A panel data analysis of temporary and permanent effects of fixed broadband penetration over economic growth

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Abstract

This article presents an econometric analysis for the effects of fixed broadband penetration on the growth rate of GDP per capita for a panel of 35 developed and developing countries over an annual period of 33 years (1981 - 2013). The article contributes to the telecommunications literature by distinguishing between temporary and permanent impacts of fixed broadband penetration on economic growth. Our methodology consists of two models, the first one is a fixed effects panel data model which is used as a benchmark, and it controls for contemporaneous and one-period lagged effects of the penetration variable on economic growth. The possibility of an endogeneity issue due to reverse causality is addressed by considering a two-stage instrumental variables (IV) fixed effects model. In a first stage we instrument the fixed broadband penetration variable with fixed telephony subscribers and the internet users, both of them for every 100 inhabitants. Then, in a second stage we use the generated fitted values in a panel regression to determine the impact over the growth rate of GDP per capita. Our approach includes as an explanatory variable the Standard and Poor's 500 real index to control for the business cycle of the global economy. Furthermore, we consider the growth rate of countries' population between the ages 15 to 64, as a proxy for the growth rate of workforce. Also, the differences in countries' population size are taken into account by applying analytic weights. Finally, we verify the existence of a positive and statistically signiffcant temporal and permanent effect of fixed broadband penetration variable over economic growth.

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Keywords: Fixed Broadband Penetration; Economic Growth; Panel Data Fixed Effects; Instrumental Variables; Temporal and Permanent Effects.

JEL Classifications C23 C26 O47

1. Introduction

The information and telecommunications technologies (ICT) have evolved to play a critical role on the development of the global information economy (Crandall, 2007) and for the diffusion of knowledge (Mokyr, 2000). Specifically, the fixed broadband as a wide bandwith data transmitter is considered a key component of the knowledge economy (Lee and Brown, 2008). This is because of its capability of carrying integrated traffic consisting of voice, video and data. Also, it has accelerated the diffusion of ideas and it has made geographical distances insignificant. We use World Bank data[2] to estimate a panel data fixed effects regression in order to capture the temporal and permanent effects resulting from an increase in fixed broadband penetration over the growth rate of GDP per capita. Furthermore, we develop an instrumental variables (IV) approach in order to address the possible endogeneity problems due to reverse causality in our model. Also, we specify two more versions of the IV fixed effects model, the first one by using a subsample time, and the second just considering the high income countries of our sample. We find that the temporal, or one-time, effect at the year of broadband introduction is a relevant factor for economic growth, while the permanent effect is smaller though positive and stable. The paper is organized as follows. Section 2 presents a literature review of broadband penetration and economic growth. Section 3 describes our sample and variables used. Section 4 presents the methodology. Section 5 estimates the model. And finally in section 6 we conclude.

[2] http://data.worldbank.org/

2. Literature Review

The effects of fixed broadband penetration over economic growth have been studied by numerous authors throughout the last years. The relevance of fixed broadband consists on its ability to spread knowledge -for instance, from research centers to companies and individuals- which magnifies its effects over time after its creation. The diffusion of knowledge has chiefly been considered as a trigger of economic growth through the development of a telecommunications infrastructure. Thus, broadband is mainly considered as a catalyst for the development of markets or industrial sectors relying on information and data as inputs. In current times a prerequisite for the access to knowledge is the existence of an adequate infraestructure of general telecommunications networks, and specifically of fixed broadband. Following the pioneers of endogenous economic growth theory (Barro, 1990; Mankiw, Romer and Weil, 1992; Romer, 1989, 1990) some authors have assessed the impact of broadband penetration on the average growth rate of GDP per capita (Qiang, Rossotto and Kimura, 2009; Scott, 2012). Quiang et al. (2009) analyze this association for the 1980 to 2006 period distinguishing between developed and developing countries, and finding that a 10% increase in the number of broadband subscribers in developed countries results in a 1.21% increase in the growth rate of GDP per capita. According to the authors, a 10% increase in the number of subscribers in developing countries results in a growth of 1.38% in the growth rate of GDP per capita. A similar analysis is conducted by Scott (2012) who analyzes a richer dataset, obtaining smaller results than the ones of the previous authors. His results establish that a 10% increase in broadband penetration would result in an expansión of 1.35% of the growth rate of GDP per capita for developing countries, and of 1.19% for developed countries.

Another research line is the study of the effect of broadband penetration over economic development. Kolko (2010) analyzed the association among public policies designed to increment broadband disposal and economic development. By using United States' data the author finds a positive correlation between broadband penetration and employment, and even a stronger association for technology intensive industries. Katz (2009) assesses the economic impact of broadband technology in terms of job creation and development in Latin America. Based on a broadband gap estimation for 2008 of 11 millions lines for the region, the author estimates that the impact on employment resulting for addressing that gap would result in 378,000 new jobs. Katz et al. (2010) estimate the impact of broadband infraestructure investments on the German economy based on two government's programs (the National Broadband Strategy and the ultra-broadband evolution, 2015-2020), particularly on employment and output. The results indicate that a total investment of 36 billion euros would generate 968,000 new jobs, allocated into 541,000 jobs necessary for the construction of the broadband network and 427,000 jobs derived from externalities as new business creation. Moreover, both effects would approximately generate a total of 170.9 billion euros of additional GDP.

Some other authors are skeptical about the measures of the effects of broadband penetration over economic growth. Holt and Jamison (2009) note that an economic analysis should consider the fact that broadband usually replaces other communication technologies, such as dial-up modems. In a counterfactual scenario where dial-up connnectivity is not replaced by broadband technology the contribution of the previous ICT to economic growth would keep to be significant (Greenstein and McDevitt, 2009). Arvin and Pradhan (2014) use a multivariate framework instead of the traditional bivariate framework in order to find Granger causality relationships between broadband penetration, degree of urbanization, foreign direct investment (FDI) and economic growth for a data set of G-20 countries. The authors find a short-run bidirectional causality between broadband penetration and economic growth in the presence of FDI and urbanization exclusively for developed countries within G-20. On the other hand, for the rest of the countries of the group the authors find a one directional way causal relationship: economic growth leads to broadband penetration. Bojnec and Fert (2012) analize the effects of broadband availability on economic growth by using a cross-country panel data for 34 OECD nations over the years 1998 - 2009: Their study uses three different broadband availability related variables: standard access lines per 100 inhabitants, access channels per 100 inhabitants and total broadband per 100 inhabitants. They do not find a positive and statistically significant impact of total broadband per 100 inhabitants on the real growth rate of GDP per capita, while the most relevant and significant variable is the access channels per 100 inhabitants.

Other authors as Dimelis and Papaioannous (2011) present a comparison of the effects of ICTs over different industries and decades for the US and EU by applying a generalized method of moments approach. The authors find that the ICT effect is positive but not statistically significant for the $1980's$ decade. On the other hand, during the $1990's$ the impact increased significantly reflecting a positive association with output growth. However that effect was effectively realized on the second half of the decade, reflecting that a time learning period is necessary to effectively exploit the investment in telecommunications technology. Furthermore, some concerns among authors are the reverse causality and the spurious correlation problems which may be present in the relationship between the growth rate of GDP per capita and broadband penetration. In that respect some authors as Czernich et al. (2009) use an instrumental variable (IV) approach by suggesting that the penetration of an underlying technology infraestructure network as the extension of traditional fixed telephone and TV-cable network have influence on the deployment of fixed broadband. The authors use a panel data of 25 OECD nations for 1996 to 2007 period, concluding that an increase in broadband penetration would promote an annual growth rate in a range of 0.9% to 1.5% in GDP per capita. Other authors as Koutroumpis (2009) use a simultaneous equations model that endogenizes broadband investment and incorporates three equations: demand, supply and output. The result establishes that the coefficient of the broadband penetration variable is positive and statistically significant implying that a 10% increase in accessibility to this technology would result in an increase of 0.38% in economic growth when fixed effects are not specified, and 0.26% when they are specified. On the other hand, Atif et al. (2012) compare the results obtained from a static fixed effects model and a dynamic linear model for a panel data of 31 OECD nations for 1998 to 2010. The authors use a basic macroeconomic model for GDP as a function of capital stock and labour using a Cobb-Douglas function. They conclude that an increase of 10% in broadband penetration would result in an increase of 0.035% of the growth rate of per capita GDP.

3. Data

In this paper we use an annual panel of 35 developed and developing countries for a period of 33 years (1981 - 2013): The countries are: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Greece, Indonesia, India, Ireland, Iceland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, Norway, New Zealand, Peru, Portugal, Spain, Sweden, Switzerland, Turkey, United Kindgdom and the United States. The regressors we use are: fixed broadband penetration per 100 people, gross capital formation to GDP, total government expenditure on education to GDP, mobile cellular subscriptions per 100 people, research and development expenditure to GDP, growth rate of population ages 15 - 64. The data are taken from World Bank's World Development Indicators catalog. The Standard & Poor's 500 index is deflated by using US consumer price index (CPI). According to its definition, the fixed broadband technology is the one that offers a high speed access to the public internet. While, the downstream speeds must be equal to, or greater than, 256 kbits. In this regard, it includes cable modem, DSL, fiber-to-the-home/building and other fixed broadband subscriptions.

4. Model Framework

Our approach considers the temporary and permanent effects of fixed broadband penetration over the growth rate of GDP per capita. The main purpose is to individually assess each effect over economic growth. In this regard, the importance of lasting effects lies on the fact that the impact of broadband penetration over economic growth occurs over time rather than all at once. The model is the following:

$$GDPpc_{it} = \alpha_i + \beta_1 K_{it} + \beta_2 H_{it} + \beta_3 FB_{it} + \beta_4 FB_{it-1} + \beta_5 Mob_{it} + \beta_6 RD_{it} + \beta_7 RD_{it-1} + \beta_8 n_{it} + \beta_9 S\&P_t + u_{it} \quad (1)$$

Where $GDPpc_{it}$ means the real growth rate of GDP per capita in country i at time t; K_{it} is the gross capital formation to GDP; H_{it} is total government expenditure on education to GDP; FB_{it} and FB_{it-1} represent contemporaneous and one-period lagged fixed broadband penetration per 100 inhabitants, respectively; Mob_{it} is the mobile cellular subscriptions per 100 inhabitants; RD_{it} and RD_{it-1} stand for the contemporaneous and one-period lagged research and development expenditure to GDP; n_{it} is the growth rate of population ages 15 - 64 years and $S\&P_t$ is the Standard & Poor's 500 deflated index. The investment on ICTs has been significant since the middle of the $1980's$ and through the beginning of the XXI century (OECD, 2009), just before the sinking of the Nasdaq index generated by the dot-com bubble collapse in 2001. Furthermore, since the $1960's$ and $1970's$ the ICT has represented a leading movement of progress and technical innovation through computerization and information technology, and it has triggered a long wave of economic development (Bernard et al., 2013). Then, the inclusion of $S\&P_t$ variable in our model controls for the business cycle of the global economy. Finally, n_{it} represents a proxy for the annual growth rate of workforce.

On the other hand, the variance of the error term in (1) associated with countries with large population might be larger than for error terms associated with countries with small population. For instance, the growth rate of population ages 15 - 64 or the mobile penetration per 100 inhabitants in countries with large population might be more volatile than for countries with small population. Then, giving equal weight to all observations generates biased standard errors when heteroskedasticity is present. This in turn leads to a bias in test statistics and confidence intervals. In order to solve the heteroskedasticity problem we apply an analytic weight to transform the dependent and independent variables. In this case, we have the model (1) where the variance of u_i is thought to be proportional to the weight a_i. Then, it is assumed to be proportional to αa_i, where α is a positive constant. Gould (1999) details the alpha as the average value of the inverse of a_i; i.e. α=$\Sigma_k(1 = a_k) = N$. Thus, the $Var(u_i) = k\alpha a_i \sigma^2$, where k represents a constant of proportionality which is not a function of the scale of weights. If we divide (1) by the $\sqrt{a_i}$ we obtain $Var\left(u_i/\sqrt{a_i}\right) = k\alpha\sigma^2$, which represents the constant part of the variance of the error term, $Var(u_i)$.

The estimated model considered is a panel data fixed effects model. The reason is that fixed effects models provide a means for controlling for omitted variable bias. For instance, the deployment of a telecommunications network in a particular country is directly related with the country's size in square miles or kilometers. In this regard, we expect that the effects of the omitted variables are time-invariant. Additionally, an important complication in empirically studying the impact of fixed broadband on economic growth is the potential of endogeneity bias as a result of reverse causality. It is a critical issue since fixed broadband penetration could be a function of economic growth. We address this problem by performing an instrumental variables (IV) approach. In this respect, broadband technologies as the asymmetric digital subscriber line (ADSL) base its data transmissions over copper telephone lines. Also, the digital subscriber line (DSL) uses existing telephone wiring, known as the plain old telephone system. The DSL system represents the 42% of global broadband customers and it still dominates in Europe and the rest of the world (Frenzel, 2013). Then, we can assume that the extension of the fixed telephony copper network is a necessary infraestructure for the deployment of fixed broadband. Then, we use the number of subscribers to fixed telephony per 100 inhabitants as an instrument. Furthermore, a necessary condition to have access to a more advanced technology as fixed broadband is the internet accessibility, then we consider the internet users per 100 inhabitants as another determinant for fixed broadband penetration. Thus, in a first stage we regress fixed broadband penetration on fixed telephony penetration and internet penetration.

$$FB_{it} = \beta_0 + \beta_1 FTel_{it} + \beta_2 Int_{it} + e_{it} \tag{2.1}$$

In equation (2.1) the variables $FTel_{it}$ and Int_{it} stand for the number of subscribers to fixed telephony per 100 inhabitants and internet users per 100 inhabitants, respectively. The generated fitted values are used in a second stage panel data fixed effects model.

$$GDPpc_{it} = \alpha_i + \beta_1 K_{it} + \beta_2 H_{it} + \beta_3 FB^{IV}{}_{it} + \beta_4 FB_{it-1} + \beta_5 Mob_{it} + \beta_6 RD_{it} + \beta_7 RD_{it-1} + \beta_8 n_{it} + \beta_9 S\&P_t + u_{it} \tag{2.2}$$

Where $FB^{IV}{}_{it}$ represents the fixed broadband penetration fitted values. Moreover, in (2.2) we utilize a deterministic one-period lagged fixed broadband penetration variable, FB_{it-1} .

5. Results

Table 1 shows model (1) panel regression estimates for the determination of the growth rate of GDP per capita as a function of broadband penetration and the rest explanatory variables. Contemporaneous fixed broadband penetration has a statistically significant positive effect on economic growth. Hence, a 10 percent increase in fixed broadband penetration increases annual per-capita GDP growth by 3.07 percentage points. Besides, the one-period lagged fixed broadband penetration has a negative effect on the growth rate of GDP per capita significant at a 99% confidence level. The permanent effect of fixed broadband penetration over economic growth is calculated by subtracting the one-period lagged coefficient from the contemporaneous coefficient, i.e. (0.307 – 0.306) = 0.001. That means that an increase on fixed broadband penetration will have a yearly permanent effect over economic growth equal to 0.01 percentage points. Furthermore, the temporal, or one-time, effect at the time of technology introduction, when $t = 0$, is calculated as the difference between the contemporaneous effect and the permanent effect, i.e. $\beta_3 - (\beta_3 + \beta_4) = -\beta_4 = -(-0.306) = 0.306$. Thus, at the year of fixed broadband introduction, the one-time effect will be positive and statistically significant.

Regarding the coefficients of the other explanatory variables, we have that physical capital accumulation as a proportion of GDP (K_{it}) is positive and statistically significant at a 99% confidence level. While the total government expenses on education (H_{it}) is not statistically significant. On the other hand, in the technology life cycle theory (Bayus, 1998) it is stated that the technology development timeline implies a recovery time period for initial costs and investments. In this regard, the one-period lagged research and development coefficient has a positive and statistically significant effect over economic growth. While the contemporaneous coefficient has a negative and statistically significant effect at a 99% confidence level. As regards the coefficient of the growth rate of population ages 15 - 64 (n_{it}) it has a negative and statistically significant effect over economic growth. Lastly, another telecommunications indicator, the mobile cellular subscriptors per 100 inhabitants (Mob_{it}) shows no significant impact.

Table 1. Panel data fixed effects results

Variables	**Fixed Effects**
α_i	-8.527** (3.777)
K_{it}	0.355*** (0.0656)
H_{it}	-0.137 (0.538)
FB_{it}	0.307** (0.131)
FB_{it-1}	-0.306*** (0.116)
Mob_{it}	-0.0132 (0.0156)
RD_{it}	-8.645*** (2.821)
RD_{it-1}	9.854*** (2.817)
n_{it}	-1.827*** (0.545)
$S\&P_t$	0.749*** (0.177)
Observations	319
R^2	0.728

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

We now turn to the two-stage instrumental variables analysis (equation 2.2) which results are reported in Table 2. The third column shows the results when we control for time fixed effects. In the second column we observe that the instrumented contemporaneous fixed broadband penetration effect is slightly shorter than in the first model. Then, a 10 percentage points rise in broadband diffusion increases economic growth in 1.88 percentage points. Furthermore, the one-period lagged fixed broadband penetration coefficient is negative and statistically significant at a 95% confidence level. In this regard, the fixed broadband permanent effect resultant from the difference between contemporaneous and one-period lagged coefficients is 0.088. This result is larger than the obtained in the non-instrumental variable model. On the other hand, the temporal effect is 0.100. In the case of the time fixed effects model (third column, Table 2) the contemporaneous and one-period lagged fixed broadband penetration coefficients are not statistically significant.

Futher, the impact of gross capital formation to GDP is positive and statistically significant at a 99% confidence level (second column, Table 2). As in the first model, the one-period lagged research and development investment coefficient is positive and statistically significance, while the contemporaneous coefficient has a negative impact over the growth rate of GDP per capita. In the time fixed effects model (third column, Table 2) the RD_{it} coefficient is not statistically significant. Standard & Poor's 500 real index shows a direct relation with economic growth; i.e. an upward movement in economic cycle positively affects the growth rate of GDP per capita. As in first model the growth rate of population ages 15 - 64 is negative and statistically significant.

Table 2. Panel Data IV Fixed Effects Results

Variables	(1) FE-IV	(2) FE-IV
α_i	-9.929** (4.006)	88.91 (118.3)
K_{it}	0.375*** (0.0690)	0.341*** (0.115)
H_{it}	-0.196 (0.536)	-0.418 (0.469)
${FB_{it}}^{IV}$	0.188** (0.0787)	0.0691 (0.0876)
FB_{it-1}	-0.100** (0.0414)	-0.0514 (0.0726)
Mob_{it}	-0.0199 (0.0173)	0.00529 (0.0206)
RD_{it}	-8.762*** (2.831)	-4.745 (3.090)
RD_{it-1}	9.509*** (2.839)	6.597** (2.851)
n_{it}	-1.557*** (0.529)	-1.925** (0.834)
$S\&P_t$	0.780*** (0.180)	-15.51 (20.02)
Observations	321	321
R^2	0.731	0.803
Year FE	NO	YES
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

In Table 3 we consider two versions of model (2.2), the first one using a subsample time, while the second targets in high income countries. In this regard, the first deployment of fixed broadband in any country of the sample was in Canada in 1998. Hence, the subsample period starts on that year. Then, for the subsample time specification we can identify positive and significant effects of the contemporaneous instrumented fixed broadband penetration variable on the growth rate of GDP per capita. The result is larger than in the previous specification, while the standard error is smaller. The effect is not statistically significant when just considering high income countries (see third column, Table 3). The one-period lagged fixed broadband penetration coefficient is negative and statistically significant for both model versions. Again, the permanent effect of the subsample time model version is larger than in the non-instrumental variable model of Table 1 (0.086). Same story in the case of the temporal effect (0.106) with respect to IV fixed effects model with complete time sample.

Table 3. Panel Data IV Fixed Effects Results

Variables	**(1) FE-IV (1998-2013)**	**(2) FE-IV (HIC)***
α_i	-7.883 (4.958)	-13.95* (8.068)
K_{it}	0.341*** (0.0833)	0.495** (0.205)
H_{it}	-0.430 (0.586)	-0.462 (0.643)
${FB_{it}}^{IV}$	0.192** (0.0783)	0.120 (0.0792)
FB_{it-1}	-0.106** (0.0415)	-0.0849* (0.0443)
Mob_{it}	-0.0173	-0.00969 (0.0164)

	(0.0168)	
RD_{it}	-8.316*** (2.778)	-7.940*** (3.021)
RD_{it-1}	8.841*** (2.777)	9.232*** (2.856)
n_{it}	-1.475*** (0.531)	-2.088** (0.947)
$S\&P_t$	0.751*** (0.186)	0.758*** (0.147)
Observations	320	246
R^2	0.732	0.495
Year FE	NO	NO
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

* High Income Countries

6. Conclusions

This article proposes a panel data fixed effects model to estimate the temporal and permanent effects of an increase in fixed broadband penetration over the growth rate of GDP per capita. In contrast to other researches we consider a larger time span which includes economic turning points as the information technology bubble during 1999 - 2001 period and the global financial crisis of 2007 – 2008. In this regard, we consider the Standard & Poor's 500 deflated index as explanatory variable to control for the economic business cycle. Futhermore, in order to address possible endogeneity problems due to reverse causality we specify an IV fixed effects model by instrumenting the fixed broadband penetration with fixed telephony subscribers per 100 people and the number of internet users for every 100 inhabitants. Our results suggest that at the year of broadband introduction or deployment, there is a strong one-time stimulus on economic growth. In the first model, the contemporeanous fixed broadband penetration has a positive and statistically significant effect on the growth rate of GDP per capita. Also, the permanent effect is positive and significant (0.001). On the other hand, for the two model versions of our second approach the permanent effect has a positive impact over economic growth. It is larger when considering the complete time sample. Still, the temporal effect has a positive impact at the year of the technology introduction. The overall result indicates that fixed broadband penetration is a significant factor in the determination of the growth rate of GDP per capita for our sample of 35 developed and developing countries. Then, we consider that it is important to separately analyze the one-time and permanent effects of broadband penetration. Furthermore, we consider that government's policies should advocate for the difussion and deployment of fixed broadband.

Like any research, the findings of this article should be viewed in the light of its limitations. For instance, the suggestion that there exists an immediate positive effect after a discrete growth in broadband penetration could be influenced by the fact that at this point of time there already exists a prior knowledge to comprehend the utilization of the technology in most countries, specially in developed ones. In other words, there is a general belief that broadband adoption has a positive association with productivity, performance and satisfaction (Hill et al, 2014). However, if it would be the case that a completely new telecommunications technology could arrive, it would take a time window to observe the benefits from its investment and introduction for the well-being of the general population.

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