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The Effects of Broadband Infrastructure on Economic Growth in Developing Countries*

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Abstract

In this paper we investigate the effects of broadband infrastructure providing high speed internet, on economic growth in developing countries. We have used two different broadband measures to classify developing countries into two groups for the period 1999-2008. By using logistic diffusion model and IV approach, a nonlinear diffusion model is specified. Differences in ceiling of diffusion curve of this technology across countries are defined by pre-existing telephone networks. Then, after predicting broadband penetration rates through the diffusion curve and controlling for fixed effects, the effects of introduction and distribution of broadband on economic growth are estimated. The results indicate that these effects are significant and positive.

Keywords: broadband; diffusion model; economic growth; panel data; developing countries.
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1. Introduction

Identification and explanation of the determinants of economic growth have been one of the most important subjects in economic over decades. Preliminary studies on the evolution of patterns of economic growth have considered physical capital growth as the sole factor of economic growth. However, further empirical evidences showed that physical capital cannot explain all the changes in production. The efforts for finding the main determinants of output qrowth led to the formation and evolution of neoclassical and endogenous growth models.

Neoclassical growth models introduced exogenous technological improvements as the main factor of economic growth (Solow, 1956). In the light of endogenous growth theories, the generation and distribution of ideas and information are the essential factors that affect economic growth (Lucas, 1988; Romer, 1990; Aghion and Howitt, 1997).

The world's economic system is rapidly turning to a system based on information as a fundamental input. High-speed internet via broadband infrastructure facilitates distribution of information and ideas. This leads to improvements in communication between firms with far distances. It lowers the costs of information acquisition which, in turn, increases market transparency and competition and thereby develops new products and business models. Therefore, economic growth is affected by these developments and adoption of innovation processes.

It is noteworthy that broadband networks have a special characteristic that makes an important distinction between broadband infrastructure and public infrastructures. Broadband expansion has positive network externalities and increasing in the numbers of subscribers raise the attained overall value of network. In fact, network externalities can even change the linearity effect of broadband infrastructure on growth into the nonlinearity. After exceeding specified levels of network, known as critical masses, the obtained value of network will drastically spike.

Previous studies about infrastructures have reached notable results. Early studies on public infrastructures have shown a very significant effect of public infrastructures on economic growth; however, conducting more research and benefiting from more precise econometric methods have shown a much less impact of public infrastructures. It is claimed that the significant effect can be due to reverse causality and spurious correlation that should be considered in assessing other infrastructures effects too.

This paper investigates the effect of broadband infrastructure on economic growth, using an annual panel of 46 developing countries with some similarities at their ICT status (info-density and info-use of communication and information technology and consequently digital divide), during 1999-2008 period with first introduction of broadband at 2000.

The remainder of the paper is organized as follows. First we review the most recent relevant studies in Literature Review section. Next, in Model Specification section, the models will be specified presenting causal effect of broadband introduction and penetration on economic growth. Then, the data and descriptive statistics will be presented in Data section, followed by discussion on the results in Model Result section. Finally, we discuss Broadband Infrastructure Critical Mass briefly and conclude.

2. Literature Review

For investigating the effects of an infrastructure on economic performance, we should make distinction between various kinds of infrastructures.

Public infrastructures: A seminal study by Aschaure (1989) on the returns to public infrastructures investments has attracted a lot of attention. Using time series data on production function, the study concluded that public infrastructures have a great impact on output; however, after using more complicated econometric methods, those empirical results appear to fall down. Roller & Waverman (2001) criticized the Aschaure model as not accounting for the appropriate causalities and correlations. Further studies by Holtz-Eakin (1993, 1994), Garcia-Mila and McGuire (1992), Kelejian and Robinson (1997) and Pereira and Frutos (1999) showed that Aschaure's results are not reliable and Balmaseda (1994, 1996) claimed that those high impacts can be explained by simultaneity and aggregation biases.

Information and communication technology: Najarzadeh et al. (2007) studied the relationship between ICT and economic growth for OIC (Organization of Islamic Conference) countries during 1996-2004. Their results indicated a positive and significant relationship between ICT and economic growth.

Asaari and Aghaei Khondabi (2008) using OPEC countries data from 1992 to 2004 found similar results. Also Komeyjani and Mahmoudzadeh (2008) examined this relationship for a group of 51 developing countries in the period of 1995-2003. The results once again were positive and significant.

Telecommunication: On a more detailed level, Hardy (1980) examined the impact of telecommunication on growth. Using data on 60 countries during 1960-1973, he concluded that telephones per capita have a significant impact on GDP per capita. However, when he investigated developing and developed countries separately, results were not significant anymore.

In other studies by Leff (1984), Cronin et al. (1991), Norton (1992), Greenstein and Spiller (1995) and Madden and Savage (1998, 2000) significant positive impact of telecommunication on economic growth was confirmed and it was concluded that presence of telecommunication infrastructure reduces transactions costs.

A basic study by Roller & Waverman (2001) estimated a model which endogenized telecommunication investment through specifying a micro model of its supply and demand. The micro model was simultaneously estimated with a macro production function for a group of 21 OECD countries, over 1970-1990. They concluded that there is a significant relationship between telecommunication infrastructure and productivity. In addition, they indicated that these results are attained only when telecommunication reaches the critical mass.

Sridhar & Sridhar (2004) studied the relationship between telephone penetration and economic growth for 63 developing countries, from 1990 to 2001. By controlling for the effect of labor and capital, they showed that mobile and landline phones have positive effects on national output. They also found that the effect is less for developing countries in comparison with OECD countries.

Datta & Agarwal (2004) reached the point that even when investment, government consumption, populating growth, openness level, past levels of GDP and lagged growth are controlled, telecommunication affects economic growth positively and significantly.

Broadband: In 2006, Lehr et al. examined the impact of accessing the broadband. After controlling for the related community level factors, the results showed that access to broadband increases the economic growth.

Koutroumpis (2009) applied an adoption of Roller & Waverman model, but he concentrated on broadband instead of telephone network, by using a group of 22 OECD countries over 2002-2007, he indicated that there is a positive and significant relationship, specially, when a critical mass of infrastructure is reached.

And finally, based on instrumental variable (IV) approach, Czernich et al. (2009) studied the impact of broadband infrastructure on economic growth for a panel of 25 OECD countries, in the period of 1996-2007, and they came to this conclusion: broadband introduction and also its development have positive significant impression on economic growth. Different tests were done and it was observed that additional controlling variables did not change the results considerably.

The numbers of studies which are done in this particular subject are few and most of them are about developed countries. This paper investigates the effect of broadband infrastructure on economic growth, using an annual panel of 46 developing countries in cluding Iran.

3. Model Specification

In this study we use Mankiw, Roamer, Weil model (1992) which is one of the propounded models in the endogenous models. We consider steady state in our macroeconomic production equation with Constant return to scale, as follows:

$$\text{Log } y_{it}=\log A_i+\beta_1 \log S_{it}+\beta_2 \log H_{it}+\beta_3 n_{it} \quad (1)$$

As “i” is country, “t” is time, “y” shows “GDP” per capita, “S” refers to physical capital stock, “H” is human capital stock and “n” shows growth rate of population at working age, and finally, “A” is technology level.

Assuming technology level is increasing along the time, we will have:

$$A_{it}=A_0e^{\lambda_i t} \quad (2)$$

Here, "λ_i" is technological promotion growth in country "i". Thus, continual increase in technology level causes to continual increase in "GDP" per capita.

Broadband through 1) facilitating dissemination of ideas and information in more distances with less costs, 2) increasing development and competition in new productions, trade models and processes and lastly 3) increasing innovation level, affects "λ".

Therefore, the effect of broadband introduction on economic growth can be estimated as follows:

$$\lambda_i t=\alpha +\alpha_1 D_{it} \quad (3)$$

In which, "D" represents a dummy variable which equals one if country "i" reaches to broadband introduction measure. A simple replacement results in:

$$\text{Log } y_{it}=\alpha+\alpha_1D_{it}+\beta_1 \log S_{it}+\beta_2 \log H_{it}+\beta_3 n_{it}+\mathcal{E}_{it} \quad (4)$$

$\mathcal{E}_{it}$ is an error term. It is clear that in addition to the first effect resulting from first broadband adoption, its subsequent penetration and development can also affect growth continually, captured by the following equation.

$$\lambda i=\alpha+\alpha_1 B_i \quad (5)$$

Where, "B" is broadband penetration rate. With a replacement in equation 1, we have:

$$\Delta \log y_{it}=\alpha+\alpha_1B_{it}+\beta_1\Delta\log S_{it}+\beta_2\Delta\log H_{it}+\beta_3\Delta n_{it}+\mathcal{E}_{it} \quad (6)$$

Generally, there are two distinctive effects on the relationship between broadband infrastructure and economic growth as follows:

i. The increase in economic growth as the result of the increase in broadband infrastructure and services development which is our considered effect.

ii. The increase in the demand of broadband services resulting from the increase in economic growth.

Therefore, and in order to disentangle the effects and at the same time avoid the reverse causality and spurious correlation, an instrumental variable approach is used. In fact by employing the preexisting networks which can be used as fixed line broadband, a diffusion logistic cure of this technology will be determined and broadband penetration can be predicted. Next, by using the predicted penetration rates, we survey the effect of attained broadband penetration and introduction on economic growth.

Since broadband standards are usually based on coper wire in telephone network and coaxial cable in television network, we can use them for determination of broadband diffusion curve ceiling in any country. In this regard, we consider differences between preexisting infrastructures. However due to absence of television cable in many developing countries and also lack of its data for other developing countries which have this facility, we just put emphasis on telephone networks, and therefore, preexisting telephone networks are considered as an instrument for fixed line broadband development. The model used in our paper is based on Czernich et al. (2009).

The logistic curve below, which is the same as what Comin et al. (2006); Griliches (1957); Czernich and et al. (2009) and many others have employed, describes extensive margin for the dissemination of a new technology.

$$B_{it}= (\gamma_i/(1+\exp(-\beta(t- \tau))))+\mathcal{E}_{it} \tag{7}$$

Where “B” is a technology diffusion which here is broadband penetration and “t” is time. ”β” refers to adoption speed and “τ” shows inflexion point in diffusion process.

Previous works have recognized the product of "β" and "τ" as a constant of integration. Finally "γ_i" is the ceiling of considered technology, equals the limit of "B" for "t" going to infinity and is determined by preexisting telephone network (telephone network in a year prior to first broadband introduction).

$$\gamma_{it}= \gamma_0 + \gamma_1 \, tel_{i0} \qquad (8)$$

So by entering equation (8) into equation (7), we will have:

$$B_{it}= \left((\gamma_0+ \gamma_1 \, tel_{i0})/(1+\exp(-\beta(t- \tau))) \right)+\varepsilon_{it} \qquad (9)$$

Using this curve broadband penetration is predicted. Roller & Waverman (2001) addressed that “spurious correlation problem may arise because regional specific infrastructure investments might be correlated with other growth promoting measures like R&D investments, investments in human capital, and taxes." In line with this statement, and for controlling these correlations, we allow for country specific fixed effects in our model.

4. Data

In this study we used Orbicom in order to determine cross sections (2005) and applied countries classification based on digital divide. We chose countries that most resemble Iran, considering info-density and info-use of communication and information technology and consequently digital divide.

In previous studies which had been generally relevant to developed countries, one percent of broadband penetration was always used as the introduction measure. However, since the rate of broadband penetration is very low in developing countries, we considered the year that each country gained 0.1 percent of broadband penetration as its introduction year (measure I). Using this measure, 46 countries including Iran have attained this measure. We put them in group "A" (see Table 1). Then we changed the measure and considered the year that every country gained 1 percent of broadband penetration as its introduction year (measure II) and grouped them in "B" consisting of 31 countries (see Table 2).

Table 1: List of countries in group A and their broadband introduction year (Based on measure I)

group A (based on measure I)					
Row	country name	introduction year	Row	country name	introduction year
1	Albania	2007	24	Lebanon	2002
2	Algeria	2004	25	Malaysia	2003
3	Armenia	2007	26	Mauritania	2007
4	Belize	2003	27	Mexico	2002
5	Bolivia	2004	28	Moldova	2005
6	Botswana	2006	29	Mongolia	2006
7	Brazil	2001	30	Morocco	2004
8	Bulgaria	2005	31	Nicaragua	2005
9	China	2002	32	Panama	2000
10	Colombia	2003	33	Paraguay	2006
11	Costa Rica	2002	34	Philippines	2004
12	Ecuador	2005	35	Romania	2003
13	Egypt, Arab Rep.	2004	36	Russian Federation	2003
14	El Salvador	2003	37	Saudi Arabia	2002
15	Gabon	2005	38	South Africa	2004
16	Georgia	2006	39	Sri Lanka	2004
17	Guatemala	2005	40	Thailand	2004
18	India	2005	41	Trinidad and Tobago	2004
19	Indonesia	2007	42	Tunisia	2005
20	Iran, Islamic Rep.	2006	43	Turkey	2003
21	Jamaica	2001	44	Ukraine	2005
22	Jordan	2003	45	Venezuela, RB	2001
23	Kyrgyz Republic	2008	46	Vietnam	2005

Note: Countries that most resemble Iran based on digital divide, are taken from Orbicom (2005) and then by using data on broadband penetration from ITU (2009) and also mentioning measure of accessibility to the 0.1% of broadband penetration, 46 countries given above are classified in group A and the first year that every country reaches measure I is considered as its broadband introduction year.

Table 2: List of countries in group B and their broadband introduction year (based on measure II)

group B(based on measure II)					
Row	country name	introduction year	Row	country name	introduction year
1	Albania	2008	17	Mongolia	2008
2	Algeria	2008	18	Morocco	2006
3	Belize	2004	19	Panama	2006
4	Brazil	2004	20	Paraguay	2008
5	Bulgaria	2005	21	Philippines	2008
6	China	2004	22	Romania	2005
7	Colombia	2006	23	Russian Federation	2005
8	Costa Rica	2005	24	Saudi Arabia	2007
9	Ecuador	2008	25	Thailand	2007
10	El Salvador	2006	26	Trinidad and Tobago	2006
11	Georgia	2007	27	Tunisia	2008
12	Jamaica	2004	28	Turkey	2005
13	Jordan	2007	29	Ukraine	2006
14	Malaysia	2004	30	Venezuela, RB	2005
15	Mexico	2004	31	Vietnam	2007
16	Moldova	2007			

Note: Countries that most resemble Iran based on digital divide, are taken from Orbicom(2005) and then by using data on broadband penetration from ITU(2009) and also mentioning measure of accessibility to the 1% of broadband penetration, 31 countries given above are classified in group B and the first year that every country reaches measure II is considered as its broadband introduction year.

Since 2000 is the first year in our overall observations that broadband has reached an introduction measure, time period have begun from 1999 i.e. one year before the first broadband introduction. Based on the above explanations, the applied model is presented as follows(equations 4, 6 and 9):

$$\text{Log } y_{it}=\alpha+\alpha_1 D_{it}+\beta_1 \log S_{it}+\beta_2 \log H_{it}+\beta_3 n_{it}+\varepsilon_{it}$$

$$\Delta \log y_{it}=\alpha+\alpha_1 B_{it}+\beta_1 \Delta \log S_{it}+\beta_2 \Delta \log H_{it}+\beta_3 \Delta n_{it}+\varepsilon_{it}$$

$$B_{it}= ((\gamma_0+\gamma_1 \, tel_{i0})/(1+\exp(-\beta(t- \tau))))+\varepsilon_{it}$$

"Y" is gross domestic production per capita (constant 2000 US$), that changes of its logarithm represent economic growth rate (Δlogy).

"D" is a dummy variable for broadband introduction which after introducing broadband in a country equals one and thus "α" shows the effect of broadband introduction on "GDP" per capita.

"S" is gross fixed capital formation percent of "GDP" which demonstrates physical capital stock.

"H" is the ratio of secondary school pupils to population which is indicative of human capital stock.

"n" is the growth rate of working aged population, at the age of "15" to "64".

"B" is broadband penetration that is measured by broadband subscribers per 100 inhabitants i.e. its extensive margin.

Finally, for demonstrating extent of traditional telecommunication networks (tel_{i0}), number of fixed telephone lines per 100 inhabitants in the year before first broadband introduction (1999) is used. The data for "n" , "S" , "Y" and population are obtained from "WDI" (2010), "tel" and "B" data are derived from "ITU" (2009) and finally "H" data (secondary school pupils) are extracted from "Euromonitor".

5. Model Results

5.1. Diffusion Curve Estimation (the first stage)

The results of estimating technology diffusion logistic model (equation 9) using nonlinear least square (NLS), are presented in “Table 3” (for group "A" countries) and “Table 4” (for group "B" countries).

Table 3: The diffusion curve of group A countries

B: dependent variable	Estimate
Tel-net	0.4195504***
	(7.53)
B	0.7899878***
	(8.22)
T	2007.058***
	(5002.73)
γ0	-0.4770734
	(-1.10)
R2	0.7484
F-test	56.7009

Notes: First stage of instrumental variable model is a nonlinear least square estimation for 46 countries in group A during 1999-2008. It is noteworthy that the saturation level is country-specific but inflexion point and diffusion speed are not different across countries.

*10% significance (t-statistics), **5% significance, ***1% significance.

Table 4: The diffusion curve of group B countries

B: dependent variable	Estimate
Tel-net	0.4061792*** (7.14)
B	0.8125015*** (8.49)
T	2007.126*** (4728.78)
γ0	0.4620398 (0.61)
R2	0.8078
F-test	50.9796

Notes: First stage of instrumental variable model is a nonlinear least square estimation for 31 countries in group B during 1999-2008. It is noteworthy that the saturation level is country-specific but inflexion point and diffusion speed are not different across countries.

*10% significance (t-statistics), **5% significance, ***1% significance.

According to the results of both samples (group "A" and group "B") telephone network size has a positive and significant effect on saturation level of broadband diffusion curve. Actually based on the F-test, null hypothesis of telephone network coefficient equal to zero is rejected.

“Fig. 1”, “Fig. 2” and “Fig. 3”, “Fig. 4” illustrate actual and predicted broadband diffusion curves for both studied groups. As it is shown, the employed logistic shape is approximately fits the process of broadband dissemination across countries.

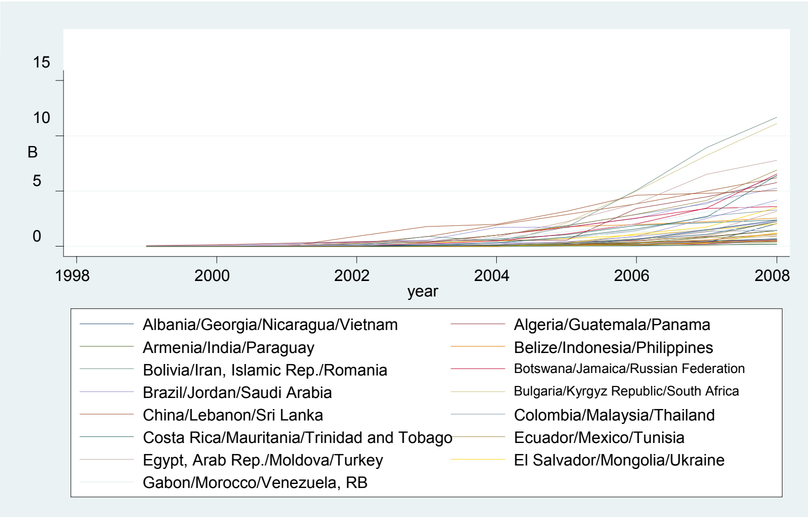

Figure 1: Broadband diffusion in group A countries: Actual curves

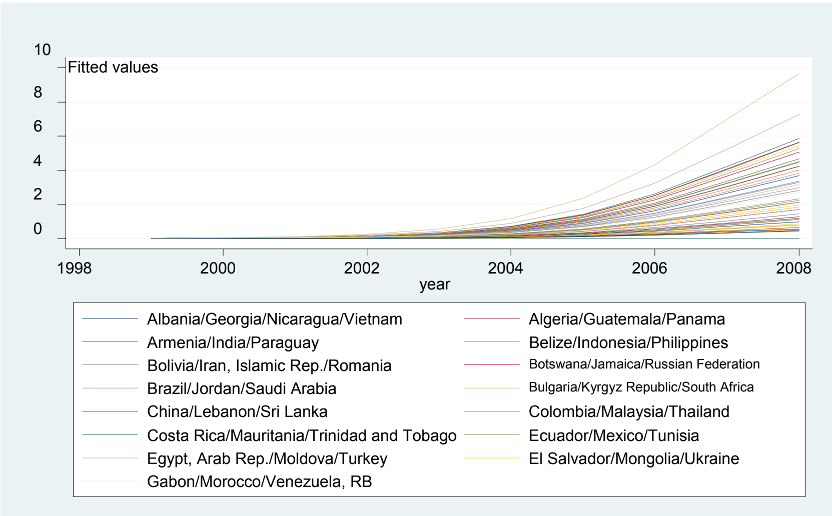

Figure 2. Broadband diffusion in group A countries: Predicted curves

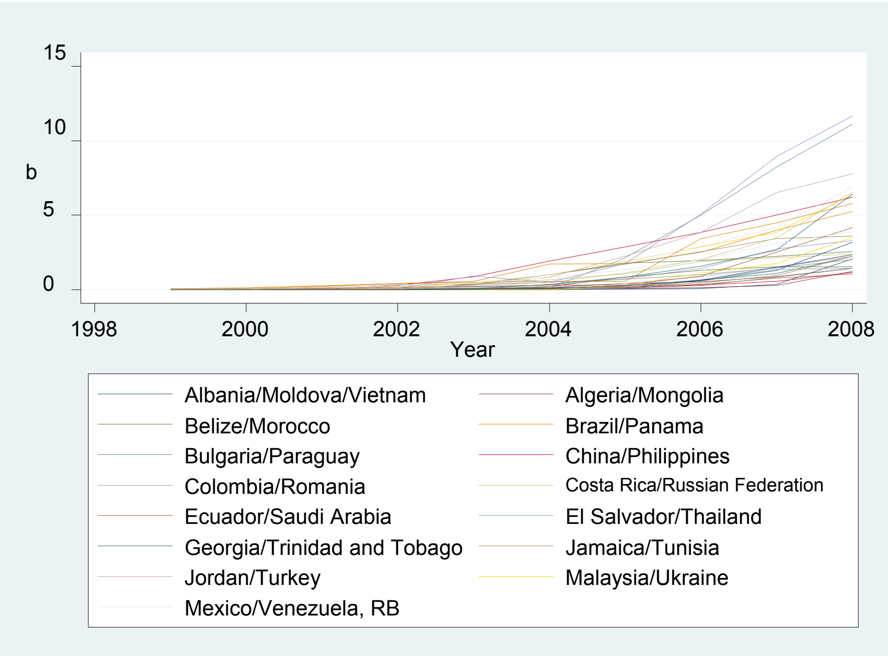

Figure 3. Broadband diffusion in group B countries: Actual curves

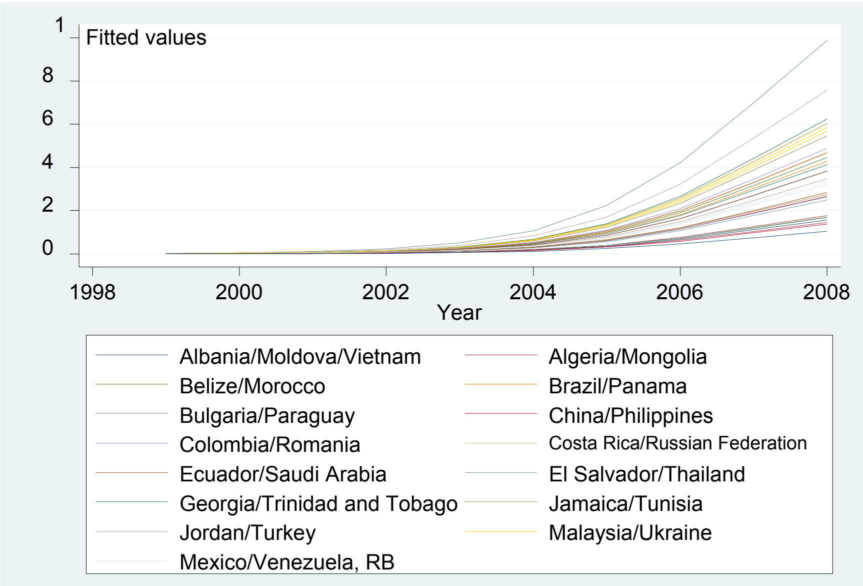

Figure 4. Broadband diffusion in group B countries: Predicted curves

5.2. The second stage of estimation

5.2.1. Estimating the broadband introduction effect on GDP per capita

Using the results of first stage estimation and predicted broadband penetration rates, we obtained two dummy variables; for group "A" after achieving 0.1 percent of predicted broadband penetration (measure I), variable "D1" is equal to one and before that, it is zero. For group "B" after achieving one percent of predicted broadband penetration (measure II), variable "D2" equals one and before that is zero. Then, given these dummy variables, we estimated equation 4. The results are shown in two Tables ("Table 5" for group "A" and "Table 6" for group "B").

Table 5: The effect of broadband introduction on GDP per capita for group A countries

log(y): dependent variable	Estimate
D	0.02279***
	(6.09)
log(s)	0.063119***
	(5.86)
log(h)	0.001989
	(0.10)
N	-0.011915**
	(-2.58)
(log(y))(-1)	0.928239***
	(58.41)
Constant	0.391473***
	(3.71)
R2	0.999205
F-test	8695.023
chi2(breusch and pagan test)	1365.87

Notes: Second stage of instrumental variable model for 46 countries in group A during 1999-2008. The year of broadband introduction in every country is predicted by using the results of first stage diffusion curve, referring to the year that each country in this group reaches measure I.

*10% significance (t-statistics), **5% significance, ***1% significance.

Table 6: The effect of broadband introduction on GDP per capita for group B countries

log(y): dependent variable	Estimate
D	0.117618*** (9.58)
log(s)	0.246526*** (4.78)
log(h)	0.144227 (0.67)
N	-0.069667** (-2.36)
Constant	6.130096*** (4.70)
R2	0.993845
F-test	655.3434
chi2(breusch and pagan test)	298.28

Notes: Second stage of instrumental variable model for 31 countries in group B during 2003-2008[1]. The year of broadband introduction in every country is predicted by using the results of first stage diffusion curve, referring to the year that each country in this group reaches measure II.

*10% significance (t-statistics), **5% significance, ***1% significance.

The results show that coefficient of D in both groups is positive and significant at one percent level. As it can be seen after broadband introduction with the measure I in group "A", considering fixed effects, GDP per capita has increased 2.27 percent and in group "B" with the measure II, it has risen by 11.76 percent.

In both groups, physical capital has positive and significant coefficient, too. However, the effect of investing in human capital on GDP per capita is not significant in both groups. This result is in accordance with the results of some other investigations, such as Pohjola (2001, 2002). The reason may be explained by the fact that in developing countries which do not have an appropriate competition environment and enough physical capital, the effect of investing in human capital is not evident. At last, the growth of population at working age in both groups has a negative and significant effect on GDP per capita.

5.2.2. Estimating the broadband penetration effect on economic growth

Now with estimating equation 6, based on a standard growth regression and with considering fixed effects, we present the effect of broadband penetration on economic growth in both groups. As it is shown in "Table 7" and "Table 8", broadband dissemination has a positive and significant effect on GDP per capita for both groups; a 10 percent increase in broadband penetration rate will increase annual per capita growth rate 0.019 percent in group "A" and 0.014 percent in group "B".

Table 7: The effect of broadband diffusion on economic growth for group A countries

$\Delta\log(y)$: dependent variable	Estimate
B	0.001904**
	(2.59)
$\Delta\log(s)$	0.056571***
	(5.64)
$\Delta\log(h)$	-0.020439
	(-0.71)
Δn	-0.003768
	(-1.25)
Constant	0.035387***
	(33.10)
R2	0.655803
F-test	13.69442
chi2(breusch and pagan test)	134.93

Notes: Second stage of instrumental variable model for 46 countries in group A during 1999-2008. Predicted penetration rates are obtained from first stage diffusion curve.

*10% significance (t-statistics), **5% significance, ***1% significance.

Table 8: The effect of broadband diffusion on economic growth for group B countries

$\Delta\log(y)$: dependent variable	Estimate
B	0.001461**
	(2.11)
$\Delta\log(s)$	0.069654***
	(5.42)
$\Delta\log(h)$	-0.002172
	(-0.43)
Δn	-0.002962
	(-0.89)
Constant	0.038000***
	(30.01)
R2	0.639386
F-test	12.41132
chi2(breusch and pagan test)	81.52

Notes: Second stage of instrumental variable model for 31 countries in group B during 1999-2008. Predicted penetration rates are obtained from first stage diffusion curve.

*10% significance (t-statistics), **5% significance, ***1% significance.

It is notable that, because broadband was propounded at the beginning of 2000, our results show medium-term effects. A better comprehension of broadband effect on important economic elements will be achieved, only if we have access to a longer sample period. The results obtained in this study provide a general framework of potential long-run effect of broadband infrastructure.

6. Broadband infrastructure critical mass

Sometimes studying the communication infrastructure is referred to as studying the network effects. Broadband expansion has positive network externalities and thus has more effects than only infrastructure effect itself. These effects include many applications that broadband makes them possible and also include participating majority of population that affect gained value from network and determines an important stage of its evolution. Network externalities may imply the nonlinearity of broadband infrastructure effect on growth. In other words, whenever a special network size is attained, there might be a dramatic growth effect that is not like the previous proportion of broadband penetration to gained growth impact.

This issue has attracted a lot of attention in previous studies. For example, one study by Roller and Waverman (2001), was performed for 21 OECD countries with average penetration rate of 30 percent to assess the effect of telecommunication infrastructure on economic growth and its results indicated the existence of critical mass at a penetration rate of approximately 24%. Also by investigating 14 developing countries, they observed that those countries average penetration rate was 4% which is extremely less than critical level.

Another study by Koutroumpis (2009) investigated broadband penetration effect on the economic growth of 22 OECD countries and concluded that there is a positive and significant causal relationship especially when a critical mass of infrastructure in the 30% threshold of broadband penetration rate is present.

In the present study, broadband penetration rates of our studied countries are higher than 10% for only two cases and the rest of them are well lower. Given “Table 9” and “Table 10”, in both groups highest actual penetration rate is 11.6 percent and highest predicted penetration rate is almost 10 percent. According to “Table 9”, in group "A" average actual broadband penetration rate and average predicted broadband penetration rate are less than 1 percent and according to “Table 10” for group "B" they are just a little more than "1" percent. So, only with about 1 percent penetration rate and without longer sample period, it is impossible to analyze the amount of network critical mass in these countries and we postpone it to upcoming investigations in the future.

Table 9: Summary statistics of actual and predicted penetration rate variables for group A countries

Variables	Observation	Mean	Minimum	Maximum
actual broadband penetration rate	460	0.7640587	0	11.66
predicted broadband penetration rate	460	0.7625629	0	9.686477

Table 10: Summary statistics of actual and predicted penetration rate variables for group B countries

Variables	Observation	Mean	Minimum	Maximum
actual broadband penetration rate	310	1.006281	0	11.66
predicted broadband penetration rate	310	1.003075	0.0021201	9.893462

7. Conclusion

In this paper we investigated the special causal effect of broadband infrastructure on economic growth in selected developing countries. There may be a two-way causation between broadband and economic growth. To solve the reverse causality problem, an instrumental variable approach was used.

Broadband expansion has positive network externalities and thus has more effects than only infrastructure effect itself that has been shown in studies of OECD countries. In this paper the concentration was on developing countries. We used Orbicom (2005) and applied countries classification based on digital divide. We chose countries that most resemble Iran and we found that only with about 1 percent penetration rate and without longer sample period, it is impossible to analyze the amount of network critical mass in these countries. However, even with these low rates, the results showed the importance of broadband.

The results indicated that the introduction of broadband has a significant positive effect on GDP per capita. Actually, in group "A" after achieving 0.1 percent of broadband penetration, GDP per capita has increased 2.27 percent and in group B with the measure II (achieving 1 percent of broadband penetration), GDP per capita has been 11.76 percent higher than before the introduction.

In addition, the subsequent dissemination also affects the economic growth significantly and positively. We found that a 10 percent increase in broadband penetration rate increases the GDP growth rate 0.014 to 0.019 percent. So, economic growth in developing countries will be increased by:

1- Achieving a critical mass through the expansion of investment in ICT and therefore broadband.

2-Encouraging research and development in the field of ICT adoption.

Endnote

1- 2000 is the first year in our overall observations that broadband has reached a measure of broadband introduction. Then, time period has begun from 1999 i.e. one year prior to first introduction. But since the first year, that one of the countries in group B has achieved measure II (1%) is 2004, so here for estimating the effect of broadband introduction by this measure (1%), time period is confined to 2003-2008.

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