a broadband connection during one month. Measured in Mbyte/month or Gbyte/month	■ Measured data ■ Provides a measurement of the actual volume (bytes) used per month	■ The monthly data rate is not of high relevance when trying to measure broadband speed, as seconds matter to Internet users



Broadband speed: various source of data to collect from

Figure 2 Speed level from different data sources

Akamai	OECD	Ookla
The 3 countries with the highest achieved broadband speeds (Mbits/s) 	The 3 countries with the highest achieved broadband speeds (Mbits/s) 	The 3 countries with the highest achieved broadband speeds (Mbits/s) 
Akamai has servers placed world-wide in order to speed up downloads from the Internet. It also measures the download speed from these servers, which forms the data on which these figures are based.	The statistics are based on the data from the Speedtest.net which is a service provided by Ookla. The measurements were done in 2009. The figures are indicative-the OECD does not provide exact numbers.	The statistics are based on millions of recent test results from the Speedtest.net. The top 10 countries each require at least 100,000 unique IP addresses. The speeds were measured from Nov 3, 2008 to May 5, 2011.

Source: ADL (2011)

Method
Treatment effect

Example:

- Investigating the impact of drug (a *treatment variable)* on blood pressure (*a response variable*) by comparing two people
  - with treatment (drug)
  - without treatment.
- If two people are exactly the same other than the treatment status; then the difference in their blood pressure can be inferred as the impact of drug treatment.
- However, if they are different in many ways, the different in blood pressure might be as the results of many aspects (other than the drug treatment).
- Hence, the treatment effect is ***"comparing comparable people"*** where comparable means "homogenous on average" (Lee, 2010)

Method
Treatment effect and Propensity Score Matching (PSM)

- If the treatment group (T) and control group (C) are hugely different in many observed variables (X), e.g., socio demographic aspects (ages, 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 similar in X. To facilitate such comparisons, an index with a single value is constructed, so-called propensity matching estimators.
  - Matching by the propensity score can be done by selecting two individuals with the same propensity score, where the first individual receives treatment and the second does not. The level of propensity score p(x) is obtained by a random model (probit).
  - Ignorability of treatment hold!

Previous studies

- Beard, Ford, Saba, and Seals (2012) estimate the effect of Internet use on job search. The study indicate broadband use at home or at public locations reduces the probability that the unemployed cease job search by over 50% relative to unemployed persons who do not use the Internet at all.
  - As policy implication even public connections (e.g., at libraries) in unserved and underserved areas may produce substantial social benefits.
- Grimes, Ren, and Stevens (2012) investigates the role of broadband for increasing productivity level in large micro-survey of firms. Employing propensity score matching to control for factors, the study indicates that broadband adoption boosts firm productivity by 7-10%; effects are consistent across urban versus rural locations and across high versus low knowledge intensive sectors.

Operationalization

Probit regression

Number of obs = 1756
LR chi2(33) = 448.83
Prob > chi2 = 0.0000
Pseudo R2 = 0.1846

Log likelihood = -991.27743

s4_512	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	-.0055025	.0035691	-1.54	0.123	-.0124978	.0014927
male	.1968857	.070664	2.79	0.005	.0583869	.3353846
urban	.3789063	.1327716	2.85	0.004	.1186788	.6391338
educ1	-.3754027	.2184687	-1.72	0.086	-.8035934	.052788
educ2	.0643428	.0992358	0.65	0.517	-.1301558	.2588414
hhsize	-.1044632	.0270491	-3.86	0.000	-.1574785	-.0514479
d_mar	.1158839	.0733525	1.58	0.114	-.0278844	.2596523
manager1	-.0677815	.1222466	-0.55	0.579	-.3073805	.1718175
manager2	-.1984597	.1045528	-1.90	0.058	-.4033795	.00646
manager4	-.123557	.0987323	-1.25	0.211	-.3170688	.0699548
work_state1	-.0190642	.3241786	-0.06	0.953	-.6544425	.6163141
work_state2	.1268552	.3131004	0.41	0.685	-.4868104	.7405208
work_state3	.0497015	.327227	0.15	0.879	-.5916516	.6910545
d_fix	-.0315993	.1196567	-0.26	0.792	-.2661221	.2029236
d_com	-.3555562	.1041608	-3.41	0.001	-.5597077	-.1514047
d_lap	-.2740613	.0793928	-3.45	0.001	-.4296683	-.1184543
d_note	-.2968146	.076207	-3.89	0.000	-.4461776	-.1474516
int_work	.0365736	.0182599	2.00	0.045	.0007849	.0723624
phone_work	.0149856	.0104997	1.43	0.154	-.0055935	.0355646
housing1	-.328883	.3029676	-1.09	0.278	-.9226886	.2649225
housing2	-.1146219	.2979015	-0.38	0.700	-.6984981	.4692543
housing3	-.4638061	.3133025	-1.48	0.139	-1.077868	.1502555
housing4	-.1718366	.2954922	-0.58	0.561	-.7509906	.4073175
housing5	-.3119171	.7384116	-0.42	0.673	-1.759177	1.135343
housing6	.0717192	.4110575	0.17	0.861	-.7339388	.8773772
country1	.8280462	.1736452	4.77	0.000	.4877078	1.168385
country2	.509093	.1509151	3.37	0.001	.2133048	.8048813
country3	1.189646	.1544658	7.70	0.000	.8868983	1.492393
country4	1.126035	.1405536	8.01	0.000	.8505553	1.401515
country5	1.7464	.138229	12.63	0.000	1.475476	2.017324
country6	1.170645	.2013851	5.81	0.000	.7759372	1.565352
country8	.1112192	.2070344	0.54	0.591	-.2945608	.5169991
country10	.5745548	.1440205	3.99	0.000	.2922799	.8568298
_cons	.8216679	.5383799	1.53	0.127	-.2335373	1.876873

First Step

- Probit models:
  (i) on access to broadband (impact from access);
  (ii) subscription to a particular speed level (impact from speed upgrades)
- The dependent variables:
  (i) Access (Yes) (No)
  (ii) Subscription to particular speed level (e.g. 4 Mbps) compared with the lower one (e.g. 2 Mbps)

Operationalization

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
income_oecd	Unmatched	39247.6679	22461.5873	16786.0806	1391.13179	12.07
	ATT	38856.8921	32676.9214	6179.97069	1901.47455	3.25

Note: S.E. does not take into account that the propensity score is estimated.

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	0	842	842
Treated	30	884	914
Total	30	1,726	1,756

- Comparison **without** matching
- Comparison **with** matching
- Number of individuals being compared

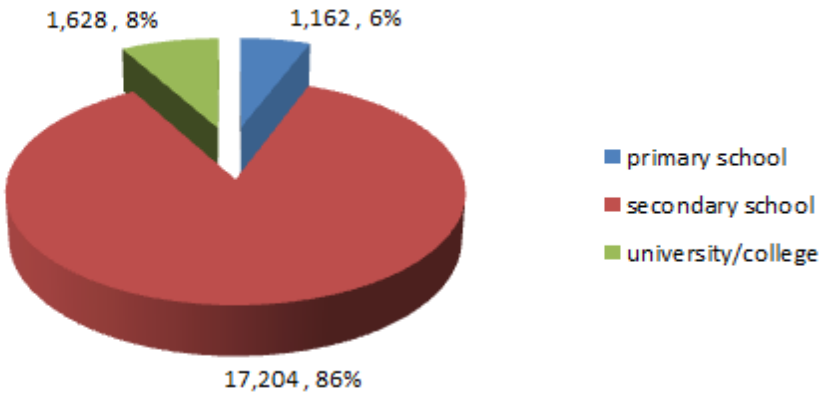
Second Step

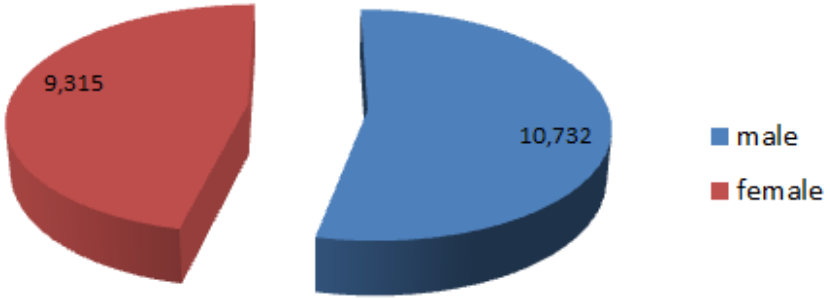
- Based on the probit model, the propensity score is constructed.
- The income is then compared between matched individuals
- The comparison excludes the outliers, i.e. only those in the category “common support” in which the propensity score is comparable

Countries investigated

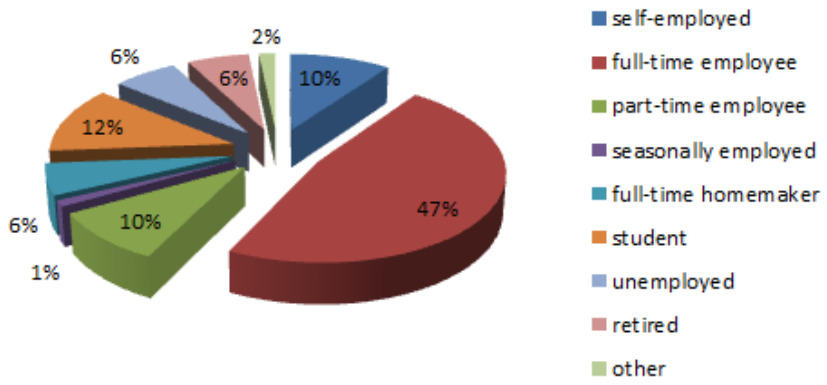
Country	Number of respondents	Percent of total sample
UK	2,001	8,98
France	2,026	9,10
Germany	2,019	9,06
Italy	2,040	9,16
Spain	2,026	9,10
Sweden	2,003	8,99
China-urban	1,014	4,55
Japan	2,046	9,19
Brazil	1,018	4,57
US	2,013	9,04
India	1,000	4,49
Russia	1,058	4,75
Mexico	1,007	4,52
South Africa	1,003	4,50
Total	22,274	100,00

Education and gender





Occupation, age and size of HH



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**

Demographic Characteristics

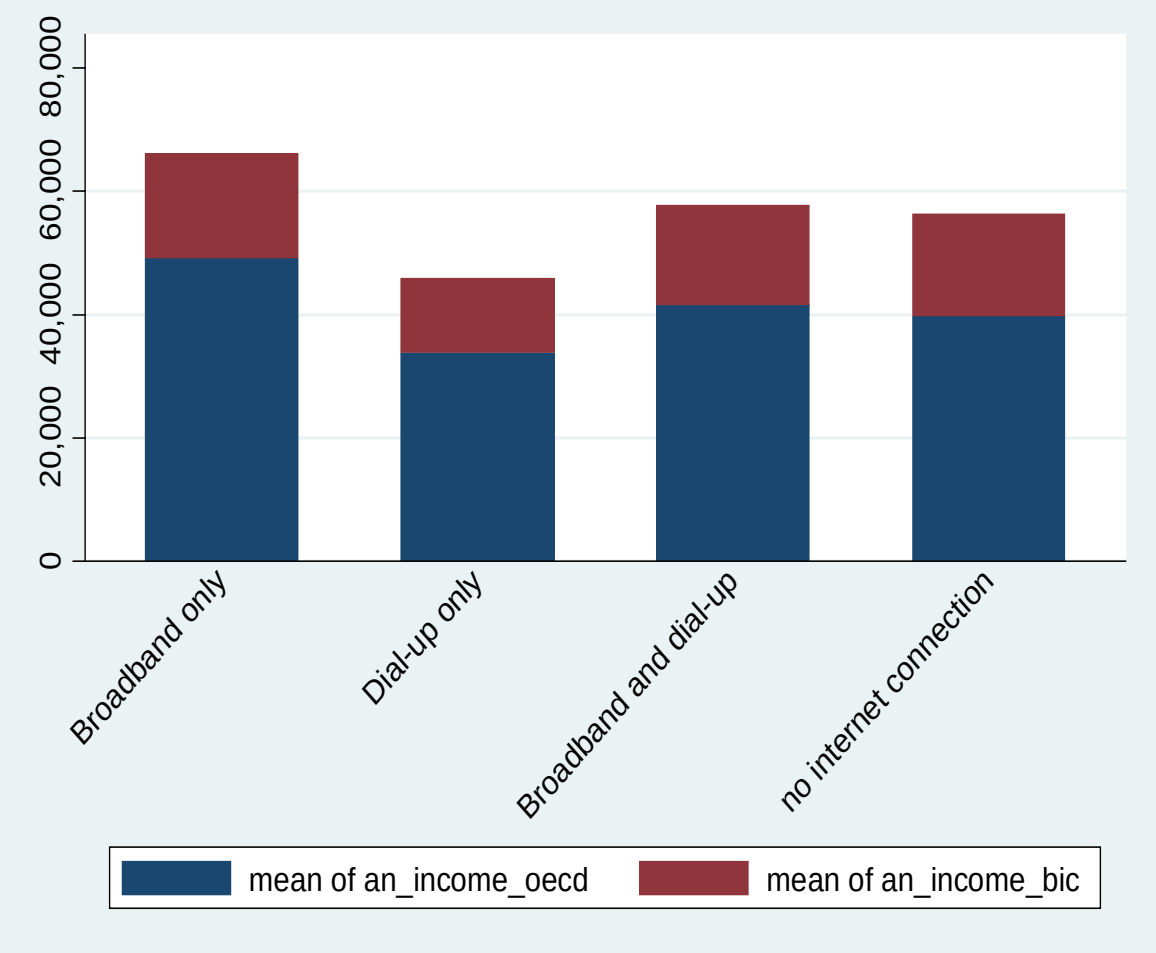
Demographic Characteristics of Respondents in Percentage	
Gender	
Male	53.5
Female	46.5
Marital Status	
Single	35.0
Married	44.3
Living together with partner/ Significant other	14.1
Separated or divorced	5.6
Widowed	1.0
Age	
15 to 19 years	7.8
20 to 24 years	13.7
25 to 29 years	12.0
30 to 34 years	12.0
35 to 39 years	12.5
40 to 44 years	10.5
45 to 49 years	9.9
50 to 54 years	7.7
55 to 59 years	7.1
60 years and over	6.9

Demographic Characteristics of Respondents in Percentage	
Education	
Primary or less	5.8
Some high school	85.8
Some college/university	8.1
Occupation	
Self-employed	10.0
Full-time employee	47.4
Part-time employee	9.5
Temporarily/seasonally employed	1.1
Full-time homemaker	5.7
Full-time student	12.1
Unemployed	6.4
Retired	6.1
Other	1.6
Household Size	
One	12.1
Two	25.8
Three	24.4
Four	23.8
Five	9.5
Six or more	4.4

Internet Access

Internet Access of Respondents in Percentage	
Type of Internet Access	
Broadband	95.1
Dial-up	30.6
Broadband Speed	
Up to 256 Kbit/s	4.3
Up to 512 Kbit/s	7.0
Up to 1024 Kbit/s	6.9
Up to 2 Mbit/s	10.3
Up to 4 Mbit/s	7.6
Up to 8 Mbit/s	13.7
Up to 12 Mbit/s	6.3
Up to 24 Mbit/s	5.1
Up to 50 Mbit/s	2.0
50 Mbit/s or higher	6.6

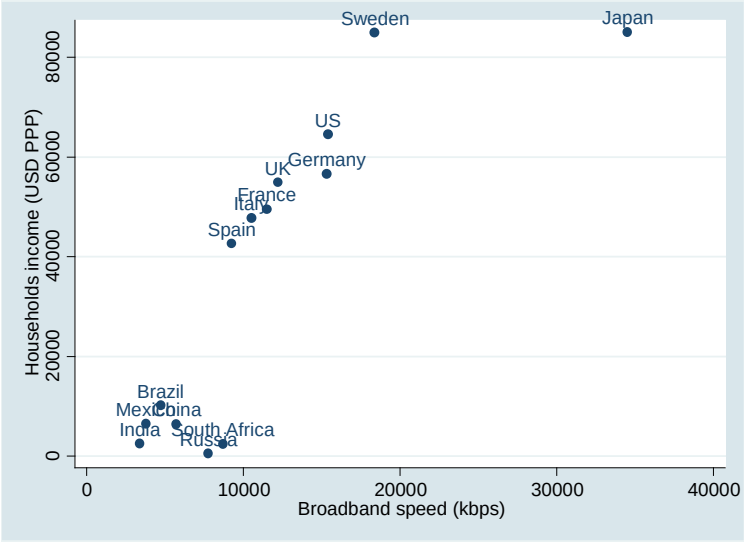
Annual household income USD PPP

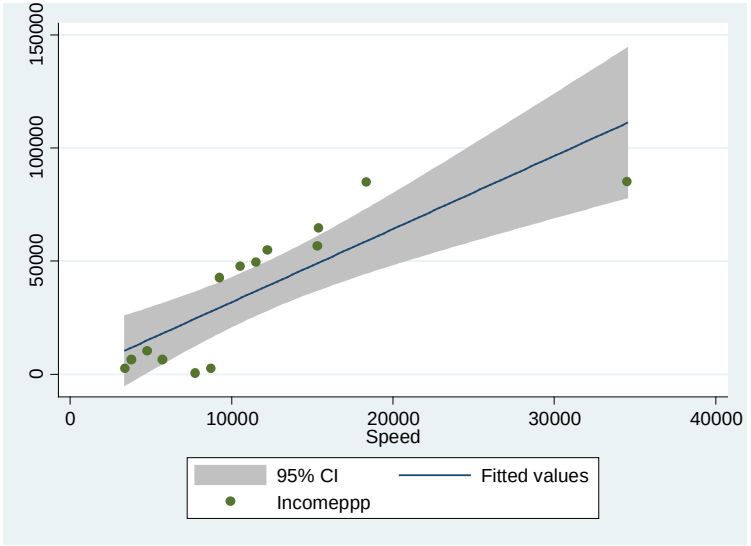


Generally

- The annual income is different very considerably between OECD and BRIC countries
- A higher speed level might be associated with the annual household income
- A more advanced internet connection corresponds to a higher income (dial-up vs. broadband.

Correlation: Income and speed

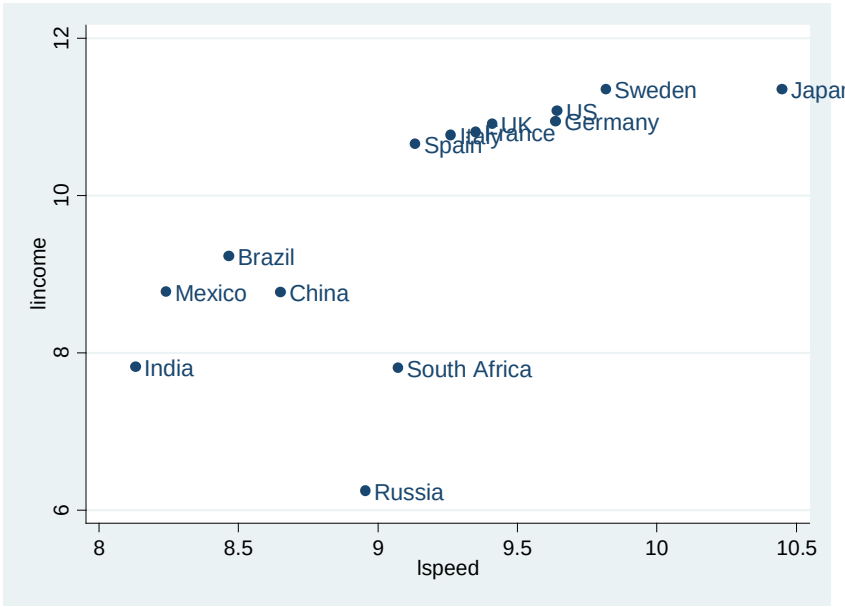


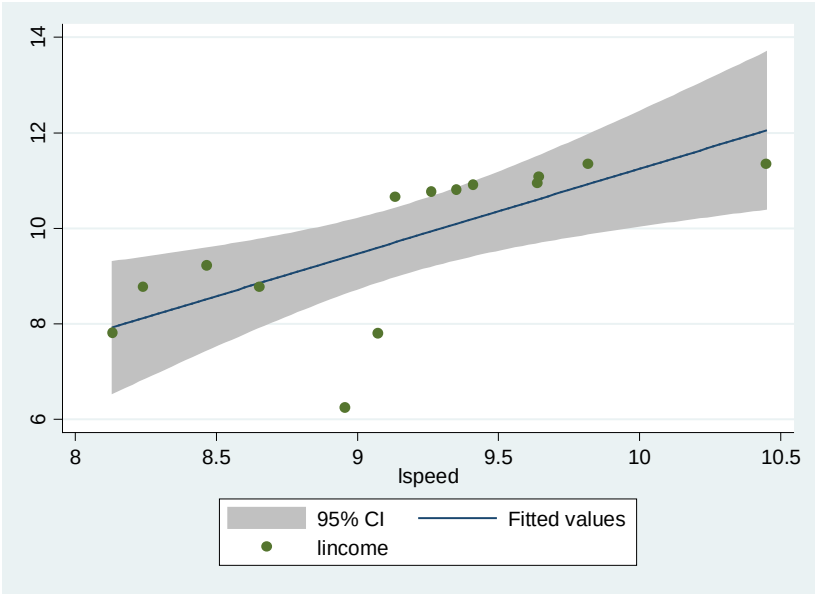



```
pwcorr speed incomeppp
```

	speed	income~p
speed	1.0000	
incomeppp	0.8319	1.0000

Correlation: Growth and speed (log levels)






```
pwcorr lspeed lincome
```

	lspeed	lincome
lspeed	1.0000	
lincome	0.6995	1.0000

The figure indicates that **"a higher speed level contributed to a higher income level"** is a possible hypothesis to be tested with a more formal econometric techniques.