Internet usage and economic growth in Australia: An ARDL Bounds Testing Approach

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Abstract

This study explores the short- and the long-run effects of internet usage, financial development and trade openness on growth in Australia using annual data for the period 1985-2012. ARDL bounds test for cointegration and Granger causality test for causal link are applied. Results indicate that internet usage and financial development spur economic growth in the long-run. Trade openness has positive but insignificant long-run effect on growth. However, the short-run growth effects of all these variables are insignificant. Dynamic OLS (DOLS) estimation confirms the robustness of the long-run findings. The Granger causality test reveals that both internet usage and financial development granger-cause economic growth in Australia. Internet usage also granger causes financial development. The findings are supportive of the claim that internet is transforming Australian economy at a rapid pace while IT productivity decline can not be ignored. As such, the current implementation of the NBN roll out should be done more cautiously and the government should reframe the digital divide policy addressing its weaknesses so as to boost internet growth and productivity impacts on Australian economy.

Keywords: ARDL, Australia, DOLS, Economic growth, Granger causality, Internet usage

JEL Classifications:

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1. Introduction

The enormous spread of the internet in the last 20 years has drawn keen interest in research on its various economic consequences. The effects of internet on the economy span a wide range of areas from technological productivity to foreign direct investment, from inflation (Sassi and Goaeid, 2013) to political economy issues and from corruption to democratic freedom issues and shadow economy (Elgin, 2013).

The current study aims to empirically investigate the growth effect of internet, financial development and trade openness using the most recent (1985-2012) macro data for Australia. Australia is one of the very few advanced countries that survived the period of financial crisis in the 1990s. It was dubbed as a 'miraculous economy' (Krugman, 1998) because of its robust growth performance during the period.
Rapid expansion of IT usage has been identified as a major contributor towards this success in growth and productivity performance (Parhan, 2005a; Parhan et al., 2001).

From a broader perspective, the spread of internet usage is part of ICT revolution. Internet continues to transform the economy of Australia (Zhang, 2013; Bowles, 2012; Deloitte Access Economics, 2011). An overwhelming majority of Australians are now internet users (Ewing and Thomas, 2012). In 2011, 87% of Australians had used the internet up from 81% in 2009 and 73% in 2007. The vast majority of household connections are now broadband (96%) while the proportion of Australians accessing the net through a mobile device more than doubled between 2009 and 2011 from 15% to 37% (Ewing and Thomas, 2012).

Internet is likely to play even a greater role in daily lives and businesses (Deloitte Access Economics, 2012) in Australia. The direct contribution of the internet to the Australian economy is worth approximately $50 billion which is 3.6% of its GDP in 2011. More than 190,000 people are employed in occupation that are directly related to the internet. In 2011, there was a productivity increase of $27 billion due to internet use (Deloitte Access Economics, 2012). The internet is the catalyst for the success of Australian small and medium enterprises (SMEs) improving how they interact with their customers and suppliers and manage their internal operations. Despite all these fascinating numeric figures of the rapidly increasing use of internet, the growth performance of Australian economy during 2000s fell short of expectations and the role of IT capital to spur growth and productivity remains questionable. The growth rates in multifactor productivity plummeted on average from 1.7% during the 1990s to 0.4% in 2000s and to -1.3% in 2011 (ABS, 2012).

The slowdown of the growth in growth rates and productivity performance of Australian economy during 2000s reveals the fact that the growth and productivity achievements have not been without opportunity cost. The rapid expansion of internet usage has resulted in the creation of a kind of social inequality- popularly known as digital divide- a phenomenon that already proved to have the potential to undermine the growth and productivity achievements (Doongan and Ho, 2012). Recent literature confirms the presence of digital divide in Australia and claims that it is in the danger of widening (Charlson, 2013; Bowles, 2012; Bowles, 2011). Some other studies also emphasize the restricted role of internet on the economy. According to these studies (Shahiduzzaman and Alam, 2013; Ceccobelli et al., 2012), ICT is at best, a General Purpose Technology (GPT) and can maximally play the role of enabler which means the economy must invest adequately in the complimentary assets in order to reap the long-run benefits from ICT usage.

The widespread adoption of broadband (i.e. a form of high speed internet) has been linked with economic growth and social wellbeing (Dwivedi et al., 2009; Reede, 2011). The availability of high speed broadband for business and households is a well understood factor in any modern nation's efforts to stimulate growth (Bowles and Wilson, 2010). Australia is currently implementing the largest ever single broadband infrastructure project worth $43 billion, the National Broadband Network (NBN) project to build high speed broadband infrastructure across the nation over the next ten years in a bid to facilitate the digital delivery of government and public services including health and education as well as addressing the digital divide (DBCDE, 2011).
Against the reality of mounting importance of internet growth studies, there has been almost no or very little empirical research on the internet growth relationship in Australian context. Most of the previous causality analyses were limited to bivariate models that suffer from the omission bias (Shahiduzzaman and Alam, 2013). This study overcomes this limitation and is also expected to have a number of other contributions. First of all, it uses the most recent data (1985-2012) to analyze a multivariate model and to provide with a policy implications discussion that is more relevant to the current policy perspective of Australia especially in the context of the ongoing roll out of the NBN. It employs an alternative econometric technique that offsets the shortcoming of small sample bias arising from data limitation. The econometric technique applied in the study resolves endogeneity problem resulting from the spill-over and externality effects of internet usage ((Li, M., 2013; Zhao and Lu, 2012; Levendis and Lee, 2012; Tanya and Marcus, 2008).

Unlike previous Australian studies, the current study includes two important growth variables financial development and trade openness in the model (Shahbaz, 2013; Sassi and Goaied, 2013, Yartley, 2008). Finally, against the backdrop of the recent declining trend in the IT productivity (Shahiduzzaman and Alam, 2013), this study is an attempt to investigate (Deloitte Access Economics, 2012) whether internet expansion is still impacting the economic growth in Australia with alternative estimation methods.

The rest of the paper is structured as follows; Section 2 discusses literature review while section 3 is dedicated to data and methodology. Estimation results and a discussion are presented in section 4. The paper concludes with conclusions, policy implications and limitations in section 5.

2. Literature Review

2.1 Economic impacts of internet: empirical evidence

Despite the economic potentials of ICT, empirical studies on the effect of ICT on economic growth produced mixed results. Sassi and Goaied (2013) find positive and significant effect of ICT on economic growth using a panel data of the Middle Eastern and North African (MENA) countries. Also they find a positive effect of the interaction between ICT penetration and financial development on economic growth. Ceccobelli et al. (2012) use data for 14 OECD countries and confirm the role of ICT as a general purpose technology (GPT). By applying a non-parametric test, the study shows that the ICTs positively contribute to labor productivity. Vu (2011) finds positive relationship between ICT penetration and economic growth using a panel data set covering 102 countries over the period 1996-2005. Seu et al. (2009) also find positive effect of ICT on economic growth using data of 29 countries.

Using a panel data of 95 countries and 8 MENA countries over 1980-2001 period, Hassan (2005) was able to support the positive effect of ICT infrastructure on growth for 95 countries but failed to do so for MENA countries. Nour (2002) investigated the impact of ICT investment on growth in 7 MENA countries and find evidence of the expected positive effect of ICT investment on economic growth. Pahjola (2001) find a meaningful and positive effect of ICT on growth for a sample of 23 OECD countries. Kraemer (2000) use a sample of 36 countries over the period of 1985-1993 and find evidence for positive relationship between ICT and growth only for developed countries. Apart from the growth effect, the development in ICT has a substantial positive impact on various economic outcomes (Noh
and Yoo, 2008), productivity increase (Dewan and Riggins, 2005), inflation reduction (Choi and Yi, 2005) and higher volume of trade (Frehund and Weinhold, 2004).

Zhang (2013) develops the internet consumption model and conducts a cross-country empirical research examining the relationship between income, Gini index and the pattern of the internet diffusion curve. Findings indicate that the developed countries have steeper internet diffusion curves and shorter time lags than the developing countries. The GDP per capita had positive correlation with the slope of internet diffusion curve while Gini index had negative correlation. The divergence argument was strongly supported by the empirical analyses for the countries approaching the two extremes of the income spectrum.

Elgin (2013) examines the empirical relationship between the degree of internet usage and the size of the shadow economy using a panel data of 152 countries over 9 years from 1999 to 2007. The findings indicate that the association between internet usage and shadow economy size strongly interacts with GDP per capita. Goel et al. (2012) study the effect of the internet on corruption and their empirical analysis shows that with its news-disseminating capacity, the internet increases corruption awareness and therefore deters corruption.

Choi (2010) and Choi and Yi (2009) investigate the effects of internet usage on foreign direct investment, service trade, inflation and economic growth in various panels of countries and find evidence toward the existence of significant economic effects of the internet. Nande and Saayam (2005) show internet usage as one of the main determinants of tourist arrivals in Africa. Weinhold (2004) examine the relationship between internet usage and international trade and found that the internet stimulates trade. Colecchia and Schreyer (2001) analyze the level of diffusion and contribution of ICT in nine OECD countries and show that EU countries are still behind America in ICT diffusion and investment.

Despite the fact that most of the literature support positive impact of ICT on economic growth, skepticism is there about the exact extent of ICTs impact and its role in reshaping the economy. Gordon (2010) questions the extent of the ongoing economic impact of ICT stating that the problem of the ICT revolution is that it is increasingly burdened with the diminishing returns. There is also evidence of the ambiguous effect of ICT accumulation on economic growth. Some studies (Freeman and Soete, 1997; Aghion and Howitt, 1998) found that ICT had negative impact on employment and labor market in developing countries. The rapid accumulation of ICT eliminate unskilled workers and exclude poor people since they are not well furnished and qualified enough to take advantage of that resulting in increased poverty and inequalities.

Notwithstanding the increasing focus on the economic aspects of internet usage, the impact of the internet on various economic, political and social variables is still an under-investigated field of research (Elgin, 2013) and the literature dealing with the growth effect of internet, in particular, in Australian economy is very inadequate (Shahiduzzaman and Alam, 2013). Also to the best of our knowledge, no other study has ever attempted to examine the long run relationship between economic growth and internet usage in Australia despite internet’s ever-growing role to transform its economy. This study is expected to fill in this void. Nevertheless, the findings of such study are believed to help
policy makers better coordinate between the digital divide policies already being pursued and the growth policies in Australia and in other advanced countries.

2.2 Internet usage and digital divide in Australia

Most of the recent studies on internet usage and digital divide in Australia indicate that despite significant increase in the level of internet usage, digital divide resulting from various factors such as lack of tertiary education, age, affordability and ethnical diversity etc. still persists.

Rennie et al. (2013) in a recent study in some indigenous communities known as outstation finds the evidence that indigenous Australians living in remote Australia are unlikely to have access to the internet at home. They identified money including affordability, priority and demand sharing as the major perceived barrier. They further mentioned other barriers to internet use as limited English literacy, security of hardware and power supply. The study also recommends education, online services and entertainment space for the uptake of internet. Charleson (2012) argues that enhancing empowerment and social capital through internet network for those already burdened with disadvantage and marginalization could be a potential mean to narrow the current digital divide in Australia.

Bowles (2012) indicate that digital divide in Australia is in the danger of widening. The same author in another study (Bowles, 2011) identify income, education, age and ethnical diversity as the key reasons for the current digital divide in Australia. Lee (2011) in a recent study highlights the presence of digital divide resulting from inequity in the ability to use internet (the so called, second level digital divide) in Australia and focus on Australian government's programs and policies aimed to address digital divide. The study also focuses on the government facilitated educational and informational policies designed to reduce the knowledge digital divide. It recommends further educational measures to enhance peoples' ability to make use of available technology and reap the maximum benefits from the ongoing roll out of NBN.

Almost all earlier studies and reports of the Australian Bureau of Statistics indicated the presence of digital divide in Australia. Atkinson et al. (2008) while exploring digital divide in Albury, a regional city in Western Australia, found the presence of digital divide in relation to income and different city locations. The study also identifies age, education and income levels as the key factors that contribute to digital divide in the city. Tanya and Marcus (2008) discussed how network society thesis extends the information/knowledge society credo by providing a way to understand and value new forms of internet participation. They further argued that within the network society thesis social capital and social inclusion can be understood as two frameworks that can be used by policymakers to define the social benefits of internet participation and focused on funding and initiatives on ensuring that these benefits are strengthened and more equally dispersed.

Data from the Australian Bureau of Statistics (ABS, 2007) indicated that households with particular characteristics are less likely to be connected to a computer and/or the internet. These characteristics include; lower household incomes, number of children under 15 years of age and located whether in non-metropolitan or remote areas of Australia. Willis and Tranter (2006) assessed inequalities in internet use through analysis of national survey data of Australia over the period 1998-2003 and
explored persisting barriers to internet diffusion in Australia. They argued that although the internet has become more accessible to all social categories and further technological diffusion should widen this accessibility, household income, age, education and occupational class still remain the key dimensions for digital divide. Byrne et al. (2006) uses ABS data from Multipurpose Household Survey (MPHS) and found that similar percentage of men and women use internet indicating closure of the gender gap in Australia.

Feldman (2004) found that poor English language skills affect internet usage. He argued that those with English language background are more likely to find internet use easy than those without, as the internet features and software are mostly available in English. Riley (2004) found that females in Australia use the internet less often than their male counterparts. This finding was supported by an ABS report later (ABS, 2007) which confirmed that 53 percent of Australian males use the internet as against 47% female internet users. Gibson (2003) in a study warned that despite increase in computer usage and internet access, digital divide was not decreasing in Australia until the time of the study. He identified a number of factors as contributing to the digital divide in Australia such as, income, education, age, location, disability, opinion, gender and culture. Curtin (2001) suggested that the level of education is a key factor in predicting internet access in Australia. Keller (1995) indicated that education and income are the most likely determinants of society's access to internet.

An Australian government study (Department of Communication, 2003) highlighted the issues of the digital divide for the first time mentioning the lack of research and evaluation of perceived gaps in the digital divide and of funded initiatives attempting to address this issue. Despite this disappointment from the government long ago regarding research on this crucial issue, this area is still largely untapped.

From the above review (1995-2013), it can be summarized that internet use is increasing significantly while digital divide still persists in Australia. The key factors contributing towards the current digital disparity in Australia are income, education, age, ethnical diversity, gender and language background.

2.3 Digital divide policies in Australia: a brief overview

The first significant national digital divide policy intervention in Australia was announced by the Coalition government in 1996. Networking the Nation (NTN) was aspired to enhance telecommunications infrastructure and services; increase access to, and promote use of services available through telecommunications network and reduce disparities in access to such services and facilities. However, this initiative was dubbed as an inadequate response to the Australian digital divide that did not operate from an information need assessment (Van Vuuren, 2007).

The NTN was followed by the 2004 Co-ordinated communication infrastructure fund to encourage health, education and other sectors of public interest to maximize opportunities for improved broadband access and services in rural, regional and remote Australia. In addition, two other initiatives: Communications Fund for future-proof telecommunications services in rural, regional and remote Australia and Connect Australia to roll out broadband to people living in regional, rural and remote areas, extend mobile phone coverage, build new regional communications networks and set up telecommunications services for remote Indigenous communities (Coonan, 2005). Two more initiatives
were taken to address the infrastructure needs of the indigenous communities: The 2002 Telecommunications action plan for remote indigenous communities and the 2006 Backing Indigenous ability to redress low level of telecommunications access and access quality in Indigenous communities.

The new Labor government in 2007 announced a broadband future policy for Australia. The policy aimed to build an optical fiber network that would target 98 percent Australian households and offer speeds over 40 times greater than the current average (Hoy, 2007). The only other policy with a digital divide focused only on the issue of technology access. However it failed to show how it will ensure the equitable benefits of use of internet.

In 2009, the government announced the largest ever infrastructure project - the $47 billion National Broadband Network (NBN). The construction of the NBN is now underway and its roll out will continue until 2018. It provides an opportunity to address digital divide and to empower people to effectively use new technologies as they become available.

With the change in the government recently, although NBN is not expected to disappear, the implementation pattern is expected to change. The coalition policy on the NBN is expected to see FTTP (Fiber-To-The-Premises) deployed to only twenty-two percent as against ninety-three percent targeted by the former Labor government. Seventy-one percent is expected to be covered by the FTTN (Fiber-To-Node) technology where fiber will be extended to high nodes. The remainder of the distance will be covered by Telstra's copper network. Although coalitions target is to downsize the cost of the project, this may have negative cost implications for the NBN users. Experts fear that this might even deteriorate the digital divide especially in regional Australia where cost is still a vital factor to adopt internet.

One of the weaknesses in assessing the impact of Australian digital divide policy is that both policies and initiatives have been implemented by local, state and national governments as well as the third sector organizations. The third sector organizations and research bodies are not included in the Online Communications Council (OCC) resulting in a lack of coordination. It is understandable that without a strategic body and framework that connect local, state and national digital divide policies and practices, the goal to address digital divide will be undermined.

3. Data and Methodology

3.1 Method

Romer's (1986, 1990) endogenous growth model explains that balanced growth is positively influenced by knowledge spillover. Internet is hypothesized as playing a significant role in disseminating knowledge (Choi and Yi, 2009). Barro's (1998) endogenous growth model also highlights the role of knowledge and innovation in promoting economic growth. Based on these models, we construct an econometric model with economic growth as a function of real per GDP per capita growth rate (GDPPC), the number of internet users per 100 people (NET) and a couple of potential growth drivers such as, financial development (FD) [Shahbaz, 2013; Elgin, 2013; Sassi and Goaied, 2013; Yartley, 2008] and trade openness (TO)]. Therefore, the base model to be used in the study is;
Therefore, per capita output \( Y \) can be expressed as;

\[ Y = F \text{ (use of internet, financial development and trade openness)}. \]

Assuming a Cobb-Douglas type production function, we can write,

\[ Y = A(\text{IN})^{\beta_{\text{IN}}} \cdot (\text{FD})^{\beta_{\text{FIN}}} \cdot (\text{TO})^{\beta_{\text{TO}}} \]  

Log linearizing output GDPPC to obtain growth rate and for the convenience of parameter estimation, we obtain,

\[ \ln Y_t = \beta_0 + \beta_{\text{IN}} \text{IN}_t + \beta_{\text{FIN}} \text{FIN}_t + \beta_{\text{TO}} \text{TO}_t + \varepsilon_t \]  

where \( \beta_0 \) and \( \varepsilon_t \) are constant and the stochastic error term respectively.

### 3.2 Data

We used annual data from 1985-2012 sourced from the World Development Indicators database CD ROM (World Bank, 2013). Economic growth is measured from the growth of GDP per capita (GDPPC) measured at constant US$2000. Internet usage is taken as internet users per 100 people. The variable financial development (FD) is estimated from the ratio of credit to private sector as share of GDP while trade openness (TO) is taken as the total exports and imports as share of GDP (Sassi and Goaied, 2013; Yartley, 2008).

### 3.3 Unit root tests

Since unit root test helps us with a robust causality assessment (Kumar, R. R. 2013), we employ the DF-GLS (Elliott et al. 1996) unit root test to determine the order of integration of variables as this test is more powerful than other conventional tests such as ADF (Dickey and Fuller, 1979), PP (Phillips and Peron, 1988) and KPSS (Kwiatkowski et al., 1992). However, despite its superiority over other tests, it fails to identify the presence of structural break, if any (Baum, 2004) in the series. Therefore, we also conduct Zivot and Andrews (1992) unit root test which accommodates a single structural break point in the level. If we consider our series as \( X \), the structural tests take the following form;

\[ \Delta X_t = \alpha + \alpha X_{t-1} + \beta + \beta X_{t-1} + \gamma + \gamma X_{t-1} + \Omega + \Omega X_{t-1} + bT + cD_t + \sum_{j=1}^{k} d_j \Delta X_{t-j} + \varepsilon_t \]
where D is a dummy variable and shows the mean shift at each point and DT is a trend shift variable. The null hypothesis in Zivot and Andrews (1992) is c=0 meaning the presence of unit root in the absence of structural break hypothesis against the alternative that the series is trend stationary with an unknown time break. Then, this unit root test selects that time break which reduces one-sided t-statistic to test c(=c-1)=1.

3.4 ARDL bounds testing approach

Since conventional cointegration techniques have certain limitations with their findings in the presence of structural break in macroeconomic dynamics (Salahuddin et al., 2014), we employ ARDL (Autoregressive Distributed Lag model) bounds testing approach developed by Pesaran (1997, 2001) to estimate the long-run relationship between the variables. The ARDL technique has several advantages over other conventional cointegration techniques; first of all, this method can be applied to a small sample size study (Pesaran et al., 2001) and therefore conducting bounds testing is justified for the present study. Secondly, it can be applied even in case of mixed order of integration of variables [both for I(0) and I(1) variables]. Thirdly, it simultaneously estimates the short-run dynamics and the long-run equilibrium with a dynamic Unrestricted Error Correction Model (UCEM) through a simple linear transformation of variables. Fourth, it estimates the short- and the long-run components simultaneously potentially removing the problems associated with omitted variables and autocorrelation. In addition, the technique generally provides unbiased estimates of the long-run model and valid t-statistic even when the model suffers from the problem of endogeneity (Harris and Sollis, 2003). The empirical formulation of ARDL equation for our study is specified as follows;

\[
\Delta \ln GDPC_t = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 \ln GDPC_{t-1} + \beta_4 FD_{t-1} + \beta_5 NET_{t-1} + \beta_6 TO_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta \ln GDPC_{t-i} + \sum_{j=0}^{q} \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_8 \Delta \ln FD_{t-j} + \beta_9 \Delta \ln NET_{t-k} + \beta_{10} \Delta \ln TO_{t-l} + \varepsilon_t \]

\[
\Delta FD_t = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 \ln GDPC_{t-1} + \beta_4 FD_{t-1} + \beta_5 NET_{t-1} + \beta_6 TO_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta \ln FD_{t-i} + \sum_{j=0}^{q} \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_8 \Delta \ln GDPC_{t-j} + \beta_9 \Delta \ln NET_{t-k} + \beta_{10} \Delta \ln TO_{t-l} + \varepsilon_t \]
\[ \Delta \text{NET}_t = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 \ln \text{GDPC}_{t-1} + \beta_4 \text{FD}_{t-1} + \beta_5 \text{NET}_{t-1} + \beta_6 \text{TO}_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta \ln \text{NET}_{t-i} + \sum_{j=0}^{q} \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_8 \Delta \ln \text{GDPC}_{t-j} + \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_9 \Delta \ln \text{FD}_{t-k} + \sum_{l=0}^{s} \beta_{10} \Delta \ln \text{TO}_{t-l} + \epsilon_t \] 

\[ \Delta \ln \text{TO}_t = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 \ln \text{GDPC}_{t-1} + \beta_4 \text{FD}_{t-1} + \beta_5 \text{NET}_{t-1} + \beta_6 \text{TO}_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta \ln \text{TO}_{t-i} + \sum_{j=0}^{q} \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_8 \Delta \ln \text{GDPC}_{t-j} + \sum_{k=0}^{r} \sum_{l=0}^{s} \beta_9 \Delta \ln \text{FD}_{t-k} + \sum_{l=0}^{s} \beta_{10} \Delta \ln \text{NET}_{t-l} + \epsilon_t \] 

where \( \ln \text{GDPC}, \ln \text{FD}, \ln \text{NET}, \ln \text{TO} \) indicate log values for real GDP per capita, financial development, internet users per 100 people and trade openness respectively. \( \Delta \) is the difference operator. \( T \) and \( D \) denotes time trend and dummy variable respectively. The dummy variable is included in the equation to capture the structural break arising from the series. \( \epsilon_t \) is the disturbance term.

To examine the cointegrating relationship, Wald Test or the F-test for the joint significance of the coefficients of the lagged variables is applied with the null hypothesis, \( H_0: \beta_3 = \beta_4 = \beta_5 = \beta_6 \) indicating no cointegration against the alternative hypothesis of the existence of cointegration between variables. F statistics are computed to compare the upper and lower bounds critical values provided by Pesaran (2001).

### 3.5 Dynamic Ordinary Least Squares (DOLS)

Next, we apply the Dynamic Ordinary Least Squares (DOLS) method (Stock and Watson, year?) and estimate long-run coefficients between the variables in order to check the robustness of the findings. The application of this method for robustness check is appropriate in that this estimator is robust to small sample bias and eliminates simultaneity problem. Moreover, the obtained co-integrating vectors from DOLS estimators are asymptotically efficient.

### 3.6 The VECM Granger causality test

According to Granger (1969), once the variables are integrated of the same order, the VECM Granger causality test is appropriate to estimate their causal link. Since all the variables in our study are first difference stationary \([I(1)]\) this study proceeds further to determine the causal direction between them. The exact direction of causal link helps with better policy implications of the findings (Shahbaz, 2012). The potential causality pattern for our study is represented by the following VAR specification in a multivariate framework;
\[
\Delta \ln y_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln y_{t-i} + \sum_{i=0}^{p} \beta_{2i} \Delta \text{NET}_{t-i} + \sum_{i=0}^{p} \beta_{3i} \Delta \text{FD}_{t-i} + \sum_{i=0}^{p} \beta_{4i} \Delta \text{TO}_{t-i} + \varepsilon_{t-i} \]

4. Estimation results and discussion

Table 1 reports descriptive statistics. The standard deviations in all the series are quite low implying that the data are evenly dispersed around the mean. Hence it was convenient for us to proceed with the datasets for further estimation.

The DF-GLS unit root results are reported in Table 2 which shows that all the series in our study are first difference stationary, i.e. I(1). However, we are not convinced with these findings yet as this test does not consider the presence of structural break (Baum, 2004). To overcome this shortcoming, we employ Zivot and Andrews (1992) unit root structural break test. The results of this test are presented in Table 3 which confirms that all the series have unit root i.e. I(1) in the presence of structural break.

Since ARDL is sensitive to lag order, for calculating the F statistic, first of all, we need to identify the appropriate lag order. To do this, we choose AIC (Akaike Information Criterion) as it provides better results than other lag length criteria (Luitkepohl, 2006). The reported ARDL result in Table 4 suggests that the calculated F statistic is 4.689 which is higher than the upper bound critical value generated by Pesaran et al. (2001) at 1 percent level of significance. Therefore, there is highly significant cointegrating relationship between economic growth and the predicted variables; internet use, financial development and trade openness.

Table 5 reveals that the variables internet usage and financial development spur Australia's economic growth in the long-run while trade openness has positive but insignificant growth effect.

The short-run effects of the independent variables on growth are reported in table 6. The findings indicate that there is no significant growth effects of internet usage, financial development and trade openness in the short-run. The coefficient of the error correction term, \( ECT_{t-1} \) is -0.438 and has the expected sign. It also implies a relatively speedy convergence (the short-run deviations being corrected at the speed of 43% towards the long-run equilibrium each year).
Table 7 demonstrates results from the diagnostic tests carried out from the ARDL lag estimates. The LM test confirms no serial correlation while Ramsey's RESET test suggests that the model (equation 1) boasts the correct functional form. The normality test reveals that the disturbance terms are normally distributed and are homoscedastic as supported by the heteroscedasticity test. The stability of parameters over time is justified by the graphical plots of CUSUM and CUSUM of Squares (Figure 1).

The results from the Dynamic Ordinary Least Squares (DOLS) are reported in table 8. The DOLS estimation confirms that our findings are robust.

The Granger causality results are presented in table 9 which indicates that there is unidirectional causal link between internet usage and the variables, growth in GDP per capita and financial development. However, trade openness granger causes internet while financial development granger causes GDP per capita in Australia. The causal findings support the earlier claim that internet usage has significant impact on Australian macro economy despite the recent productivity decline in IT investment (Shahiduzzaman and Alam, 2013). Also the unidirectional causal link between internet usage and financial development is not unexpected. Internet usage promotes information dissemination and thus positively contributes towards a financially more developed market by reducing information asymmetry in the credit market.

5. Conclusions, policy implications and limitations

Based on the endogenous growth models of Romer (1986, 1990) and Barro (1998), this study investigates the growth effects of internet usage, financial development and trade openness using the most recent Australian annual time series data for the period 1985-2012. Because of the long sample period, structural break unit root test is conducted. Having found the presence of structural break in the series, an ARDL bounds testing approach is applied taking into account the structural break. Granger causality test is performed to determine the causal link between the variables under study. The findings from the ARDL estimates suggest that internet usage and financial development have long-run positive and significant effects on growth while their growth effects in the short-run are insignificant. Multivariate Granger causality test confirms unidirectional causal link from internet usage to growth and financial development. The long-run findings are robust as checked by an alternative Dynamic Ordinary Least Squares method (DOLS). The baseline model used in the study succeeded all the conventional diagnostic tests.

The findings of the study have a number of policy implications. First, despite the recent decline in the productivity of IT investment in Australian economy, internet continues to boost its growth and as such the NBN (National Broadband Network) roll out for expansion of internet use is quite justified. But its implementation which is already in place needs to be cautious as the widening digital divide in Australia may affect the growth potential of internet and may be responsible for the productivity decline of IT investment. Second, the current weaknesses in the digital divide policy such as too much focus on the supply side issues need to be addressed and emphasize the demand side issues in the policy. Third, since it is argued that social capital generated through internet has the potential to reduce digital divide in Australia, it should be incorporated in the digital divide policy framework. Fourth, recognizing the GPT nature of ICT, further steps need to be taken to promote investment in the complimentary assets so as to ensure the maximum benefit from internet usage.
Despite stupendous efforts, the current study suffers from a number of limitations. First, it estimates the direct growth effect of internet in Australian economy but internet impacts economy through different indirect channels as evident from the empirical literature. It has the potential to contribute to the economy through a range of indirect ways from improving international capital movement in favor of a country, enriching human capital, productivity, reducing corruption as a result of better information flow to reducing uncertainty in the market by reducing information asymmetry etc.

Internet is also believed to have the potential to generate social capital which potentially boosts economic growth and reduce digital divide. Since social capital generated through internet is advocated to be incorporated in the digital divide policy in Australia (Tanya and Marcus, 2008), future study may attempt to estimate its exact effect on the economy. The generalizability of the study should be taken with caution as it deals with macro data hence ignoring the regional impact of internet usage which is of prime importance from policy perspective in the current Australian context. Also one must not forget that the findings of the current study are not invariant across the spectrum of different methodological applications. Finally, the policy implications of the study are limited in that the findings do not provide any forecast on the future behavior of the variables. Innovation Accounting Approach (IAA) such as variance decomposition and Impulse Response function (IRF) could be used in future study to forecast the future relationship between internet usage and economic growth to provide with a more pragmatic policy implications discussion.

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Appendix

Table 1: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observation</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGDPC</td>
<td>28</td>
<td>10.280</td>
<td>0.170</td>
<td>10.005</td>
<td>10.526</td>
</tr>
<tr>
<td>FD</td>
<td>28</td>
<td>83.963</td>
<td>28.607</td>
<td>37.031</td>
<td>126.36</td>
</tr>
<tr>
<td>NET</td>
<td>28</td>
<td>34.355</td>
<td>32.095</td>
<td>0.530</td>
<td>82.349</td>
</tr>
<tr>
<td>TO</td>
<td>28</td>
<td>37.783</td>
<td>3.938</td>
<td>32.128</td>
<td>44.778</td>
</tr>
</tbody>
</table>

Table 2: Unit-Root test DF-GLS

<table>
<thead>
<tr>
<th>Log Levels (Z_t)</th>
<th>Log 1st Difference (ΔZ_t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>DFGLS stat</td>
</tr>
<tr>
<td>LGDPC</td>
<td>0.239</td>
</tr>
<tr>
<td>NET</td>
<td>1.644</td>
</tr>
<tr>
<td>FD</td>
<td>-0.475</td>
</tr>
<tr>
<td>TO</td>
<td>-1.016</td>
</tr>
</tbody>
</table>

Note: a, b, & c indicate 1 %, 5%, & 10 % significance level respectively.
Table 3: Zivot–Andrews structural break unit root test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Z&amp;A test for level</th>
<th>Z&amp;A test for 1st difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-Statistic</td>
<td>TB</td>
</tr>
<tr>
<td>LGDPC</td>
<td>-2.795</td>
<td>2008</td>
</tr>
<tr>
<td>FD</td>
<td>-1.588</td>
<td>1994</td>
</tr>
<tr>
<td>NET</td>
<td>-8.979&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1997</td>
</tr>
<tr>
<td>TO</td>
<td>-3.466</td>
<td>2001</td>
</tr>
</tbody>
</table>

Note: a, b, & c indicate 1 %, 5%, & 10% significance level respectively.

Table 4: Results from Bounds Test

<table>
<thead>
<tr>
<th>Dep. Var.</th>
<th>AIC Lag</th>
<th>F-stat.</th>
<th>Probability</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{LGDPC}(LGDPC</td>
<td>FD,NET, TO) )</td>
<td>2</td>
<td>4.689&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.019</td>
</tr>
<tr>
<td>( F_{FD}(FD</td>
<td>LGDPC, NET, TO) )</td>
<td>2</td>
<td>6.471&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.006</td>
</tr>
<tr>
<td>( F_{NET}(NET</td>
<td>LGDPC, FD, TO) )</td>
<td>2</td>
<td>2.390</td>
<td>0.114</td>
</tr>
<tr>
<td>( F_{TO}(TO</td>
<td>LGDPC, FD,NET) )</td>
<td>2</td>
<td>1.963</td>
<td>0.170</td>
</tr>
</tbody>
</table>

Pesaran Critical value at 1 % and 5 % , 3.43 , 4.60 and 2.86 , 3.99 respectively

Table 5: Estimated Long Run Coefficients using the ARDL Approach, (2,0,0,1) selected based on AIC, Dependent variable is LGDPC,

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD</td>
<td>0.003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.827</td>
<td>4.059[.001]</td>
</tr>
<tr>
<td>NET</td>
<td>0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.727</td>
<td>2.018[.058]</td>
</tr>
<tr>
<td>TO</td>
<td>0.007&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.003</td>
<td>1.841[.081]</td>
</tr>
<tr>
<td>C</td>
<td>9.693&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.122</td>
<td>79.136[.000]</td>
</tr>
</tbody>
</table>

Note: a, b, & c indicate 1 %, 5%, & 10 % significance level respectively.
Table 6: Error Correction Representation for the Selected ARDL Model(2,0,0,1) selected based AIC, Dependent variable is dLGDPC

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>dLGDPC1</td>
<td>0.352</td>
<td>0.207</td>
<td>1.696[0.105]</td>
</tr>
<tr>
<td>dFD</td>
<td>0.001</td>
<td>0.940</td>
<td>1.565[0.133]</td>
</tr>
<tr>
<td>dNET</td>
<td>0.644</td>
<td>0.499</td>
<td>1.289[0.212]</td>
</tr>
<tr>
<td>dTO</td>
<td>0.820</td>
<td>0.001</td>
<td>0.509[0.616]</td>
</tr>
<tr>
<td>dC</td>
<td>4.250c</td>
<td>2.291</td>
<td>1.855[0.078]</td>
</tr>
<tr>
<td>ecm(-1)</td>
<td>-0.438c</td>
<td>0.234</td>
<td>-1.869[0.076]</td>
</tr>
</tbody>
</table>

Note: a, b, & c indicate 1 %, 5%, & 10 % significance level respectively

Table 7: Diagnostic Tests

<table>
<thead>
<tr>
<th>Test Statistics</th>
<th>LM Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Square 0.99</td>
<td>Adjusted R Square 0.99</td>
</tr>
<tr>
<td>Serial Correlation $\chi^2(1)=0.004[0.944]$</td>
<td>Normality $\chi^2(2)=1.461[0.482]$</td>
</tr>
<tr>
<td>Functional Form $\chi^2(1)=2.921[0.087]$</td>
<td>Heteroscedasticity $\chi^2(1)=1.516[0.218]$</td>
</tr>
</tbody>
</table>

Figure 1:

Plot of Cumulative Sum of Recursive Residuals

The straight lines represent critical bounds at 5% significance level

Plot of Cumulative Sum of Squares of Recursive Residuals

The straight lines represent critical bounds at 5% significance level
Table 8: Results from Dynamic OLS(DOLS)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Robust Std. Err.</th>
<th>P- Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Openness</td>
<td>0.0078a</td>
<td>0.0009</td>
<td>0.000</td>
</tr>
<tr>
<td>Internet Use</td>
<td>0.0009a</td>
<td>0.0002</td>
<td>0.000</td>
</tr>
<tr>
<td>Financial Development</td>
<td>0.0038a</td>
<td>0.0001</td>
<td>0.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>9.6090</td>
<td>0.0429</td>
<td>0.000</td>
</tr>
<tr>
<td>R²</td>
<td>0.999</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: a, b, & c indicate 1 %, 5%, & 10 % significance level respectively

Table 9: Granger Causality Test

<table>
<thead>
<tr>
<th>Equation</th>
<th>$\chi^2$ Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LGDPC → Trade Openness</strong></td>
<td>2.917</td>
<td>0.233</td>
</tr>
<tr>
<td><strong>LGDPC → Internet Use</strong></td>
<td>0.851</td>
<td>0.653</td>
</tr>
<tr>
<td><strong>LGDPC → Financial Development</strong></td>
<td>2.060</td>
<td>0.357</td>
</tr>
<tr>
<td><strong>LGDPC → All</strong></td>
<td>7.070</td>
<td>0.314</td>
</tr>
<tr>
<td><strong>Trade Openness → LGDPC</strong></td>
<td>4.059</td>
<td>0.131</td>
</tr>
<tr>
<td><strong>Trade Openness → Internet Use</strong></td>
<td>5.141c</td>
<td>0.076</td>
</tr>
<tr>
<td><strong>Trade Openness → Financial Development</strong></td>
<td>2.247</td>
<td>0.325</td>
</tr>
<tr>
<td><strong>Trade Openness → All</strong></td>
<td>17.444a</td>
<td>0.008</td>
</tr>
<tr>
<td><strong>Internet Use → LGDPC</strong></td>
<td>11.772a</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Internet Use → Trade Openness</strong></td>
<td>0.647</td>
<td>0.724</td>
</tr>
<tr>
<td>Relationship</td>
<td>P-value</td>
<td>Significance</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------</td>
<td>--------------</td>
</tr>
<tr>
<td>Internet Use $\rightarrow$ Financial Development</td>
<td>5.642$^c$</td>
<td>0.060</td>
</tr>
<tr>
<td>Internet Use $\rightarrow$ ALL</td>
<td>24.588$^a$</td>
<td>0.000</td>
</tr>
<tr>
<td>Financial Development $\rightarrow$ LGDPC</td>
<td>7.460$^b$</td>
<td>0.024</td>
</tr>
<tr>
<td>Financial Development $\rightarrow$ Trade Openness</td>
<td>1.565</td>
<td>0.457</td>
</tr>
<tr>
<td>Financial Development $\rightarrow$ Internet Use</td>
<td>0.529</td>
<td>0.767</td>
</tr>
<tr>
<td>Financial Development $\rightarrow$ All</td>
<td>13.839$^b$</td>
<td>0.031</td>
</tr>
</tbody>
</table>