Resolving the Productivity Paradox

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EXTENDED ABSTRACT

Solow (1987) made the statement that 'we see computers everywhere except in the productivity statistics'. This has come to be known as the "productivity paradox." Whether this is in fact a paradox or a direct implication of the diffusion of technical change is the focus of this paper. In particular, the implications of two different theoretical treatments of technology diffusion in an economy are considered; the traditional model of Solow (1956) and the alternative view of Carlaw, Lipsey and Bekar (2004). These two distinct views articulate two general empirically testable hypotheses that are captured in a number of specific tests including measures of the diffusion of information and communication technologies (ICT). Although weak, the evidence supports the view of Carlaw, Lipsey and Bekar.

1. INTRODUCTION

This paper seeks to demonstrate that the apparent "productivity paradox" is a creation of the modelling approach taken to explain the role of technology in an economy. The paper focuses, in particular, on economic growth caused by Information and Communication Technology (ICT) which is regarded as a modern General Purpose Technology (GPT) The following question is also raised "has ICT caused a revolution in global production and communication, or not?" The answer to this question lies in separating the diffusion of this technology from measured output or productivity gains generated by it. There seems to be little disagreement that computers, the Internet and the myriad supporting complementary technologies that they have enabled, have revolutionized production taking the world into the age of the global economy. What is debated is whether this technological revolution is having the kinds revolutionary influences on economic growth that were witnessed with the First and Second Industrial Revolutions, themselves based on the technologies of automated textile manufacturing and steam in the case of the First and electricity, machine tools and chemicals manufacturing in the case of the Second. The view proposed here is that in order to become productively useful all technological knowledge must become embodied in some real physical component of the work whether it is physical or human capital (including all tacit skills), laws and legal institutions, or social and cultural norms. This is why we do not immediately see the benefits of new technologies in the National Accounts. Only when these new technologies have been sufficiently diffused to actually register in the accounts, do we actually 'see computers everywhere'.

Furthermore, each of these embodiments requires costly investment, so the separation of the contribution of technological change from measured factors such as physical and human capital to economic growth is difficult. The key to connecting technological change to economic growth lies in identifying specific embodiments of new technology and determining their contribution to economic growth over a long horizon.

The debate about technologies' contribution to economic growth is currently focussed on ICT's impact on economic growth. At the centre of this debate is the so called productivity paradox that is a combination of a number of stylised and anecdotal observations about the proliferation of computers and ICT with the statistical observation of a decline in the growth rate of total or multi - factor productivity (TFP or MFP) in many OECD countries, starting in the early 1970's and running through to the middle of the 1990's. The erroneous presumption that underwrites the paradox is that TFP measures technological change in a perfectly, contemporaneously correlated fashion. One view in this debate holds that the paradox has been resolved by the emergence of the New Economy in the United States as evidenced by the measured increase in TFP growth starting in the mid 1990s. An alternative view is that there is no paradox at all because the productivity statistics show that no technological revolution has occurred. We take these two views as being representative of what we call the traditional view of growth driven by technological change. This view is typified by the aggregate production function first introduced by Solow (1956) in which technology is captured by an exogenous shift parameter, is unstructured and has a contemporaneous, positive impact on output. We call this the traditional view.

Another view is that there is no paradox because there is a real technology cycle that causes real productivity slowdowns. In line with this view a number of students of general purpose technologies (GPTs) argue that the introduction of new GPTs can cause large structural adjustment costs as the economy exploits the new technology see for example, Helpman and Trajtenberg, (1998a,b), Howitt, (1998), Aghion and Howitt (1998) and Lipsey, Bekar and Carlaw (1998a,b). These theoretical views reconcile the observed facts of large-scale technological change with initial declining productivity numbers by noting that some technological change brings with it a costly adjustment process. Lipsey, Bekar and Carlaw (1998b) argue that the pattern is not necessarily inherent in the new GPTs themselves, but it is a possible outcome of the interaction between new GPTs and the existing economic structure into which they are introduced. If there is sufficient friction between the new technologies and the existing economic structure, including necessary redesigns of physical capital, reskilling of human capital and changes in the organizational technology of firms then a real productivity slowdown can follow the introduction of a transforming GPT for a time.

But the introduction of the GPT ultimately rejuvenates growth and there is a long term productivity benefit. We call this third view the non-traditional view.

The traditional view of growth and technological change has an immediate and easy to test hypothesis. Output Growth and technological change are contemporaneously and positively correlated. So there is a paradox for those in the traditional view that observe the proliferation of ICT but no productivity boom until late in 1990's. So we should expect to observe a positive correlation between the diffusion of a new technology and measured productivity growth rates

The non-traditional view generates the testable hypothesis that a new technology's impact on growth will not be immediately positive and potentially can initially cause productivity slow downs which will be turned around as the technology mature. So we should expect to observe no correlation or even a negative correlation between technological diffusion rates and productivity growth rates.

In this paper we examine what if anything the data tell us in New Zealand. Our data is limited causing our conclusions to be more conjecture then final statements. What we do see is some support for the non-traditional view in the New Zealand data. For detailed discussions of the alternative models and some simulation results see Carlaw and Oxley (2004).

2. NEW ZEALAND ICT DIFFUSION AND PRODUCTIVITY

The contributions of embodied technological change to TFP growth have been studied in the growth accounting literature. Hulten (1992) and Jorgenson (1966) have focused on the measurement of the efficiency of the capital stock and the effects of measurement errors on productivity estimates. These authors argue that quality change (or Investment Specific Technological (IST) change growth) is difficult to observe, and therefore may not be measured accurately in the National Income and Product Accounts (NIPA). In order to obtain an estimate of the size of error associate with the official capital stock estimates, Hulten used quality-corrected data from Gordon (1990). Gordon found that the official deflators for producer durable equipment overstate quality-corrected inflation in capital goods, and therefore understate increases in capital input.

Following Greenwood et al (1997 and 2000), Carlaw and Kosempel (2004) adopt a computable general equilibrium approach to measuring changes in the quality of investment in Canada. They demonstrate that IST made important contributions to Canadian output growth during the 1961-96 period. One of the key results that they establish is that IST is negatively correlated with TFP particularly since 1974.

Investment Specific Technological change is calculated by making the unrealistic assumption that the economy, sector or industry under examination in is a perfectly competitive general equilibrium which has become characterized as the Ramsey-Cass-Koopmans model. In this framework the microeconomic decisions of consumers determine the saving rates, levels of consumption and stocks of capital in the economy whose aggregate production capacity is characterised by constant returns to scale production function defined over capital and labour. It is important to note that the assumption of constant returns to scale is a very strong one and one on which the entire calculation depends. In the absence of constant returns to scale it is not clear that IST is solely a measure of investment quality. We maintain the assumption here and use the measure as being indicative of the point that TFP does not measure changes in technology even though our independent measure of technological change, IST, is itself likely imperfect.

Within such a framework constant income share weights but an increasing capital to labour ratio can only be reconciled by an increasing quality of capital, which is the result that Carlaw and Kosempel (2004) verify empirically. In their analysis the measure of residual neutral technological change, which would be equal to TFP in the absence of increases in investment quality, is negative over much of the period from 1974 onward. They interpret this negative measure to potentially indicate a structural adjustment cost associated with the adoption of the new technology implicit in the high quality capital investments of the sort discussed by David (1990) and Lipsey, Bekar and Carlaw (1998b). We return to this issue latter in the paper when we discuss the industry level Australian data.

We report here some of our follow up analysis of changes in investment quality and changes in TFP in 16 OECD countries (where comparable data was available) reveals that the negative relationship between IST and TFP change appeared in most of the countries in the data set. The data span the period 1970 to

1997, although the times serries are not as long for some countries included in the analysis. Correlations and their significance are calculated by linearly regressing TFP growth on IST growth. This simple procedure allows for easy calculation of correlation and the statistical significance of the correlation between the two rates of change, however, it also has some obviously flawed assumptions in that it is unlikely that the relationship between TFP and IST growth is linear. We use it because reveals that there is clearly something wrong with TFP as a contemporaneous measure of technological change.

The results shown in Table 1 indicate that the relationship between TFP and IST is weak. In most cases there is a negative relationship, in two cases a significant one. Only in two cases is there a significant positive relationship. Given the assumptions necessary to make these calculations we do not draw any strong conclusions. But we take this as weak evidence that there is no relationship between our independent measure of technological change and TFP growth. There is possibly a negative relationship over the period examined at least for some economies. In addition to the empirical evidence on investment quality we are able to track ICT diffusion in New Zealand proximately, over a relatively short time horizon by looking at the diffusion of mobile telephones, internet domains, web sites and internet uses in the economy.

Table 1

	Corr	**Sig**	**Ave. TFP growth**	**Ave. IST growth**
Australia	-0.200	-1.625	0.005	0.030
Austria	0.082	0.797	0.006	0.014
Canada	-0.035	-0.451	0.004	0.066
Germany	-0.901	-1.908	0.002	0.010
Denmark	0.056	0.486	0.006	0.013
Spain	-0.168	-1.193	0.007	0.017
Finland	-0.355	-1.485	0.009	0.001
France	0.095	0.664	0.008	0.022
UK	-0.356	-3.451	0.008	0.011
Greece	-0.123	-2.570	0.001	0.025
Ireland	-0.047	-0.350	0.015	0.017
Italy	-0.029	-0.184	0.005	0.010
Japan	0.429	2.932	0.009	0.039
Nether lands	0.292	2.300	-1.9E-05	0.017
NZ	-0.217	-1.299	-0.001	0.049
Sweden	0.062	0.559	0.003	0.020

Figure 1 shows the levels of use of mobile phones, Internet domains, web sites and Internet users in New Zealand during the period 1988-2002. The data have a logistic looking diffusion pattern. Unfortunately not all of the series cover the whole period. For example, the number of web sites only runs from 1998 to 2002. In spite of the limited data we are able to do some analysis that goes some way toward testing the hypotheses that emerge from the traditional and non-traditional views.

The traditional view argues that technological change is contemporaneously correlated with productivity change. The non-traditional view argues that technological change will be either uncorrelated or negatively contemporaneously correlated with productivity change. It also argues that productivity change will understate technological change. Figures 2 and 3 below, show the rates of TFP change and diffusion rates for the nine industrial sectors of New Zealand and the four measures of diffusion. The diffusion rates are all above the TFP growth rates. This is consistent with the non-traditional arguments that TFP is not a measure of the rate of technological change. To test the hypothesis that TFP change is contemporaneously correlated with technological change we linearly regress TFP growth on the diffusion rate of mobile telephones in New Zealand. We choose only mobile telephones because it is the longest time series we have, allowing for the best statistical result. Table 2 reports correlation coefficients and *t* statistics as well average growth rates of TFP for each industry. The critical value of the one tailed test with a 95% level of confidence and 13 degrees of freedom is 2.16. In all cases we have a failure to reject the null hypothesis that the coefficient is significantly different from zero.

3. CONCLUSIONS

We set out in paper to analyse two views of technology diffusion in the context of ICT diffusion in New Zealand. In doing so, we begin the development of a theory of MFP or TFP by developing a multi-sector model of endogenous GPT-driven growth. The need for such a theory arises out of the mutually incompatible interpretations of the measures technological and productivity change. Such a need also arises out of the inconsistency in the interpretation of TFP growth as a measure of technological change when compared to other independent measures of technological change such as IST. The two different measures appear to be uncorrelated or even negatively correlated.

To begin the process of developing a theory of TFP we build two models of GPT-driven growth – a basic three sector model and a four sector model that includes structural adjustment costs – based on the historical and theoretical research of Carlaw and Lipsey (2002), as well as, a cruder earlier versions of the three sector model (Carlaw and Lipsey (2001 and 2005)). In the models, a sequence of GPTs arrive each at uncertain times and with uncertain productive impacts that diffuse according to a logistic process. The models assume behaviour that results in resource allocations such that a non-stationary equilibrium is generated. The model has the property that in the absence of future GPTs there are diminishing returns and growth asymptotically approaches zero. But the arrival of new GPTs rejuvenates the growth process.

Because this model requires a numerical solution procedure that is iterated through several periods it provides a ready opportunity for Monte Carlo analysis of the assumptions that underlay both endogenous growth modelling and TFP growth calculations. We do such and exercise here and confirm the arguments of Carlaw and Lipsey (2003) and Lipsey and Carlaw (2004) and Carlaw (2004) that TFP is not a measure of technological change. We find that while under some conditions TFP is positively correlated with direct and independent measures of technological change it persistently under estimates such technological change. Under other conditions, such as structural adjustment to accommodate a new GPT, TPF growth is negatively correlated with measured technological change and persistently underestimates technological change when a new GPT arrives and overestimates technological change as the GPT matures. In both model TFP fails detect the arrival of GPTs appropriately (i.e., as big technological shocks).

The findings in the IST empirical analysis and the simple empirical analysis of the New Zealand ICT diffusion data are consistent with the view that ICT is a major new transforming GPT that generates the kind of structural adjustment costs discussed in Lipsey, Bekar and Carlaw (1998b) and Carlaw et al (2004). However, all of these empirical findings have to be viewed with a critical eye because there are a number of assumptions necessary to interpret the measures of technological change as being valid. Although, they do have the property that they are independent measures of technological change and therefore provide some basis of comparison and testing of the various interpretations of TFP growth, they are limited in terms of the number of observations. Thus, very limited inference can be drawn. They point in a common direction. TFP does not measure technological change. Furthermore, it may be negatively correlated with technological change when that change is driven by a transforming GPT such as ICT, which is something that the theory predicts. What the results suggest is that further research is warranted. In particular more attention must be paid to collecting independent measures of technological change and more research need to be done to develop a theory of technological change and economic growth.

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Figure 1: ICT diffusion in New Zealand

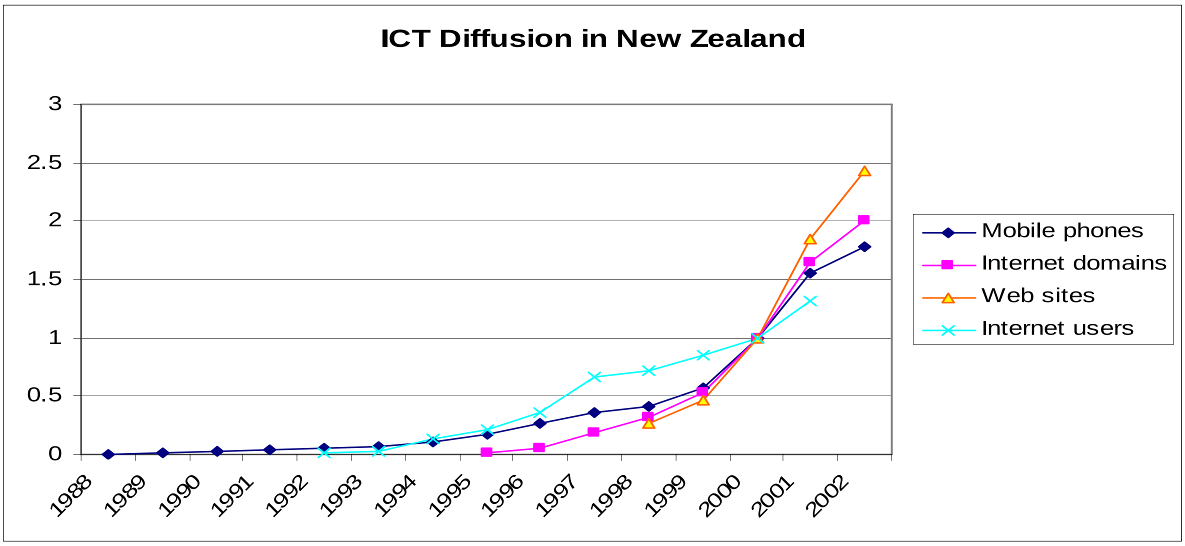

Figure 2: Economic Growth rates of TFP and Mobile Phone Diffusion rate

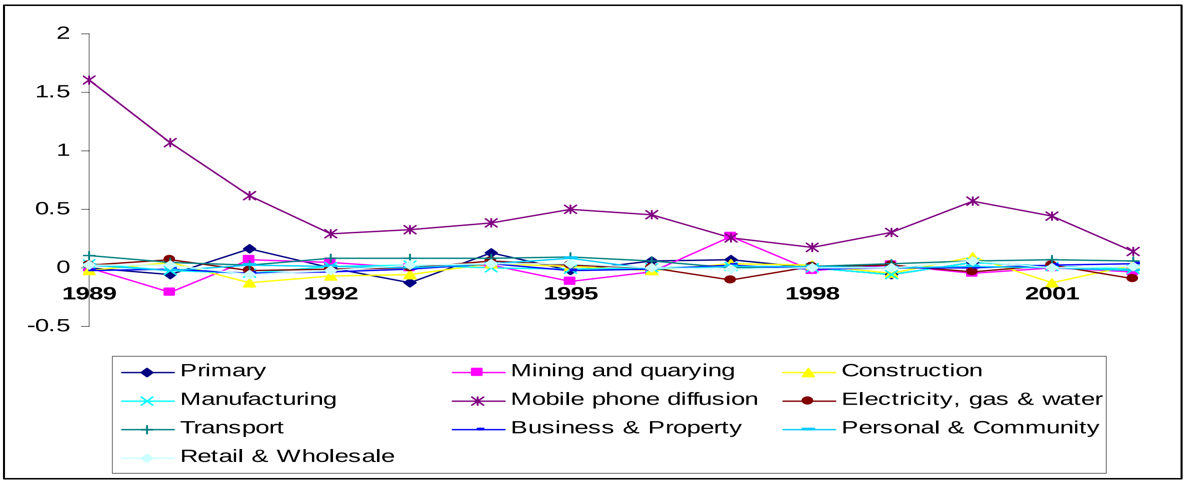

Table 2
Correlation coefficients and *t* statistics and average growth rates of TFP for each industry

SECTOR	Corr	't' ratio	Ave. TFP growth	Ave. diffusion rate
Primary	0.00	-0.08	0.01	0.51
Mining and Quarrying	-0.09	-1.19	0.00	0.51
Construction	0.00	0.08	-0.02	0.51
Manufacturing	0.02	0.74	0.00	0.51
Electricity, gas and water	0.05	1.44	0.00	0.51
Transport and communications	0.03	1.36	0.06	0.51
Business and property services	-0.03	-1.49	0.00	0.51
Personal and community services	0.00	0.13	0.01	0.51
Retail and wholesale trade	0.01	0.65	0.01	0.51