How Do Digital Technologies Drive Economic Growth?

Research Outline

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Abstract

"You can see the computer age everywhere but in the productivity statistics"

- Robert Solow, 1987

There are well-explored difficulties associated with quantifying the impact of digital technology on economic growth. This paper leverages a broad and up-to-date panel data set using a novel econometric specification. It estimates how economic growth is driven by the established technologies such as the internet and smartphones, as well as emerging technologies such as cloud computing. The main findings of this research indicate that technology is not confined to large investments in fixed plant and equipment. Instead, it has become a pervasive and quintessential tool to augment and support labour productivity. Given the growing prevalence of digital technologies in our society, the question about its role in driving economic growth is particularly important and timely. Being able to isolate the impact of these technologies could help better understand the effects of various investment strategies, regulatory rulings and policy decisions.

JEL classification: O40, O47.

1. Introduction

The past decade has witnessed technological advances that fundamentally changed how our markets and economy are organised, and promise great leaps in productivity and economic growth. Established technologies such as the internet and smartphones, as well as emerging technologies such as cloud computing and social media continuously push the frontiers of our 'old economy', redefining businesses, jobs and the way we interact with our economy.

The global diffusion of digital technologies as general use tools has also spurred arguments that it may increase knowledge diffusion through improved communication efficiency, improve consumer engagement, and allow countries to leapfrog traditional methods of increasing productivity.

While existing literature in Australia largely support the relevance of digital technologies as a factor of economic growth, this literature often relies on firm level data from the early 2000s and does not explicitly account for the impact of economy wide digital technology developments (PC, 2004). This paper seeks to shed new light on the determinants of economic growth, with two objectives in mind.

In the OECDs 2014 contribution, Measuring the Digital Economy: A New Perspective, lists six priority actions, and the number 1 action is to Improve the measurement of ICT investment including broadband investment and its link to macroeconomic performance. This paper aspires to do exactly that.

First, it assesses the extent to which the main findings from previous economic growth studies are robust to a larger and more recent sample, covering both developed and developing countries. Confirmation is found from estimates for the larger sample of countries that long-run GDP per capita levels are increased *inter alia* by education attainment, trade openness, research and development, urbanisation and a range of other factors.

Second, the paper proposes a growth regression framework that explicitly account for the impact of more recent digital technology developments. In particular, this paper attempts to provide new evidence on the economic impact of established technologies such as the internet and smartphones, as well as emerging technologies such as cloud computing and social media.

2. The Role of Technology in Literature

Economic growth literature flourished in the early 1990s, with most focusing on the role of human capital, and policy and institutional settings in stimulating economic growth (See Temple, 1999 and Ahn and Hemmings, 2000 for surveys). Among these studies, the influence of technological advances were often assumed to be exogenous and unobserved (see Barros (1991), Mankiw et. al (1992)).

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Since the late 1990s, the emergence of broadband has inspired a new stream of economic growth literature, dissecting the broader role of technology infrastructure in raising factor productivity and communication efficiency. For example, Czernich (2009) noted that early broadband infrastructure developments allowed the generation and distribution of decentralised information and ideas in markets increasingly relying on information as an input.

More recently, studies of technology and economic developments have shifted away from infrastructure investments to broader economic implications of digitisation - the increasing complexity technology plays in the interaction between capital and labour. Studies such as OECD (2013) have highlighted the importance of internet related economic activities or the digital economy, including its direct contributions in the form of emerging industries as well as the dynamic impact it has on broader economic growth through producitvity enhancing transformations. However, these studies mostly do not include new growth accounting estimates, but rely on early evidence about broadband. Other papers have progressed advanced thinking in other ways, such as Corrado et al. (2012) which shows that intangible capital investments strongly correlate with growth in labour productivity.

This paper attempts to build on developments in economic growth theory with more recent evidence of the contribution of digital technologies to economic growth.

In addition, this paper will also discuss the limitations of our potential addition to the literature: namely, how digital technologies will also have a range of social benefits and costs not captured by GDP. As outlined in OECD (2013) there are a range of consumer surplus and welfare gains from digital technologies. Brynjolfsson et al (2003), found that the choice and variety benefits of the internet were 7 to 10 times larger than lower price benefits from increased competition in the book market. A further angle is how digital technologies improve output from non-market sector industries such as health, education and government services, whose value is inadequately measured by the outputs equals inputs framework for their measurement. The non-GDP impact of digital technologies is an enormous topic in its own right, but acknowledging it is important.

3.   Proposed Methodology

This paper follows previous OECD literature in taking a panel approach to identify the growth effects of digital technology, along with policy and institutional settings. This enables us to directly estimate the contribution of these factors. In particular, we use a pooled cross-country time series data set of both developing and developed countries to explain both:

- cross-sectional differences in economic growth performance (that is, differences in performance between countries at a point in time);and
- longitudinal differences in economic growth performance (that is, how the performance of any given country changes over time).

This paper is theoretically founded in the neo-classical production function assumption outlined by Solows growth accounting model. Previous studies have shown that models of this

nature are, to a first approximation, consistent with historical data (Mankiw et al.,1992).

The model argues that economic growth is driven by the interplay between:

- labour;
- capital;
- human capital; and
- the productivity or effectiness of how each of these inputs is deployed in the economy.

The model gives simple testable predictions about how the key factors outlined above influence the steady-state level of income. In addition, the approach also allows us to ask questions about the factors influencing economic growth through enhancing productivity and efficiency. In particular, this paper will test how economic growth might be driven by a range of factors, including:

- research and development activity;
- urbanisation;
- development of communications technology;
- macroeconomic and structural policy settings;
- trade policy;
- influence of financial market conditions on economic efficiency; and
- digital technologies such as smartphones, cloud computing and online services.

4. Proposed Model Specification

In line with a large body of economic development literature, this paper seeks to quantify the effects of policy and institutional settings on economic growth using a neo-classical production function; the formal framework is first set out by Mankiw et al (1992) and its augmented-form implemented by OECD (2001). The models proposed in this proposal adhere closely to these existing literature, with modifications provided to accommodate the focus on digital technologies.

The standard neo-classical growth model is derived from constant returns to scale production function with three inputs (capital, labour and human capital) that are paid their marginal products. Production (output) at time t is given by:

$$Y(t) = K(t)^\alpha H(t)^\beta (A(t)L(t))^{(1-\alpha-\beta)} \tag{1}$$

Where Y, K, H and L are output, physical capital, human capital and labour respectively, α is the partial elasticity of output with respect to physical capital, is the actual elasticity of output with respect to human capital and $A(t)$ is a measure of technological progress and economic efficiency.

$$A(t) = I(t)\Omega(t) \tag{2}$$

This paper will incorporate a number of productivity enhancing development indicator as

key determinants of economic efficiency $I(t)$. An example of possible specification could be:

$$lnI(t) = p_0 + \sum_j p_j lnV_j(t) \tag{3}$$

Where $V(t)$ is a vector of productivity enhancing cahracteristics, including the level of digital technology development as well as policy and institutional settings.

Other technological progress is assumed to be exogenous and grows at time variant rate $g(t)$.

$$\dot{\Omega}(t) = g(t)\Omega(t) \tag{4}$$

Using this identify and substituting the steady-state values of physical capital and human capital yields the intensive form of steady-state output as a function of h^*.[1]

$$ln(y^*) = ln\Omega(t) + p_0 + \sum_j p_j lnV_j(t) + \frac{\alpha}{1-\alpha}lns_k(t)$$
$$+ \frac{\beta}{1-\alpha}lnh^*(t) - \alpha(1-\alpha)ln(g(t)+n(t)+d) \tag{5}$$

Equation 5^2 is valid in empirical cross-country analysis only if countries are in their steady states or if deviations from steady state are independent and identically distributed. If observed growth rates include out-of-steady-state dynamics, then the transitional dynamics have to be modelled explicitly (OCED, 2001). A linear approximation of the transitional dynamics can be expressed as follows (Mankiw et al, 1992):

$$\Delta lny(t) = -\phi(\lambda)lny(t-1) + \phi(\lambda)\left(\frac{\alpha}{1-\alpha}\right)lns_k(t) + \phi(\lambda)\left(\frac{\beta}{1-\alpha}\right)lnh(t)$$
$$+ \sum_j p_j\phi(\lambda)lnV_j(t) + \frac{1-\psi}{\psi}\left(\frac{\beta}{1-\alpha}\right)\Delta lnh(t) - \phi(\lambda)\left(\frac{\alpha}{1-\alpha}\right)ln(g(t)+n(t)+d)$$
$$+ \left(1 - \frac{\phi(\lambda)}{\psi}\right)g(t) + \phi(\lambda)(p_0 + ln\Omega(o)) + \phi(\lambda)g(t)t \tag{6}$$

This equation represents the generic functional form that will be empirically estimated in this research. The coefficient estimate $\phi(\lambda)$ represents the convergence parameter. The convergence parameter underlines the speed in which countries converge to their steady-state output.

In addition to estimating the steady-state solutions, this paper will also estimate another functional form that adds short-term dynamics in the model to help isolate dynamic cyclical

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[1]The steady-state stock of human capital h^* is not observed, it can be expressed as a function of actual human capital: $lnh^*(t) = lnh(t) + \frac{1-\psi}{\psi}\Delta ln\left(\frac{h(t)}{A(t)}\right)$.

[2]Where y^* is the steady-state output per capita, s_k is the investment rate in physical capital, $n(t)$ is the population growth rate, and d is the rate of depreciation.

effects. This augmentation is advantageous as it relaxes the assumption that countries are in their steady states and that deviations from the steady state are independent and identically distributed. Its functional form can be expressed as follows:

$$\Delta lny(t) = a_0 - \phi lny(t-1) + a_1 lns_k(t) + a_2 lnh(t) - a_3 n(t) + a_4 t + \sum_{(j=1)}^{3} a_{j+4} lnV_j \tag{7}$$

$$+ b_1 \Delta lns_k(t) + b_2 \Delta lnh(t) + b_3 \Delta lnn(t) + \sum_{j=1}^{3} b_{j+3} \Delta lnV_j$$

The estimates will be produced using a pooled mean group estimator. It is important to recognise that under the dynamic model specification, the observed growth in output in any given period, abstracting from cyclical fluctuations, can be seen as the combination of three different forces:

1. underlying technological progress which is assumed to be exogenous;
2. a convergence process towards the country-specific steady-state path of output per capita; and
3. shifts in the steady state that can arise from changes in policy and institutions as well as investment rates and changes in population growth rates.

This means that the exclusions institutional factors does not necessarily constitute omitted variable bias, the effect of these variables on economic growth could simply be factored in as an unidentified underlying change in the technological progress, the specification remains consistent and estimates unbiased.

Alternative functional forms that allow for both cross country differences in steady-state level of TFP and speed of technology diffusion will also be considered. The latter feature is especially attractive when dealing with a sample widely heterogeneous countries.

5. Determinants of Economic Growth

The literature on the impact of policy and institutions on economic growth is vast. However, there is little agreement on which policy and institutional settings have a material impact on growth, or the mechanisms through which transmit these impacts.

In this research, we test the impact of a range of possible macro-economic variables empirically, and attempt to validate their contributions to more recent economic growth. These are briefly described below.

5.1. Digital technologies

Digital technologies referred to in this research can include a range of technological developments in the last decade. For example, emergence of the internet and mobile technologies, new digital tools such as cloud computing, mobile web services, smart devices, and social

media have significantly contributed to innovation, competitiveness and growth. Depending on data availability, this research will seek to establish economy wide indicator for the development and diffusion of these technologies in order to identify their impact on economic growth.

5.2. Physical capital

Economists have long stressed the importance of physical capital to the process of growth. The accumulation of capital (capital deepening) increases the supply of capital stock, such as plant and equipment, for production processes. This greater availability of capital to augment production drives growth. It is one of the main factors determining the level of real output per capita. However, the permanence of its effects depend on the extent to which innovation is embodied in new capital.

In our model, we measure capital investment as the ratio of gross capital formation to GDP. Capital investment varies significantly across countries, and is a key element of explaining the variation of income per capita across countries.

5.3. Human capital

Recent growth accounting literature has placed substantial emphasis on the importance of human capital in the production process. The formal skills, experiences and education attached to the workforce are often modelled as a form of intangible capital (e.g. Jones, 2014). In the empirical analysis, we measure the accumulation of human capital as the share of the working population who are tertiary graduates.

5.4. Research and development

The effects of knowledge capital on productivity may work through various channels depending on the source of the knowledge. For example, R&D, which is a major component of knowledge capital, can be performed either by the business sector, higher education, public sector or beyond the borders of a country. Each of these types of R&D performers can be a source of significant domestic technological change. R&D performed by the higher education sector may result in new innovative technologies which can used to produce new goods and services, improving productivity at the firm or national level.

Empirically, we separately identify the effects of R&D by higher education institutions and other sectors of the economy using their R&D expenditure to GDP ratio.

5.5. Urbanisation

Urbanisation the process of an increasing share of the national population moving to live within urban settlements has been a key driving force in human and economic development. Settlements in urban areas are often associated with an increasing proportion of the

population being engaged in non-agricultural occupations, which can serve as a proxy for underlying shifts in the economic structure of a country.

We estimate the effects of urbanisation using the ratio of urban population to total population.

5.6. Trade exposure

International trade is another factor that influences the improvements in productivity, particularly through competition and the diffusion of knowledge across borders. This is especially the case in developing countries (which do not, in general, perform research and developments), where productivity growth depends, to a large extent, on the rate at which they can acquire technology developed by industrial countries. We measure trade exposure by taking the ratio between the value of exports and imports against the value of outputs.

5.7. Other

A range of other variable were considered to be significant influencers of economic growth and will be tested in this research (depending on data availability), including:

- The size of government (measured as the ratio of tax revenue to GDP);
- Levels of financial development (measured as equity capitalisation to GDP ratio);
- Monetary policy effectiveness (measured by the inflation rate);and
- Broader levels of communications technology development (measured by the number of fixed broadband subscribers per 100 inhabitants).

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