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30 June 2012

Online at https://mpra.ub.uni-muenchen.de/42177/
MPRA Paper No. 42177, posted 25 Oct 2012 08:57 UTC

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A Panel Data Analysis of OECD Countries

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ABSTRACT

Broadband infrastructure facilitates the generation and distribution of decentralised information and ideas in a knowledge economy comprising of markets that rely on information as an input. This paper analyses the effect of broadband penetration on output per capita by estimating a static fixed effects model and a basic linear dynamic model using an annual panel of 31 OECD countries over a period from 1998 to 2010. The results suggest that broadband penetration has had a positive impact on economic growth, and a 10 percent increase in the growth of broadband penetration will raise economic growth per employee by approximately 0.035 percentage points. The conclusion adds further weight to calls for Governments to adopt policies that accelerate broadband penetration and promote investment in broadband infrastructure.

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1 Introduction

High-speed internet access via broadband infrastructure has developed rapidly in the last decade and is increasingly viewed as essential infrastructure for a globally competitive economy (OECD (2008)). Broadband infrastructure facilitates the generation and distribution of decentralised information and ideas in a knowledge economy comprising of markets that rely on information as an input (Czernich et.al (2011)). Accordingly endogenous growth theory suggests that broadband infrastructure should accelerate economic growth by facilitating the development and adoption of innovation processes.

This paper seeks to analyses the effect of broadband penetration on output per capita by estimating both a static fixed effects model as well as a basic linear dynamic model using an annual panel of 31 countries over a period from 1998 to 2010. Consistent with endogenous growth theory we expect that both estimators will indicate a strong causal relationship between broadband penetration and economic growth.

The remainder of this paper is organised as follows. Section 2 briefly summarises the existing literature dealing with the relationship between broadband and economic growth. Section 3 introduces the empirical framework and the derivation of both the fixed effects and the linear dynamic models. Section 4 presents the data and some summary statistics. Section 5 presents and compares the empirical results of the estimation methods. Section 6 concludes and proposes some policy implications from the study

2 Literature on Broadband and Economic Growth

Economic growth is driven by many factors, including product, process and organisational innovations based on technological change and the generation and distribution of ideas and information. Technological change results from small incremental improvements over time. However, a few technological improvements fundamentally change how and where economic activity is organised. These are often referred to as general-purpose technologies (GPTs) and are commonly thought to include the printing press, steam engines, combustion engines and electricity (Majumdar (2009), OECD (2008), Czernich et.al (2011)).

According to the Organisation for Economic Cooperation and Development (OECD (2008)) broadband is a GPT that when combined with other information communication technologies (ICTs) can fundamentally change how and where economic activity is organised. This change is effected through several channels. Direct impacts arise from investments in the

infrastructure itself and associated ICTs. Indirect impacts come from all aspects of economic activity affected by broadband and which drive economic growth (Collins et.al. (2007)).
Several studies have examined how firm level productivity is impacted by broadband (See Holt and Jamison (2009) for an extensive review of this literature). A key theme of this literature is that broadband enables the emergence of new business models, processes and innovation. This in turn reduces costs, increases productivity and improves firm efficiency. A study by The Allen Consulting Group (2002) reports findings from a survey of Australian businesses on the cost savings derived from using broadband Internet. The survey results indicate that businesses experienced cost savings of around 6.3 per cent from the use of broadband internet compared to 1.5 per cent from the use of dial up internet. The study claims that the reported average cost savings would result in an overall productivity gain of around 0.32 per cent for Australian businesses. These findings are consistent with a more recent survey by the Australian Industry Group (2008) reported that over 93 per cent of the firms surveyed indicated that broadband had a positive impact on their productivity and efficiency.

A 2011 study by Grimes, Ren and Stevens (2011) uses a panel of 6060 New Zealand firms to determine the impact that differing types of internet access have on firm productivity. The data sourced from two surveys conducted by Statistics New Zealand allows the authors to control for a range of firm characteristics including those factors that may determine a firm's choice of internet access. Two estimation approaches are used: propensity score matching (PSM) and an instrumental variables (IV) estimator. Results from PSM indicate that productivity rises by 6.9 to 9.7 percent as a result of broadband connectivity. These effects are consistent across different types of firms with no significant differences across an urban versus rural split or across high versus low knowledge industries. The IV estimation results indicate even higher productivity impacts from broadband adoption. Specifically, that broadband adoption increases firm productivity by between 21 and 25 percent. Although the IV estimation results are significantly higher than those obtained from PSM the authors favour the PSM estimates because they lack of specific knowledge about the correct functional specification in relation to a firm's labour productivity relative to its sector and therefore have low confidence in the IV estimation results.

In addition to those studies that look at the impact of broadband on firm level productivity, there is a growing body of literature that examines the association between broadband and macroeconomic level indicators such as economic growth and employment. Czernich et.al (2011) uses an instrumental variable model to estimate the effect of broadband infrastructure on economic growth in a panel of 25 OECD countries. The authors conclude that the introduction and diffusion of broadband had an important impact on GDP growth in those countries included in the panel. After a country had introduced broadband per capita GDP was on average 2.7 and 3.9 per cent higher than before its introduction, controlling for country and year fixed effects. In terms of subsequent impacts the authors found that a 10 percent point increase in broadband penetration raised annual per-capita growth by between 0.9 and 1.5 percentage points.

A study by Lehr et.al (2006) analysed the impacts of broadband penetration on employment growth, wages, rents, business growth and industry structure at the community (zipcode), industry and state levels. The results indicate that the broadband take-up enhances economic activity with significant effects on job growth and business growth, particularly for larger business and business in IT intensive sectors. The study found that broadband take-up had no significant impact on wages but that there was a significant association between broadband take-up and residential property values.

Using data from 120 developed and developing countries Qiang and Rossotto (2009) employ the Barro cross-sectional endogenous growth model to analyse the impact that broadband has had on long-term economic growth rates over the period 1980 to 2006. The results from this empirical analysis suggest a robust and noticeable growth dividend from broadband access in developed countries. Specifically, all else being equal, a 10 per cent increase in broadband penetration in a developed country would yield a 1.21 percent increase in economic growth. For developing countries it was found that, all else being equal, a 10 percent increase in broadband penetration would yield an increase in economic growth of 1.38 percent.

A study by Koutroupis (2009) employs a macroeconomic production function with a microeconomic model for broadband investment to estimate how investment in broadband infrastructure impacted economic growth in 22 OECD countries over the period 2002-2007. The results suggest that there is a strong causal link between broadband and economic growth. The findings also suggest that there are increasing returns to investments in broadband infrastructure and that countries with broadband penetration rates of more than 30 per cent enjoy higher returns from broadband investments relative to those countries with lower broadband penetration rates

Finally a widely cited econometric study by Crandall, Lehr and Litan (2007) estimates the effects of broadband penetration on economic output and employment, in aggregate and by industry sector for 48 States of the United States over the period 2003-2005. The study finds that non-farm employment in several industries is positively associated with broadband use. More specifically, for every one per cent increase in broadband penetration in a State, employment is increased by 0.2 to 0.3 per cent per year. At a more disaggregated level the study finds that employment in both manufacturing and service industries (especially finance, education and health care) is positively related to broadband penetration. The study also concludes that State output of goods and services is also positively associated with broadband use.

3 Methodology

The basic framework of methodology is to estimate parameters based on panel data for defined variables for all 31member countries under of the OECD using a static (Fixed Effects Estimator) and a dynamic model (Basic Linear Dynamic Model).

Starting with the basic macroeconomic model, where output is the function of capital stock in the economy and per unit effective labor (Romer (2006))

$$Y_{it} = F(K_{it}, AL_{it}) \quad (1)$$

where Y_{it}, K_{it} and AL_{it} are the output, capital and effective labor of country *i* at time *t*.

The Cobb-Douglas formation of the above functional form is given as:

$$Y_{it} = {K_{it}}^{\alpha} (AL_{it})^{1-\alpha} \quad (2)$$

The log-form of model in equation (2) is given as:

$$lnY_{it} = \alpha. lnK_{it} + (1-\alpha). lnA_{it} + (1-\alpha). lnL_{it} + u_{it} \quad (3)$$

where A_{it} is the technological state of a country *i* at time *t*. Furthermore, the stochastic error term u_{it} is defined as:

$$u_{it} = \gamma_i + \varepsilon_{it} \quad (4)$$

where γ_i is the country-specific time-invariant effect and ε_{it} is the non-stochastic error term with zero mean and constant variance. Therefore, based on (3), and (4), we can rewrite (3) as:

$$lnY_{it} = \alpha. lnK_{it} + (1-\alpha). lnA_{it} + (1-\alpha). lnL_{it} + \gamma_i + \varepsilon_{it} \quad (5)$$

The technology term *A* can be divided into non-communications technology and communications technology, which can then be divided into broadband and telephony technology:

$$lnA_{it} = lnF_{it} + ln\theta_{it} +. lnB_{it} \quad (6)$$

where B_{it} is the penetration of broadband technology in country i at time t, T represents non-communication technology and θ_{it} represents fixed-line technology other than broadband. This leaves us with:

$$lnY_{it} = \alpha.lnK_{it} + (1-\alpha).(lnF_{it} + ln\theta_{it} + lnB_{it}) + (1-\alpha).lnL_{it} + \gamma_i + \varepsilon_{it} \quad (7).$$

Given (7) and assuming $y_{it} = lnY_{it}, k_{it} = lnK_{it}, l_{it} = lnL_{it}, f = lnF, \theta = ln\theta \ and \ b = lnB$ and $\beta = 1 - \alpha$, and the final output model for our problem is given as:

$$\boldsymbol{y_{it} = \beta.f_{it} + \beta.\theta_{it} + \beta.b_{it} + \alpha.k_{it} + \beta.l_{it} + \gamma_i + \varepsilon_{it}} \qquad (8)$$

where y is given by GDP per worker, l is controlled for by measuring y in terms of labour, k is given by gross capital formation, θ_1 is broadband subscribers per 100, θ_0 is fixed-telephone subscriptions, and the proxy for f is given by proportion of the labour force with tertiary education.

3.1 Fixed Effects Model:

The Fixed Effects model for the output function given in equation (8), is derived by time demeaning the variables, and subtracting them from the original model. The final model for Fixed Effects Estimators is given in (10):

$$\boldsymbol{y_{it} - \bar{y}_i = \beta.(f_{it} - \bar{f}_i) + \beta.(\theta_{it} - \bar{\theta}_i) + \beta.(b_{it} - \bar{b}_i) + \alpha.(k_{it} - \bar{k}_i) + \beta.(l_{it} - \bar{l}_i) + (\varepsilon_{it} - \bar{\varepsilon}_i)} \qquad (9)$$

where the country-specific time-invariant effect (γ_i) has been eliminated from the model, to increase the precision and consistency of the model.

3.2 Basic Linear Dynamic Model:

The fundamental assumption of a dynamic model is that a regressor impacts the regressand with a lapse of time. Therefore, apart from the functional regressors, the dynamic model also includes lagged value of the regressand as the regressor in the model.

Accordingly, the Basic Linear Dynamic model for output function given in equation (8), is given by equation (11):

$$\boldsymbol{y_{it} = \lambda y_{it-1} + \beta.f_{it} + \beta.\theta_{it} + \beta.b_{it} + \alpha.k_{it} + \beta.l_{it} + \gamma_i + \varepsilon_{it}} \qquad (10)$$

By estimating the models in (9) and (10), we can examine the impact of broadband penetration on GDP (Y_{it}) for the panel of countries under consideration, and later on compare the results for both static and dynamic models of panel data analysis.

4 Data

Broadband penetration is measured as the total number of broadband subscribers per 100 inhabitants and is sourced from the OECD Communication Outlook 2011 (OECD (2011)). A broadband connection is defined as a fixed communications service providing connection to the internet at speeds above 256 kilobits per second (kbps). This definition typically captures broadband connections provided using digital subscriber line (DSL), cable modem, fibre and some fixed wireless (such as satellite and WIMAX) technologies but excludes mobile broadband technologies (such a 3G).

Other data sourced from the OECD includes:

- Total fixed telephone subscriptions per 100 inhabitants. This is used as a proxy for the availability of broadband infrastructure[1].
- Tertiary education attainment as a proportion of the population aged 25 to 64. This is used to control for different productivity levels between workforces.

The remaining data is sourced from the World Bank Development Indicators (2012). This data includes gross capital formation as a percentage of GDP. Gross capital formation consists of outlays on additions to the fixed assets[2] of the economy plus net changes in the level of inventories. Importantly, this measure includes both public and private sector outlays on capital assets, which is appropriate given that in many OECD member counties Government accounts for a significant share of outlays on fixed assets and public infrastructure.

The dependent variable is real GDP expressed in 1990 purchasing power parity (PPP) and normalised by persons employed. This controls for various demographics difference among countries.

Table 1 gives descriptive statistics for the countries in our sample:

[1] To date the provision of fixed broadband services has been largely dependant on the availability of legacy copper telephony and cable TV networks.

[2] Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.

	GDP Per Worker		% With Broadband		Total Communications Access		Gross Fixed Capital Formation		% Labour with Tertiary Education	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
AUS	48018.31	1625.17	10.92	10.56	48.60	4.74	26.64	1.87	31.45	3.20
AUT	45674.54	1920.33	11.39	8.81	45.21	4.39	23.07	1.20	16.77	2.77
BEL	53351.54	1778.41	15.05	11.48	46.72	2.23	21.31	1.44	34.48	2.61
CAN	47829.46	1349.13	17.04	10.77	60.54	6.48	21.14	1.45	43.19	3.21
CZE	21602.00	2665.39	7.19	8.38	30.80	5.67	26.68	2.37	13.48	2.01
DNK	45367.46	1637.69	19.31	15.52	61.81	8.72	20.56	1.80	28.78	2.96
EST	36610.00	6973.95	11.42	10.42	35.41	1.78	30.11	6.24	32.25	2.28
FIN	47664.77	2996.51	15.15	12.73	42.85	11.70	20.42	1.39	32.98	2.50
FRA	52943.23	1826.00	13.11	12.51	56.51	0.71	19.68	1.24	27.09	2.99
DEU	42012.69	1296.29	12.72	12.21	62.14	3.91	19.06	1.94	24.11	1.23
GRC	32858.23	2622.89	5.13	7.33	51.75	4.24	23.19	2.97	22.41	3.04
HUN	19362.46	2255.38	7.04	7.73	33.42	2.65	23.95	2.95	18.99	2.65
ISL	41851.62	3611.87	17.87	13.96	64.66	3.04	22.79	6.11	23.98	3.72
IRL	52732.31	4037.40	8.13	9.41	48.64	2.60	22.44	4.77	30.06	5.29
ITA	46171.69	836.63	9.16	8.55	43.09	4.80	20.82	0.83	13.82	2.26
JPN	42214.23	2377.01	13.72	10.54	44.32	5.96	23.48	1.76	37.92	3.44
KOR	37322.54	4520.85	22.70	12.03	52.90	3.54	29.10	1.67	30.76	5.89

	GDP Per Worker		% With Broadband		Total Communications Access		Gross Fixed Capital Formation		% Labour with Tertiary Education	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LUX	54456.77	1714.73	13.26	13.59	54.91	1.96	21.63	2.08	25.84	6.88
MEX	19166.00	664.39	2.78	3.45	15.75	2.75	23.97	1.83	20.38	6.24
NLD	44773.23	1833.98	18.89	15.27	49.83	6.44	20.34	1.51	27.48	3.39
NZL	35041.77	865.21	9.15	9.72	44.17	2.38	22.14	1.75	31.52	4.96
NOR	50448.69	2053.47	16.31	14.43	46.42	6.82	22.00	2.65	32.42	2.11
POL	22239.54	2843.64	4.38	5.08	27.47	4.24	21.80	2.53	17.61	5.11
PRT	29187.15	1032.46	8.38	7.40	40.66	1.03	24.51	3.02	12.31	2.65
SVK	26294.54	4393.41	4.03	5.08	24.83	3.33	27.12	3.31	13.42	2.63
ESP	39425.54	857.72	9.72	8.82	43.36	1.57	27.03	2.64	29.46	2.76
SWE	46511.92	3354.50	17.29	12.67	62.64	5.15	18.10	1.18	28.48	2.28
CHE	40635.92	1263.57	17.39	14.83	68.49	5.37	21.60	1.36	27.11	3.83
TUR	23726.31	4205.43	3.10	3.82	26.81	2.29	19.37	2.45	11.83	2.54
GBR	49624.77	2542.20	13.16	12.64	56.86	1.71	17.08	1.15	29.26	3.40
USA	62090.00	3759.13	13.49	10.24	59.57	6.90	18.57	2.03	54.41	14.45

5 Results and Analysis

Based on the methodology devised in previous section, the results were estimated using computer package STATA (Statistics/Data Analysis) Version 11.0. Following sections discuss all relevant results and their significance for the study.

5.1 Stationarity of Series

The Levin-Lin-Chu test for stationarity of panel data series, assuming null hypothesis of unit root in the series, exhibits that natural-log form of variables GDP per person employed (lgdp), gross capital formation (lgfc) and broadband internet subscribers (lbb) are stationary at level, however the labor force with tertiary education and total fixed telephone subscriptions per 100 inhabitants (*ltca*) are non-stationary at level. The results for Levin-Lin-Chu test are explained in table-2

'tledu' and *'tltca*' in column-VII and –VIII of the above table are stationary counterparts of *ledu* and *ltca* respectively, de-trended by using moving average technique of data smoothing. Levin-Lin-Chu test shows that both these series stationary at level, with 1 percent level of significance.

5.2 Estimation

The data contains observations for a panel of 31 OECD countries across four cross sections for each country (N=31, K=4), spanning over a time period of 1998 to 2010 inclusive (T=13, i.e. T<N). The fact that T<N, waives off the possibility of using static modelling techniques such as Random Coefficients, Linear Restrictions, Seemingly Unrelated Regression, and Mean Group Estimator, hence the possible techniques under static models comprise of Random Effects and Fixed Effects estimators.

However, we have tried to estimate the coefficients using various estimation techniques and the best technique has been selected through rational argumentation relevant to properties of different models. Table-3 shows estimation results based on techniques such as Pooled Ordinary Least Square (P-OLS), Fixed Effects (FE) model, Random Effects (RE) model, Random Coefficients Model, Basic Linear Dynamic model with one lag, and the Dynamic model with two-periods lagged instrumental variable as the explanatory variable.

Table-4 shows results for different hypothesis tests performed to examine the significance of time-invariant country-specific effect across each cross section, and in relation to other explanatory variables.

The null hypothesis of identical country-specific effects (i.e. $\alpha_1 = \alpha_2 \ldots = \alpha_N$) under the F-test introduced for FE model is rejected at 1 percent level of significance, meaning thereby that individual specific effects are not the same across different countries for the given set of data. The conclusion from this is that Pooled OLS is less efficient than the FE estimator.

Likewise, the null hypothesis of homogeneous country-specific effects (i.e $\sigma_\alpha = 0$) under the Breusch-Pagan test introduced for RE model, is also rejected at 1% level of significance, and hence the country-specific effect is heterogeneous over different countries. However, the Breusch-Pagan test 'can suffer from serious size distortion when N/T is not small" (Halunga et al., 2011). Thus the small T of our sample may invalidate the results of the Breusch-Pagan test.

The final test used was the Hausman test for effectiveness of RE model, with null hypothesis of no correlation between country-specific effects (i.e. $Cov(\alpha_i|X_{Kit}) = 0$) is rejected at 1 percent level of significance (Table-4). Hence, individual effects are uncorrelated with explanatory variables, meaning the RE model is not the best-fit static model based on the data, and that FE is preferred over RE.

Moving from static to dynamic modelling, Table-3 gives the estimates of basic linear dynamic model, first by using one-period lagged GDP per person employed, and secondly by using two-period lagged variable as an explanatory variable. However, the results for estimated dynamic models demonstrate an insignificant second-period lagged explanatory variable at 5 percent level of significance, further suggesting that one-period lag is appropriate model under the Akaike Information Criteria.

Hence, based on the above inferences, the fixed effects estimator is considered as the primary static estimator, and single-period lagged variable as the dynamic estimator for the study under consideration.

Table-2

	y_{it}	B_{it}	k_{it}	e^{lit}=$ledu$	e^{Tit}=$ltca$	l_{it}	T_{it}=$tltca$
Test Statistic	-5.8302	-5.2034	-2.4022	-0.6198	4.6205	-10.8029	-6.6802
p-value	0.0000	0.0000	0.0081	0.2677	1.000	0.0000	0.0000
Conclusion*	Reject H_0	Reject H_0	Reject H_0	Accept H_0	Accept H_0	Reject H_0	Reject H_0
Remarks	Stationary	Stationary	Stationary	Non-stationary	Non-stationary	Stationary	Stationary

* assuming 5 percent level of significance

Table-3

	Pooled OLS	FE	RE	Random Coefficients	Dynamic (1-lag)	Dynamic (2-lag)
b_{it}	0.0238 (.0047) * (0.0000) ^	0.0153 (.0018) (0.0000)	0.0145 (.0018) (0.0000)	0.0109 (.0036) (0.003)	0.0035 (.0009) (0.0000)	0.0053 (.0013) (0.0000)
k_{it}	-0.1561 (.0558) (0.0050)	0.0724 (.0235) (0.0020)	0.7571 (.0243) (0.0020)	0.1329 (.0246) (0.0000)	0.0035 (.0096) (0.0000)	0.0661 (.0102) (0.000)
l_{it}	0.2985 (.0312) (0.0000)	0.2124 (.0391) (0.0000)	0.2857 (.0363) (0.0000)	0.3601 (.1293) (0.005)	0.063 (.0236) (0.008)	0.0548 (.0238) (0.021)
T_{it}	0.4809 (.0339) (0.0000)	-0.0379 (.0375) (0.3120)+	0.0524 (.0351) (0.1360)+	-0.0111 (.108) (0.918)+	0.0271 (.021) (0.196)+	0.0415 (.0209) (0.047)

* Standard error ^ p-value + insignificant at 5% level of significance

Table-4

Test	Null Hypothesis	Test Statistic	Computed Value	p-value	Conclusion*	Remarks
F-Test for FE	$\alpha_1 = \alpha_2 \ldots = \alpha_N$	$F = \frac{(RSS_R - RSS_U)/(N-1)}{RSS_U/(NT-N-K)} \sim F[(N-1),(NT-N-K)]$	152.47	0.000	Reject H_0	No country-specific effect
Breusch Pagan Test for RE	$\sigma_\alpha = 0$	$L = \frac{NT}{2(T-1)}\left[\frac{\sum_i(T.e_{OLS,i})^2}{\sum_i\sum_t e^2_{OLS,it}} - 1\right]^2 \sim \chi^2$	1418.16	0.000	Reject H_0	No country-specific effect
Hausman Test for RE	$Cov(\alpha_i \mid X_{Kit}) = 0$	$H = \frac{(\hat{\beta}_{FE} - \hat{\beta}_{RE})^2}{(\hat{\beta}_{FE}) - var(\hat{\beta}_{RE})} \sim \chi^2$	24.63	0.001	Reject H_0	FE is preferred over RE

* assuming 5 percent level of significance

The Fixed Effects estimator exhibits a positive and significant correlation between growth rate of broadband and the GDP per person employed, i.e. given a 10 percent increase in the growth of broadband internet subscribers (per 100 inhabitants), on average, the growth rate in GDP per person employed grows by 0.15 percent, holding all else constant. Likewise, it shows a positive relationship between growth rate of gross capital formation, labor force with tertiary education and total fixed telephone subscriptions per 100 inhabitants. However, the coefficient for *tltca* is insignificant at 5 percent level of significance, which reduces the precision of this variable as an effective explanatory variable.

Similarly, the Basic Linear Dynamic model with single period lagged variable also illustrates a significant positive relationship between growth in broadband penetration and GDP per person employed. According to the coefficient of *lbb*, given a 10 percent increase in broadband internet subscribers per 100 inhabitants, the growth rate in GDP on average increases by 0.035 percent, holding all else constant. Other variables have a similar effect on growth rate of GDP as the fixed effects model, and *tltca* is again insignificant under dynamic model.

The fact that total fixed telephone subscriptions per 100 inhabitants (being used as a proxy for availability of broadband infrastructure) is insignificant in both static and dynamic models, may suggest it is not a good proxy for broadband infrastructure. The intuition for this is clear, as not all phone subscribers want a broadband connection, and there may be a large portion who never opt for broadband. However, we are not prepared to say that availability of telephone line cannot mark the ceiling of available broadband connections.

6 Conclusions

In this paper, we analysed the effects of broadband penetration on economic growth over a 13 year period. Based on annual data for a panel of OECD countries, and using both a static and dynamic estimation approach, we find that broadband penetration has had a positive impact on economic growth. Our empirical results suggest that a 10 percent increase in the growth of broadband penetration will raise economic growth per employee by approximately 0.035 percentage points.

These findings are robust to numerous tests and the inclusion of relevant control variables. The results of Hausman test and the significance of the lagged dependant variable in the linear dynamic model provides confidence that our approach isolated the causal effect of broadband penetration on economic growth.

Our findings are consistent with a growing body of literature, which identifies broadband a general purpose technology that is fundamentally changing how and where economic activity is organised. Our finding also adds further weight to calls for Governments to adopt policies that accelerate broadband penetration and promote investment in broadband infrastructure.

We conclude by discussing two important limitations of our study. First, our measure of broadband includes fixed broadband connections only and excludes broadband connectivity provided by mobile wireless networks. From a policy perspective this is an important limitation as wireless mobile networks have a lower cost to deploy relative to fixed networks. Furthermore, several studies (see Ovum (2005) and Kathuria et.al (2009)) indicate that that there is a mobility dividend associated with wireless mobile broadband services which may further impact economic growth. Second, while our study shows that over the last 13 years there has been a positive association between increases in broadband penetration and economic growth, our study is unable to say anything about the extent to which this association will continue or whether higher levels of broadband penetration will result in a long-term competitive advantage for an economy. Consideration of these letter issues are important when deciding what policy settings are appropriate to encourage increases in broadband penetration and investment in broadband infrastructure.

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