AUSTRALIAN USE OF INFORMATION TECHNOLOGY AND ITS CONTRIBUTION TO GROWTH

John Simon and Sharon Wardrop

Research Discussion Paper
2002-02

January 2002

Economic Research Department
Reserve Bank of Australia

We would like to thank Harry Bloch, Don Brunker, Jacqui Dwyer, David Gruen, Carl Obst and Dean Parham for helpful comments. Preliminary results from part of this research were reported in Gruen (2001). The views expressed in this paper are those of the authors and should not be attributed to the Reserve Bank of Australia.

Abstract

This paper investigates the gains from the use of information technology in Australia during the 1990s using a growth accounting framework. We make use of new industry-level estimates of the productive capital stock. Our analysis suggests that Australia has done well out of the 'new economy'. Its use of computer technology is amongst the highest in the world with Australian business investment in computer and related equipment growing rapidly since the early 1990s. Computer use has not been uniform throughout the economy but concentrated in more service-oriented sectors such as telecommunications, and finance and insurance. Additionally, we find that around one-half of the gains from the use of information technology can be attributed to price falls while the other half can be attributed to higher nominal expenditure. We arrive at the conclusion that Australia has experienced significant output growth related to computer use and has benefited from the technological advances in the sector through lower prices passed on to users. Thus, we conclude that there are substantial benefits to be gained from being a net user of computers as well as the more commonly mentioned benefits from being a producer.

JEL Classification Numbers: D24, E22, O30, O33, O47

Keywords: Australia, growth accounting, information technology, productivity

Table of Contents

AUSTRALIAN USE OF INFORMATION TECHNOLOGY AND ITS CONTRIBUTION TO GROWTH

John Simon and Sharon Wardrop

You can see the computer age everywhere but in the productivity statistics
– Robert Solow

There are lies, damn lies and statistics
– Popular aphorism

1. Introduction

During the stock market volatility of 1999 and 2000 much was made of whether certain economies were 'new economy' or 'old economy'. 'New economy' countries were those that had a significant high-tech production sector, 'old economy' countries were the rest. In the hype surrounding the 'new economy' stock returns for high-tech firms soared.[1] Consequently, the stock markets of 'new economy' countries soared while 'old economy' stock markets delivered more pedestrian returns. It was generally assumed that stock market returns reflected the productivity of the broader economy and that high-tech production was delivering big productivity gains to certain countries while 'old economy' countries were largely being left behind. As the events since April 2000 demonstrate, however, equating stock market performance with real economy performance can be dangerous in the presence of an asset price bubble.

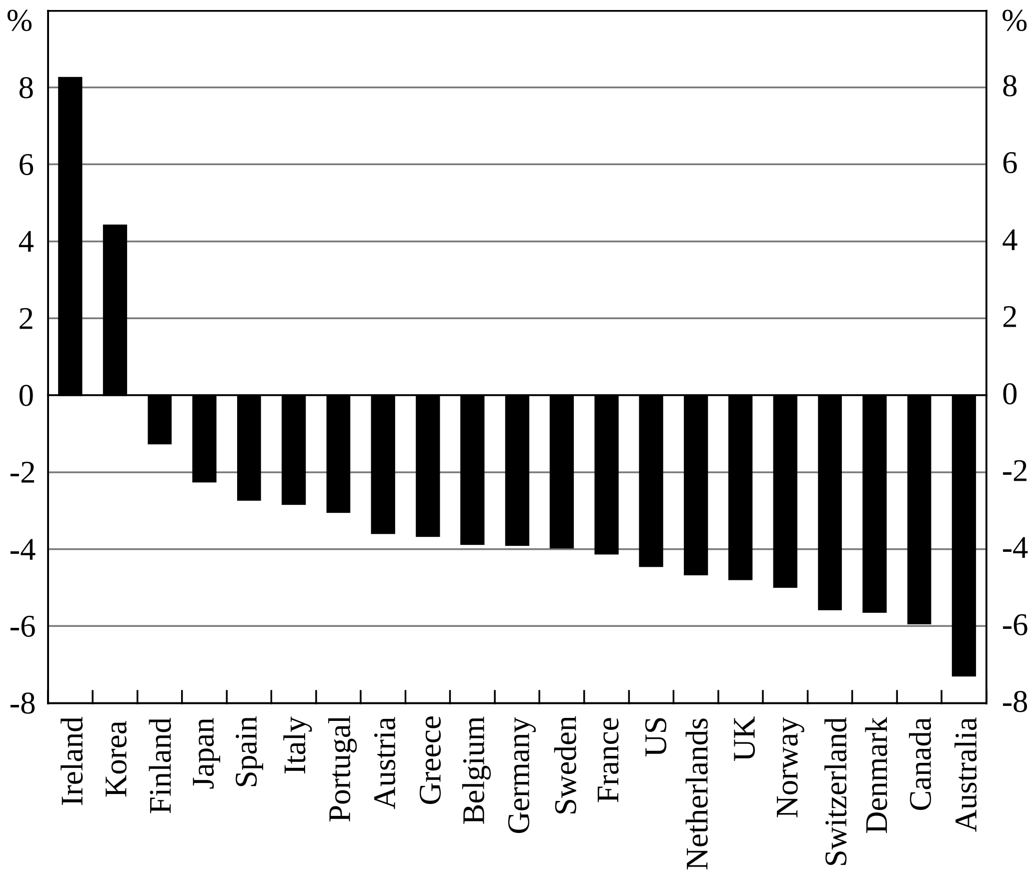
Australia, as an economy that was unequivocally dubbed 'old economy', makes an interesting case study. Australia does not have many specifically high-technology firms. Furthermore, Australian manufacturing of high-tech products is limited. Notwithstanding this, Australia is amongst the world's heaviest users of high-tech

1 Indeed, investors were so discerning that any company with a 'dot com' in its name did well. See Cooper, Dimitrov and Rau (1999) for details.

products. The use of new consumer electronic devices, most notably mobile phones, is high by world standards. The following two figures highlight these aspects of high technology in Australia. Figure 1 illustrates the imbalance between production and consumption, while Figure 2 compares Australian use of IT with the rest of the world.

Figure 1: Net Exports of Information Technology in 1997

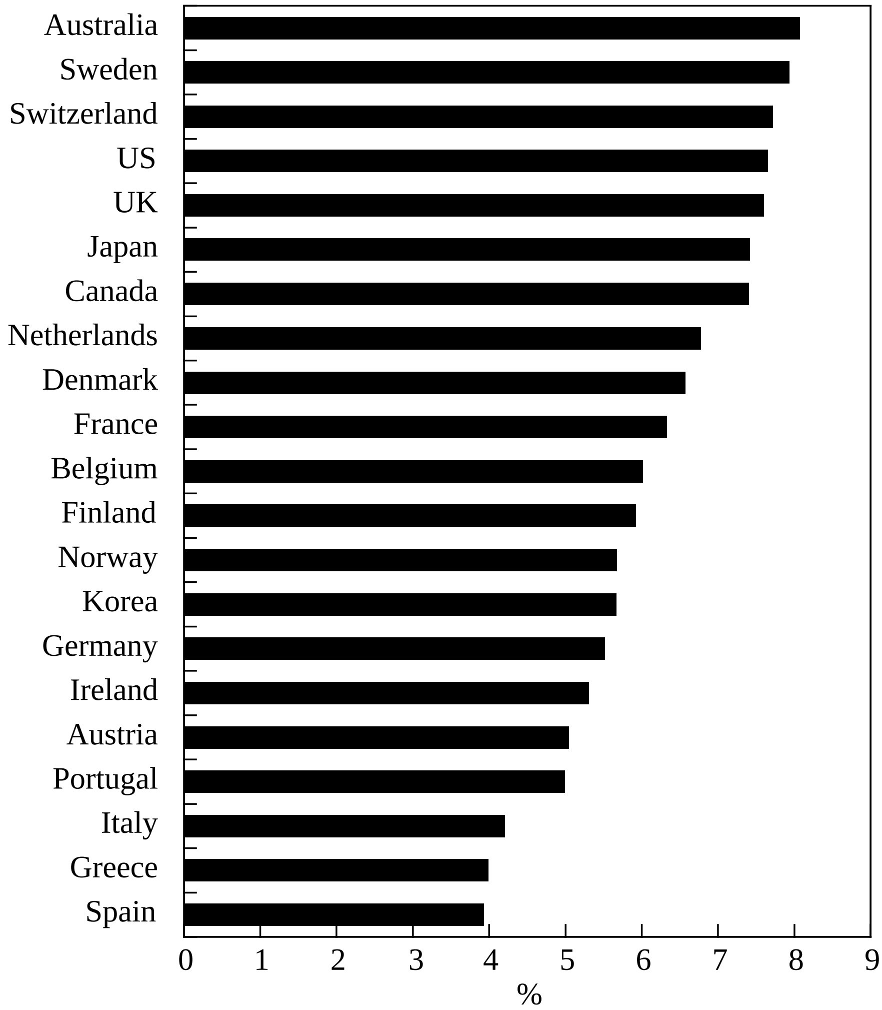
Production minus expenditure as a per cent of GDP



Notes: Data collected by International Data Corporation and provided to the authors via the OECD. Similar data have been published in the 1998 World Information Technology and Services Alliance (WITSA) report 'Digital Planet: The Global Information Economy' and the October 2001 IMF *World Economic Outlook*.

Figure 2: Information Technology Expenditure in 1997

Per cent of GDP



Note: As for Figure 1

The imbalance shown in Figure 1 has been a source of concern. If manufacturers and inventors of high-tech products capture much of the benefit from their products then Australia is largely missing out on the high-tech revolution. On the other hand, if users of high-technology goods capture much of the benefit, there are grounds for optimism. Australia, as one of the strongest adopters of IT, could also be one of the greatest beneficiaries from the high-tech revolution.

The view that users are large beneficiaries of the IT revolution has not enjoyed much currency. Nonetheless, a recent OECD report (OECD 2001) concluded that 'The key to benefiting from ICT [Information and Communications Technology] is to focus on policies to foster its use, rather than its production' – and it identified Australia as a country that had done exactly that.

In the hype surrounding the 'new economy' the distinction between simple production of a good and innovation was largely ignored. Production without associated gains in innovation, research and development has limited benefit. However, just as production may lead to greater innovation, so use of high technology may spur innovation. The difference is that the benefits to producers are likely to accrue within the industry while users may be more widely spread.

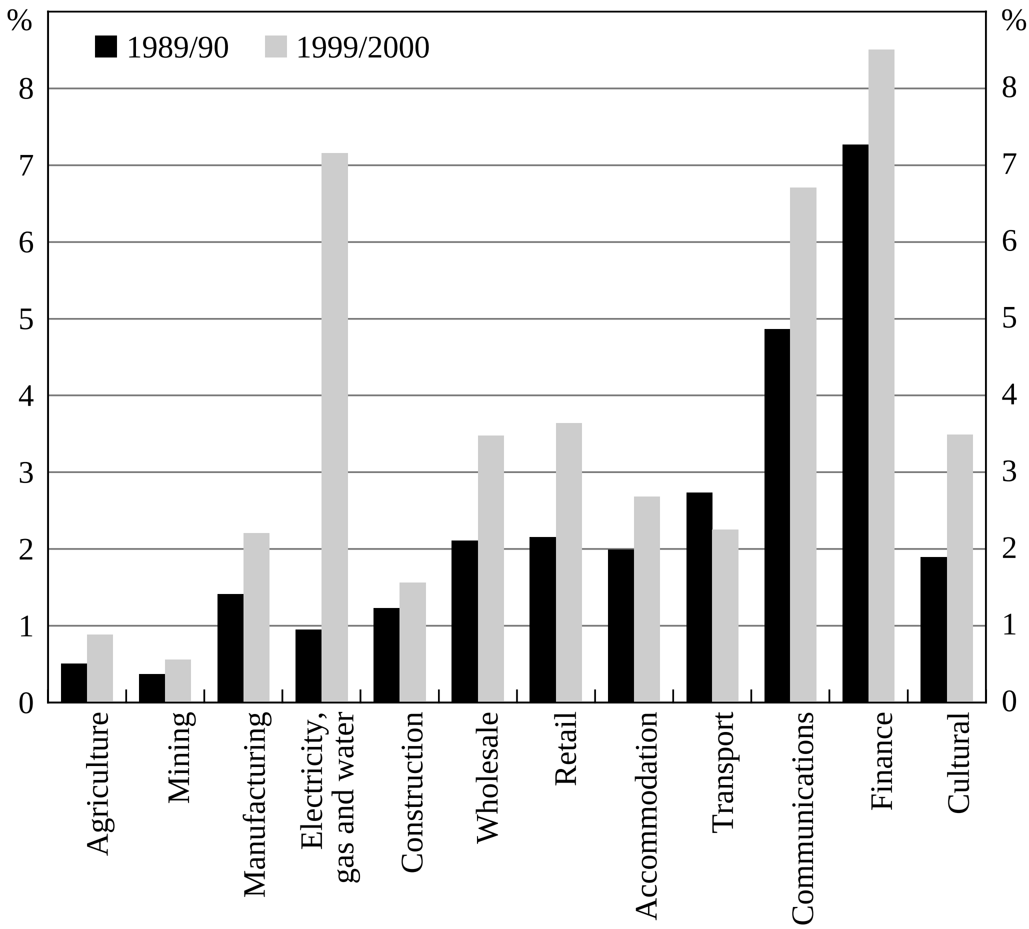
This paper looks at the historical gains from the use of information technology in Australia. Our analysis suggests that Australia has done well out of the 'new economy'. However, while Australia has high overall use of computer technology, this is not evenly spread across industrial sectors. Figure 3 shows nominal investment as a percentage of gross value added (GVA) by sector for the financial years 1989/90 and 1999/2000.

This dispersion reveals some interesting patterns. Traditional primary and secondary industries are not heavy direct users of information technology; instead service-based sectors have been the strongest adopters. Thus, the gains from information technology may not have been evenly distributed through the economy. We return to this issue when we discuss the industry results below.

The remainder of this paper is structured as follows. Section 2 provides a review of the previous literature before Section 3 discusses the relevant theory and some issues with the analysis. Section 4 discusses the data and other practical issues before Section 5 presents the results. Section 6 considers two interesting questions. The first, 'What is the counterfactual?' considers what would have happened if the computer industry had not been characterised by the rapid price falls that epitomise the industry. The second looks at whether there are any detectable spillovers from the use of IT to multifactor productivity (MFP) growth. Section 7 discusses the findings more generally and compares them with previous results before Section 8 concludes.

Figure 3: Investment to Output Ratios by Sector

Nominal investment in hardware and software as a per cent of GVA



2. Previous Research

Although there have been a number of active contributors to the literature in the US there have been comparatively few studies based on experiences in other countries. For the most part this reflects data availability; the US is one of only a few countries with sufficient data to perform the growth accounting exercises required by this type of project.[2]

Within the US, Oliner and Sichel (1994, 2000) have been prominent contributors to the literature. They find that the contribution of the use of information technology, i.e., computer hardware, software and communication equipment, to

[2] Thankfully, Australia is another.

productivity growth grew rapidly in the second half of the 1990s. They also find that technological advances in the production of computer-related goods have contributed to the higher productivity growth rates witnessed in the second half of the decade. More specifically, they estimate that the use of information technology related goods (contributing 0.5 per cent) and the advances in the production of computers (contributing 0.25 per cent) accounted for around three-quarters of the 1 per cent increase in labour productivity growth between the first and second halves of the 1990s in the US.

Gordon (1999) reaches a very different conclusion. He argues that the production of computer hardware accounts for the entire increase in *trend* labour productivity between the first and second halves of the 1990s. This implies that the *use* of computers contributed nothing to the growth in trend productivity. Of the 1 per cent increase in measured labour productivity throughout the decade he attributes 0.7 per cent to cyclical factors and the remaining 0.3 per cent to increased productivity of computer producers. This implies trend productivity growth in the US has remained roughly constant throughout the 1990s outside the computer-related sectors.

In October 1999 the US national accounts were revised and this led Gordon to modify his findings. Nonetheless, Gordon (2000) reaches similar conclusions to his earlier paper. In addition he argues that information technology has not had as large an effect on output growth as did the wave of great innovations introduced around the turn of the century such as electricity and the internal combustion engine. He argues that computer demand has primarily risen as a consequence of lower prices, that much of the development of the Internet represents a substitution away from, or a duplication of, pre-existing activities, and that much of the investment in new technology simply represents a defence of market share by incumbents rather than a conscious effort on behalf of firms to increase investment more generally. Furthermore, comparing the periods 1972–1995 and 1995–1999, he argues that much of the rise in productivity seen in the second half of the 1990s reflects an unsustainable cyclical effect and is not a direct result of higher investment in computers. Specifically, he estimates that of the 1.4 per cent increase in productivity growth since 1972–1995, 0.6 represents a cyclical effect. He attributes the entire remainder to faster multifactor productivity growth in computer-related sectors and suggests that there has been no revival in productivity growth rates in other sectors.

Jorgenson and Stiroh (2000) do not use a growth-accounting framework in their analysis; nevertheless they reach a similar conclusion to Oliner and Sichel (1994, 2000). They find that computer, and more generally information technology, investment can account for a large portion of the productivity growth that spurred the accelerated output growth in the late 1990s. They argue that rapid progress in semiconductor technology made it possible for downstream industries to reduce prices, enabling households and firms to invest in high-tech assets, which in turn drove strong output growth. However, they maintain that, while the production of high-tech products is a driving force behind recent productivity growth within the high-tech sectors, it generally does not spillover into other industries. Finally, they highlight the uncertainty surrounding the sustainability of rapid progress in high-tech industries and recognise the effect that lower productivity growth in tech-producing sectors and slower capital accumulation by high-tech-using sectors would have on growth.

Other studies for the US have generated more divergent estimates of the contribution of computers to growth. Whelan (2000) estimates that the use of computer hardware contributed 0.8 per cent to output growth between 1996 and 1998. This is higher than others' estimates.[3] This is primarily due to a difference in measurement rather than concept. In particular, Whelan's measure of the capital stock is around one-third larger than the one used by Oliner and Sichel. This increases his estimate of the income share and in turn the contribution to growth of computer capital. Whelan's capital stock is larger because he does not allow for any loss of efficiency in the productive capital stock before retirement whereas Oliner and Sichel make this adjustment.

Kiley (1999) on the other hand concludes that computer hardware has consistently detracted from growth since the mid 1970s. This stems from his assumption that there is an installation cost to new investment that detracts from growth. He argues that investment in computers involves high installation costs and, consequently, a negative contribution of computers to growth. He estimates that in the steady state the contribution from computers will be around 0.5 per cent per year. Although there may be some significant costs involved when installing new types of software and hardware, it is arguable whether they are as large as Kiley suggests.

3 For comparison, Oliner and Sichel (2000) estimate the contribution to be 0.6 per cent in the second half of the 1990s.

Generally, the literature from the US suggests that there are gains to be had from both the production and use of high-tech goods. Roughly speaking, of the 1 per cent increase in productivity growth between the first and second half of the 1990s, around half of the acceleration can be assigned to the use of IT-related goods and around a quarter to advances in the production of computers. That said, productivity developments tend to be restricted to the computer-related sectors. Evidence suggests that there has been little, or no, revival in the productivity growth rates of other sectors attributable to the accelerated growth in high-tech industries in the US economy.

Although the US has been the predominant source of research there has also been some work conducted on this issue in the UK. As an alternative to the traditional historical growth accounting framework, Bakhshi and Larsen (2001) develop a dynamic general equilibrium (DGE) model to distinguish between investment-specific and sector-neutral sources of labour productivity growth for the UK economy. This approach emphasises the importance of substitution effects. That is, that rapid technological progress in the production of a given good, say high-tech products, leads to falling prices and increased investment, i.e., substitution towards computers. Using their DGE model, they find that technological progress in high-tech industries may account for around 25 per cent of labour productivity growth in the long run. Although they identify the effect that progress in the *production* of high-tech goods may have on productivity growth, they make no reference to the contribution that the *use* of high-tech goods may have on productivity and consequently output growth.

In Australia there have been only a few investigations of the effect of computers on productivity growth. The Productivity Commission (Parham, Roberts and Sun 2001) investigates the role of information technology in the output and productivity growth of the Australian economy and compares it with the US experience. In Australia, the contribution of information technology to labour productivity growth began to accelerate around 1996. They also find that a large proportion of new investment has been in the form of IT capital. Thus, firms have generally been replacing older non-IT capital with IT capital. They provide evidence in support of the view that there are productivity gains to be had from the use of high-tech goods and not just from their production. The Productivity Commission's report also investigates the MFP gains from information technology use. They find that finance and insurance, and wholesale trade display a positive relationship between IT use and MFP growth. They cannot detect a consistent relationship for other industries.

Wilson (2000) tells the story that extensive policy reform over the last 15 years has led to what he calls the ‘first wave’ of productivity improvements for Australia and that the effect of new economy developments could allow us to benefit from a ‘second wave’ of productivity gains in years to come. He estimates that this ‘second wave’ could add anywhere between 0.5 and 0.8 per cent to Australia’s annual productivity growth rate over the next ten years. This is attributed to increased investment in computer equipment and the growing use of e-commerce by business.

Toohey (2000) analyses the contribution that investment in information technology has made to Australia’s productivity performance and benchmarks his findings to the US experience. His results suggest that although both the US and Australia experienced stronger output growth over the second half of the 1990s, information technology investment contributed 0.25 per cent per annum more to growth in the US than in Australia. This is due to the rapid build-up of computer hardware in the US relative to Australia. He finds that the US and Australia are remarkably similar in terms of IT’s contributions to growth, and that, although labour accumulation was a stronger contributor to US economic growth than to Australia’s, MFP growth was stronger in Australia in the second half of the 1990s than in the US.

Wilson (2000) and Toohey (2000) both present estimates based upon the ABS’s published capital stock numbers. For reasons that will be explained below these data create a number of conceptual problems and so lead to problems interpreting or comparing the numbers with, for example, the US studies. This paper represents the first attempt to use the appropriate capital stock measures for Australian data.

3. The Theory

3.1 Growth Accounting

The method used to identify the effects of capital, labour and productivity on growth was introduced by Bob Solow in 1957 (Solow 1957). The underlying principle is quite simple and best understood with reference to a Cobb-Douglas production function. Nonetheless, the derivation below does not rely on any feature of this production function other than it being homogenous of degree one, that is, it displays constant returns to scale.

Suppose output is produced according to Equation (1):

$$Y = A \cdot F(K, L) \tag{1}$$

where A denotes the level of productivity and K and L are factor inputs of capital and labour. Output growth can be decomposed by taking a total derivative of Equation (1):

$$dY = AF_K dK + AF_L dL + \frac{Y}{A} dA \tag{2}$$

Rearranging gives:

$$\dot{Y} = \frac{F_K K}{F(K,L)} \dot{K} + \frac{F_L L}{F(K,L)} \dot{L} + \dot{A} \tag{3}$$

where dots over a variable denote the proportionate change, i.e., $\dot{Y} = dY/Y$.

Profit maximisation allows us to make some further simplifications. The first order conditions from a firm's profit maximisation problem are:

$$\begin{aligned} pAF_K &= r \\ pAF_L &= w \end{aligned} \tag{4}$$

where r is the rental rate of capital (which includes depreciation) and w is the wage rate.

Manipulating these expressions we get:

$$\begin{aligned} \alpha &\equiv \frac{wL}{pY} = \frac{pAF_L L}{pY} = \frac{F_L L}{F(K,L)} \\ \beta &\equiv \frac{rK}{pY} = \frac{pAF_K K}{pY} = \frac{F_K K}{F(K,L)} \end{aligned} \tag{5}$$

Further, assuming that the function exhibits constant returns to scale, we know that:

$$\begin{aligned} & F_K K + F_L L = F(K,L) \\ & \Rightarrow \frac{F_K K}{F(K,L)} = 1 - \frac{F_L L}{F(K,L)} \\ & \Rightarrow \alpha = 1 - \beta \end{aligned} \tag{6}$$

Thus, we can write the decomposition as:

$$\dot{Y} = (1-\alpha)\dot{K} + \alpha\dot{L} + \dot{A} \tag{7}$$

where α is the labour share of income as given in Equation (5). Given measures of capital stock growth, labour input growth, labour's share of factor income and output growth, productivity growth is derived as a residual.

If more than two factors are considered it is a simple matter to expand the production function to include other inputs and the resulting formula is practically identical. In particular, capital can be broken into computer capital and other capital. This leads to a decomposition of the form:

$$\begin{aligned} & \dot{Y} = \beta_c \dot{K}_c + \beta_o \dot{K}_o + \alpha\dot{L} + \dot{A} \\ & \alpha + \beta_o + \beta_c = 1 \end{aligned} \tag{8}$$

where K_c represents computer capital and K_o represents other capital.

3.2 Aggregation Issues

As we are using industry-level data the aggregation method is relevant.[4] Suppose, for now, that the economy can be divided into two industries, 1 and 2, and that the only inputs to production in each sector are capital and labour. Three broad ways of aggregating the data can be considered:

$$Y = A_1 K_1^{\alpha_1} L_1^{\beta_1} + A_2 K_2^{\alpha_2} L_2^{\beta_2} \tag{9}$$

$$Y = AK^{\alpha} L^{\beta} = A\left(K_1^{\frac{\alpha_1}{\alpha}} K_2^{\frac{\alpha_2}{\alpha}} \right)^{\alpha} \left(L_1^{\frac{\beta_1}{\beta}} L_2^{\frac{\beta_2}{\beta}} \right)^{\beta} \tag{10}$$

$$Y = A(K_1 + K_2)^{\alpha} (L_1 + L_2)^{\beta} \tag{11}$$

In the first, economy-wide output is the sum of output produced in each industry. Here, the output produced in each industry is a function of capital, labour and the level of technology in that industry. We will use this method in this paper. The second can be thought of as a standard economy-wide Cobb-Douglas function where the capital and labour inputs are an index based upon individual industry capital stocks and employment. This method assumes that capital and labour are complementary across industries as well as industry output.[5] In the last there is still an economy-wide production function but the aggregation of capital and labour is different. In this case, capital and labour inputs are summed across industries. This functional form assumes that capital and labour are substitutable across industries. However, this assumption is not normally used when industry-level data are available. Implicit in this functional form is the assumption that there is no difference between capital or labour across sectors; this does not seem highly likely. Nonetheless, because they lack industry-level data, Oliner and Sichel (2000)

---

4 Even though we use a Cobb-Douglas production function to illustrate the various methods of aggregation, the approach we use does not require this assumption – the only condition we require is constant returns to scale. Nonetheless, Carmichael and Dews (1987) find that the Cobb-Douglas functional form is a reasonable first approximation for an empirical economy-wide production function for Australia.

5 Equation (10) could be rearranged to look like $Y = AY_1Y_2$ where $Y_1 = K_1^{\alpha_1} L_1^{\beta_1}$. The complementary nature of industry output is clearer in this case.

implicitly use this method. Finally, one could combine the aggregation methods in Equations (10) and (11) to produce a production function like:

$$Y = AK_1^{\alpha_1} K_2^{\alpha_2} (L_1 + L_2)^{\beta} \tag{12}$$

This is, fundamentally, the specification the ABS uses when it publishes its estimate of productivity growth in the national accounts.[6]

As each aggregation method makes different assumptions regarding the way the economy is 'structured', slightly different measures of output, capital and labour indices, and productivity will result. While none is perfect, we choose to use the method in Equation (9) due to larger problems with the other approaches. An additional reason for choosing this approach is because it means that industry-level results and aggregate results are consistent. To generate industry-level results one must use industry-level production functions like those in Equation (9). Changing to a function like Equation (10) or (11) to generate aggregate results would then involve a fundamental change in assumptions. Thus, aggregate MFP calculated using Equations (10), (11) or (12) would bear no particular relation to industry-level MFP.

The problem with the capital indices in Equations (10) and (12) is that changes in the distribution of capital, or productive units (including both capital and labour), across sectors can induce changes in the index even if there is no change in the aggregate amount of capital in the economy.[7] It is also possible for the capital stock to grow in every industry but for the index to decline.[8] We find this feature undesirable and, thus, choose an alternative method of aggregation. Equation (11), on the other hand, makes no distinction between industries or about the distribution

6 The estimates referred to are the experimental productivity measures published in the Annual National Accounts, ABS Cat No 5204.0. These can be found in Table 20 of the 2000-01 National Accounts.

7 The following numerical example may help to illustrate the point. Suppose that there are five units of capital, four in Industry 1 and one in Industry 2. Also, suppose that there is no labour involved in the production process and that the coefficients reflect income shares – an assumption that comes directly from assuming that firms maximise profit. By moving one unit of capital from Industry 1 to Industry 2 the capital index and output would be decreased since $4^{4/5}1^{1/5} > 3^{3/5}2^{2/5}$. This seems an undesirable property.

8 The following numbers may help to illustrate this point: $20^{20/21}1^{1/21} > 21^{21/23}2^{2/23}$. The assumptions are the same as in the previous footnote.

of inputs across industries. Thus, output is unaffected if all the labour is concentrated in one industry or spread evenly across all industries regardless of the distribution of capital. However, as mentioned above, this equation is only given to show the implicit aggregation method used when industry-level data are unavailable. Finally, since Equation (12) inherits problems from both of the other methods we also choose to avoid it. Nonetheless, to provide an estimate of the effect our choice has on the aggregate results we present results from using the alternative formulations in Section 5.2.

3.3 Alternative Assumptions

While it has been standard in the literature to assume constant returns to scale and profit maximisation, it is conceivable that these assumptions may not hold. Since Hall (1988) demonstrated that macroeconomic data in the US are inconsistent with the joint hypothesis of constant returns to scale and marginal cost pricing, the assumption of constant returns to scale has been under pressure. Unfortunately, attempts to quantify the degree of departure from constant returns to scale and reconcile this with observations about industry structure have been unsatisfactory. For example, if industries exhibit increasing returns to scale, theory would suggest that they would tend towards monopolisation; however, very few industries are, in fact, monopolised. Investigating the returns to scale of Australian industries would be a worthwhile project but is beyond the scope of this paper. We proceed by making the standard assumption of constant returns to scale while acknowledging that our findings would need to be revised if significant departures from constant returns to scale for Australian industries are demonstrated in the future.

Strictly interpreted, the assumption of profit maximisation in this work implies that firms adjust their inputs to profit maximising levels every year. If adjustment takes longer than a year, because there are costs to adjustment or new technologies take some time to be adopted, this will not be true. In particular, firms may have levels of computer capital that are below the profit maximising level in certain years due to limits on their speed of adjustment. In this case the marginal value product of computer capital will exceed its price. This could lead to a systematic overstatement of MFP growth and understatement of the contribution of computer capital to growth. This phenomenon is part of a broader problem with the measurement of computer productivity and embodied technical change. Specifically, if the quantity of computer capital is understated due to problems in estimating the degree of embodied technical change (i.e., comparing the output from this year's 2GHz Pentium 4 with last year's 1GHz Pentium III) a similar understatement of computer capital's contribution to growth and overstatement of MFP growth will result.[9] It is difficult to assess the extent of this problem. To address this issue we consider whether there is any consistent correlation between computer use and MFP growth across industries in Section 6.2. As argued above, problems with measurement or adjustment costs should show up in a correlation between computer use and MFP growth. The results from Section 6.2, that there is no discernable correlation, suggest that this problem may not be a significant source of error in our calculations. However, the difficulties involved in the whole exercise mean that the problem may just be well disguised – we are far from dogmatic about this point. Nonetheless, the results in Section 6.2 suggest there is no *prima facie* case for systematic errors distorting the MFP growth and computer contribution numbers.

4. The Data

While the theory used in this paper is relatively straightforward, the practice is more complicated. Getting adequate measures of the capital stock is not easy. Furthermore, the task is made more complex since, for the purposes of growth accounting, a slightly different measure of the capital stock to that which is normally used is needed. The capital stock traditionally reported in national accounts statistics is the *wealth* capital stock whereas the capital stock required for growth accounting exercises is the *productive* capital stock. The distinction is that the wealth capital stock measures what the stock could be sold for at a given point in time whereas the productive capital stock measures its income-producing capacity. A simple example may illustrate the difference more clearly: suppose the capital stock consists of two computers – a two-year-old Mac and a new Pentium. Suppose, furthermore, that computers last for four years and then cease to function with no residual value (except, perhaps, as a paperweight or modern art). Finally, assume that there is no decline in computer efficiency with age. If the two computers have the same output then the current *income* capital stock would be 2 Pentium equivalent units. The *wealth* capital stock, however, would be less. The

---

9 Of course, computer capital could be overstated but understatement seems the more likely problem.

two-year-old Mac only has half its service life left and so, abstracting from discounting, the *wealth* capital stock is only 1½ Pentium equivalent units.

It is possible to relax the assumption that computers maintain full efficiency throughout their life. Making different assumptions about the decline in efficiency of computers leads to a slight change in the arithmetic and more substantial effects on the calculated capital stocks. Nonetheless, this assumption does not affect the concepts involved.

The data used in this exercise are unpublished ABS estimates of the productive capital stock and rental returns to different types of capital, all broken down by industry within the market sector.[10] The ABS makes an adjustment for declining efficiency over the life of the capital in addition to calculating the appropriate productive capital measure. Conceptually, these estimates are the same as those of the BLS in the US, whose data has been used by most US researchers in this field. Nonetheless, there are still a number of assumptions that differ between the two estimates that make direct comparison problematic. Furthermore, it is important to note that the results are sensitive to the underlying assumptions for which no good benchmarks exist.

A further limitation in the accounts at the industry level is the apportionment of taxes and subsidies on products. Currently the ABS values industry output at basic prices, i.e., excluding taxes and subsidies on industry outputs but including taxes and subsidies on their production. Their rental income estimates, on the other hand, include taxes and subsidies on products. Ideally we would like all the components of the calculation to be valued on a consistent basis. However, while this is a problem, there are reasons to suspect that the effect may be limited. The growth-accounting exercise is primarily concerned with growth rates rather than levels. To the extent that taxes and subsidies are proportional to output this should not affect the industry-level growth estimates. Furthermore, it is a simple matter to check the size of the effect at the aggregate level since the ABS publishes the growth rate of gross value added (GVA) for the market sector valued at both basic

10 We are grateful to the Capital, Production and Deflators Section of the ABS for providing these data. The data obtained covered the period 1964/65–2000/01.

and market prices.[11] This comparison indicates that in any given year the difference could be up to 0.5 per cent. However, over the longer term the differences tend to average out. Thus, between 1989/90 and 1999/2000 the average annual growth rate only differs by 0.1 per cent.

The apportioning of taxes and subsidies also has an effect on the estimate of the capital share of income at the industry level. The ABS capital income estimates include taxes and subsidies on products while the published gross value added by industry estimates do not. This leads to an overestimate of the capital share of income. Lacking estimates of GVA at market prices by industry, it is difficult to be certain of the size of the effect. Nonetheless, an idea of the size of the mismeasurement can be gained in aggregate. Taxes and subsidies on products are, on average, 7–8 per cent of GVA valued at basic prices. This suggests, with an average capital share around 40 per cent in Australia, that the estimate of the capital share may be up to 3 percentage points too high. This figure does, unfortunately, vary by industry as products from some industries receive significant subsidies while others incur significant taxes. For the time being this paper proceeds by noting that the final estimates are based on a capital share that may be up to 3 percentage points too high and, consequently, that the contribution of capital may be overstated by an average of 7–8 per cent and that the contribution of labour may be understated by a similar amount. This could have flow-on effects to the residual MFP component but the size of this effect will depend upon the growth rates of capital and labour and so is not readily estimable. Nonetheless, given the other sources of error in these estimates, an 8 per cent variation will not significantly alter any of the conclusions.

5. Results

With the appropriate data assembled it is a simple matter to calculate income shares, growth rates and the residual, multifactor productivity. In line with previous practice the income-share weights used in the growth-accounting exercise are averages of the income shares in the two years the growth is measured over.

---

11 The growth rate of real GVA valued at market prices is published in ABS Cat No 5204.0 (2000–2001), Table 20. The growth rate of real GVA valued at basic prices can be calculated from their published industry estimates contained in Table 10 of the same publication.

Thus, computer growth from 1990/91 to 1991/92 is weighted by the average income share of computers in these two years. This is, in part, an allowance for the fact that calculations are made at discrete intervals whereas the derivation is properly applied to continuous data.

To aid the exposition we begin by discussing the aggregate economy-wide results before moving on to the more detailed industry-level estimates. The aggregate results are generated by weighting the industry-level results together by their respective output shares. Specifically, assuming that there are two industries indexed by 1 and 2, total output is given by $Y = Y_1 + Y_2$ and all other terms are the same as in Equation (9), the overall contribution of capital to output growth can be calculated as:

$$\frac{Y_1}{Y}(1-\alpha_1)\dot{K}_1 + \frac{Y_2}{Y}(1-\alpha_2)\dot{K}_2 \qquad (13)$$

5.1 Aggregate Results

It is common practice to average results over a run of years due to the substantial variations in productivity that can occur in any given year. These variations are generally related to cyclical forces so the preferred period covers an entire productivity cycle; this way the cyclical forces should 'average out'. Most US studies have presented results averaged over the first and second halves of the 90s. As Parham *et al* (2001) argue, this choice can substantially distort the findings, as the periods involved are not complete cycles. Thus, we present results in this section for the period 1993/94–1999/2000, the latest productivity cycle as defined by the ABS. We do, however, present results using the 'traditional' split as well. Despite problems, this split still provides a useful picture of how IT investment has changed over the 1990s.

Table 1 presents the results for output growth and the various contributions to growth. It also presents memo items of the growth rate of the computer stock and other inputs. The time periods average the growth contributions calculated for each (financial) year in the sample. Thus, the first column presents the average of growth for the 1993/94 financial years through to the 1999/2000 financial years – as such it is based on levels data from 1992/93 through 1999/2000.

Table 1: Contributions to Growth

	1993/94–1999/2000	1990/91–1994/95	1995/96–2000/01
Output growth	4.51	1.78	3.86
Contributions from:			
IT capital	1.13	0.89	1.26
Hardware	0.70	0.42	0.84
Software	0.43	0.47	0.42
Other capital	0.62	0.15	0.60
Labour hours	1.09	–0.37	0.57
MFP	1.67	1.11	1.43
Income shares:			
Hardware	2.3	1.8	2.4
Software	2.5	2.4	2.5
Other capital	34.2	34.8	34.0
Labour	60.9	61.1	61.1
Growth rate of inputs:			
Hardware	36.7	22.0	36.9
Software	15.5	18.8	17.1
Other capital	1.1	0.2	1.0
Labour	1.5	–0.8	0.7

Note: All numbers are expressed as percentages per annum.

Generally speaking, we see that Australia has experienced extremely high levels of multifactor productivity growth in addition to significant gains from the ‘capital-deepening’ effects from computer technology. While MFP growth was the largest single contributor to growth between 1993/94 and 1999/2000, capital deepening attributable to computer use added over 1 per cent *per annum* to output growth.

Looking at the change between the first and second halves of the decade we see that MFP and labour use have been the primary sources of the acceleration in output growth. This partially reflects the fact that the first half of the sample includes a recession that was associated with labour reductions and lower rates of productivity growth. IT investment has been relatively steady over the decade accounting for only 0.37 per cent of the 2.08 per cent pickup in growth across the decade. That being said, the contribution of computer capital to growth has been at a very high level and contributes so little to the pickup because it was relatively unaffected by the early 1990s recession. What is also clear is the amazing growth in the stock of hardware and software. This has been sustained by both increasing nominal expenditure and large price falls fuelling an increase in real inputs. We will return to the split between these two forces in Section 6.

5.2 Robustness Checks

As mentioned above, the differing aggregation assumptions may lead to different estimates of MFP and the contribution to growth of computers. Table 2 compares the results using Equation (9), as already reported in Table 1, with those from using Equation (12), the ABS method.

Table 2: Comparison of Aggregation Methods

	1993/94–1999/00		**1990/91–1994/95**		**1995/96–2000/01**	
	This paper (Table 1)	Equation (12)	This paper (Table 1)	Equation (12)	This paper (Table 1)	Equation (12)
Output growth	4.51	4.70	1.78	2.07	3.86	4.04
Contributions from:						
IT capital	1.13	1.24	0.89	0.80	1.26	1.42
Hardware	0.70	0.77	0.42	0.35	0.84	0.88
Software	0.43	0.47	0.47	0.45	0.42	0.54
Other capital	0.62	0.40	0.15	0.29	0.60	0.35
Labour hours	1.09	1.20	–0.37	–0.07	0.56	0.77
MFP	1.67	1.86	1.11	1.05	1.44	1.50
Income shares:						
Hardware	2.3	2.3	1.8	1.8	2.4	2.4
Software	2.5	2.6	2.4	2.4	2.5	2.5
Other capital	34.3	36.7	34.7	37.0	34.0	36.6
Labour	60.9	58.4	61.1	58.8	61.1	58.5
Growth rate of inputs:						
Hardware	36.7	32.1	22.0	19.3	36.9	36.2
Software	15.5	18.9	18.8	19.2	17.1	21.7
Other capital	1.1	4.4	0.2	2.7	1.0	4.7
Labour	1.5	1.7	–0.8	–0.1	0.7	1.0

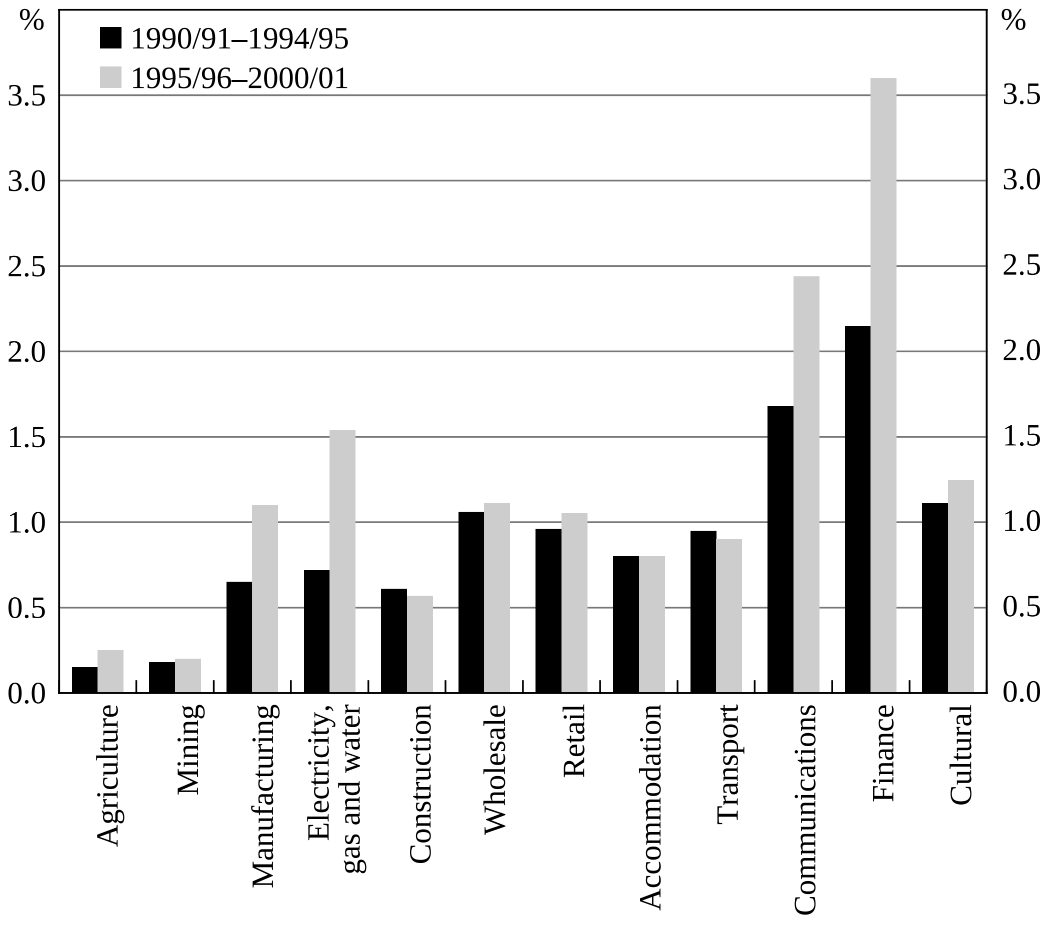
Notes: All numbers are expressed as percentages per annum. Differences in output growth rates are due to the treatment of taxes.

What we see is that there are few substantial changes in the picture. While individual results vary (up to 0.3 per cent in the case of labour hours in the first half of the 1990s) the broad sweep of the results is unaffected. On this basis we are reasonably confident about the robustness of our results to the particular aggregation method chosen.

5.3 Industry Results

Rather than look at all industries, we will focus on some pertinent results from certain industries to highlight the main findings. A table of the results for all industries can be found in Appendix A. The contribution of computers to growth by sector is presented in Figure 4 below.

Figure 4: Computer Contribution to Growth



Note: Contribution to growth measures the growth in output attributable to the growth of computer hardware and software capital as identified in Equation (8).

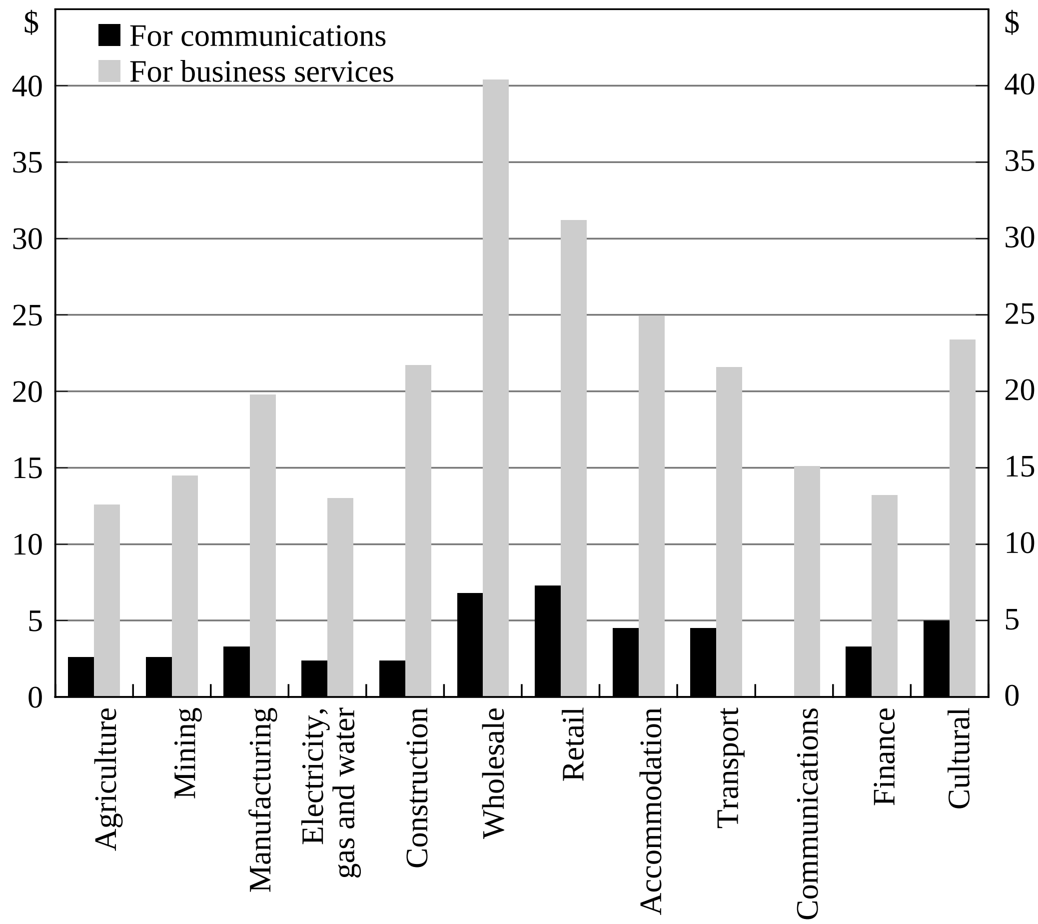
Looking at the broad patterns we see that traditional primary and secondary industries have not been significant beneficiaries from the IT revolution. That is, they have not incorporated high levels of IT capital directly into their production techniques. These results are more or less similar to the pattern of investment shown in Figure 3. The principal beneficiaries have been the service sectors, in particular communications and finance. This bias towards the service sectors is interesting. In the US most of the gains in productivity, and by implication the gains from computers, have been concentrated in manufacturing. This reflects the high level of computer and computer-related production in the US. Further evidence referred to by the Productivity Commission (Parham *et al* 2001) suggests that the gains from use have been concentrated in wholesale and retail trade, and finance, insurance and real estate. This suggests some overlap between the Australian and US experiences. At the same time, the results for electricity, gas and water (EGW) and communications highlight some results that are peculiar to Australia. These sectors have been deregulated as a part of the microeconomic reform undertaken over the 1980s and 1990s in Australia. The high levels of investment, particularly in computers, in these sectors would seem to be a product of this regulatory change.

Nonetheless, this pattern masks some important points. Examination of input-output tables for Australia allows us to identify the contribution of an input, say high-tech goods, to final output and the intensity of use of that input relative to others in the production process. This enables us to obtain a better indication of the effect on various industries from particular new economy goods and services. For instance, communication and business services incorporate much of the new economy. We can focus on the extent to which communication and business services are used as an input to production by industries to gain a better idea of the influence of high-tech capital on these industries. We do this by calculating the total requirement for inputs, including any intermediate use of goods and services, by industries as a percentage of final output for each industry. These 'total requirement coefficients' represent the dollar amount of an input required to produce $100 of final output for each industry.

Figure 5 shows that 'old economy' industries, while low direct users of IT, are high users of 'new economy' inputs. While it is difficult to separate IT services from other services, they are most likely to be concentrated in the communications and business services sectors. For example, web design firms are generally classified in the business services industry and Internet providers in the communications industry. Based on data for 1996/97, primary industries[12] used just under $3.00 of communications services and around $13.00 of business services for each $100 of output produced.[13] This usage is similar to that in manufacturing, EGW and construction. On average, service sectors used just under $4.00 of communications services and around $16.00 of business services to produce $100 of output. Thus, the gap in usage between primary and secondary sectors, and service sectors may not be as large as the results in Figure 4 suggest. Many primary sectors would seem to contract out their IT requirements.

Figure 5: Total Requirement Coefficients

Dollar amount of an input required to produce $100 of final output



12 Agriculture; forestry, fishing and hunting; and mining.

13 See Appendix B for a table of total requirement coefficients for each industry. We use data for 1996/97, as they are the latest available.

This highlights a fact that is obvious but deserves mention. The heaviest users of computer technology in Australia provide *services* to other industries. Thus, while the growth-accounting procedure we use highlights high MFP growth and large gains from capital deepening through computer usage in the communications sector, other sectors benefit through falls in telecommunications costs.[14] Similarly, large gains in productivity in retailing through the use of bar coding and scanning have translated into lower prices at supermarkets and faster checkout times.

Turning to specific industry results, the electricity, gas and water (EGW) sector results are particularly interesting. This industry experienced a decline in multifactor productivity yet a marked increase in IT investment. Looking more closely reveals that high rates of MFP growth in the first half of the 1990s were a product of significant job cuts in the industry. Hours worked declined by around ⅓ over the decade with most reductions coming in the first half. Similarly, currently low levels of calculated MFP growth are a reflection of very high levels of investment in IT capital. If these investments have not been fully integrated in the production process, it may be a few years before output responds. Nonetheless, the predominant force in this industry over the decade has been the dramatic structural reorganisation culminating in the privatisation of much of the sector. Given this change it is difficult to draw any strong conclusions about the performance of the sector.

Communications was similarly deregulated. This deregulation has spurred investment by many new participants as well as by the incumbent. The output growth effects of this high investment, seen in Figure 4, have been sustained for the past decade. In contrast to EGW there has also been significant MFP growth in communications throughout the decade (Appendix A). We address the extent to which these MFP patterns can be attributed to IT investment in the next section.

---

[14] The deregulation of national phone companies is obviously a major factor in phone call costs. Nonetheless, the development of computerised switching devices, fibre optic cables and the internet have all combined to make communications much easier and cheaper than they were previously.

6. Two Interesting Questions

Having covered the basic results from the growth-accounting exercise we turn to two more interesting questions.

6.1 What is the Counterfactual?

In assessing the benefit from computer use we have not explicitly considered what the alternative to computer investment may have been. Thus, discussion about the net benefit from information technology is difficult. This section constructs estimates of the net benefit from computers by making a number of assumptions. As with all counterfactual exercises these assumptions are not the only ones that could be made, but seem reasonable to us. As such the results they generate should be considered 'ballpark' figures rather than precise estimates.

We focus on what would have happened if the computer industry had not been characterised by the rapid productivity increases that are at the heart of the industry's uniqueness. We look at what would have happened to output if the computer price deflator had remained unchanged rather than falling rapidly as, in fact, occurred. The falls in the deflator reflect both improvements in the power of computers and falls in their price but the exact division between these two is unimportant. Specifically, we assume the same nominal spending on computers as occurred but compute a new series for real spending by assuming that the computer price deflator was flat from 1989/90. If the industry production functions are Cobb-Douglas this calculation will, in fact, reflect what fully optimising firms would have done – income shares of inputs remain constant regardless of relative price fluctuations. Alternatively, if the relevant industry production functions are not unit elastic then this will be an approximation.

Another way of considering this exercise is that we decompose the contribution of computers to output growth into the parts attributable to price falls and those attributable to increased expenditure. We take 1989/90 as the base year for these calculations as it marks the beginning of our sample. Using this interpretation it is possible to view the counterfactual as the situation that would have resulted if the producers of information technology had retained all of the productivity gains and not passed any on to users in the form of lower prices. This is, perhaps, the more relevant view of this exercise for Australia. It allows us to identify the technological and output gains Australia has realised solely from being a user of information technology, i.e., by focusing on those improvements in computer manufacturing that have been passed on to users in the form of lower prices.

Combining the nominal investment series with the new price deflator gives us a series for real investment. With the new series for real investment we calculate a series for the counterfactual capital stock. We approximate the depreciation function used by the ABS by computing the average depreciation on the capital stock for each industry in each year. Predictably, these steps result in a series for the productive capital stock that grows much more slowly than the actual. As we assume that firms are optimising each period the income shares calculated with the actual series should reflect the technological parameters of the production function, regardless of whether the underlying function is Cobb-Douglas or not. Thus, we use these same weights in calculating the contribution of computers to output growth in our counterfactual exercise.

6.1.1 Results

Table 3 presents the relevant results from this exercise:[15]

Table 3: Counterfactual Results – Computers' Contribution to Growth

	Counterfactual Per cent	**Actual** Per cent	**Difference** Per cent
1990/91–1994/95	0.64	0.89	0.25
1995/96–1999/2000	0.59	1.26	0.67

As the results make clear a substantial proportion of the gains from information technology have come in the form of lower prices. Because of our assumption in the counterfactual exercise that prices remain at 1990 levels the difference also grows with time. Prices for hardware fell by an average of 16 per cent per year over the 1990s to be six times cheaper in 2000 than in 1990. Thus, had productivity improvements not been passed on in the form of lower prices, output in Australia could have been lower by an average of $(0.25+0.70)/2 \cong 0.5$ per cent per annum.

[15] This table uses the most recent numbers available to us from the ABS, which, in this case, end in the 1999/2000 financial year.

Or, compounding the individual annual effects, output in 1999/2000 would have been 4.8 per cent lower than it actually was.

Viewed another way, this shows that Australia has benefited from intense competition in a sector where productivity advances are quickly passed on to users through lower prices. This finding does not suggest that there are no gains to producers and innovators in information technology, merely that users have received some fairly large benefits along the way – users have by no means been left behind in the IT revolution.

Another implication is also clear. Australia has increased its nominal spending on computers significantly. This increase in expenditure alone accounts for approximately 0.6 per cent per annum of output growth. This is the direct reflection of the increase in computer investment from just under 2 per cent of GDP in 1989/90 to over 3 per cent in 1999/2000 and the corresponding increase in computers' share of income (in the market sector) from 3.3 per cent in 1989/90 to 5.1 per cent in 1999/2000. This increase represents a sustained shift in production methods to more intensive use of computers. This raises the possibility that, in contrast to our assumptions, firms have been unable to fully adjust to the new technology optimally each year. We address this potential problem in the next section.

6.2 Is Computer Use Associated with Higher MFP Growth?

We now turn to the second question – are there spillovers from computer use to MFP growth? One reason that we might worry about spillovers is because of mismeasurement of the real capital stock. It is very difficult to measure the real quantity of computer capital. Comparing a 2GHz Pentium 4 with a 40GB hard drive and 128MB of RAM with a 1GHz Pentium III with a 20GB hard drive and 64MB of RAM is hard enough let alone trying to compare a Pentium 4 with a Macintosh G4. While the Bureau of Economic Analysis (BEA) in the US addresses some issues with its hedonic index, it is clearly imperfect. The rapid pace of improvement in information technology compounds these problems meaning that, even if a good estimate of the real capital stock at one point of time can be computed, it is likely to be inaccurate within a short period of time. Given the likelihood that computer capital is mismeasured some people have suggested that there may be a spillover of computer productivity into MFP estimates.

Alternatively, and potentially additionally, there may be disembodied technological change associated with computer use. Thus, computer use may be associated with new ways of organising business that are inherently more productive. In this case, productivity improvements would not be directly tied to the quantity of computer capital used but result merely from the fact that firms had reorganised their operations to use computers. In this case there may also be some correlation between MFP growth and computer use.

Thirdly, adjustment costs may mean that firms have less capital at a given point in time than the profit-maximising level. If this is the case, the marginal product of computers will be higher than measured through the growth accounting-technique. This, in turn, means that computers' contribution to growth will be understated and MFP growth overstated.

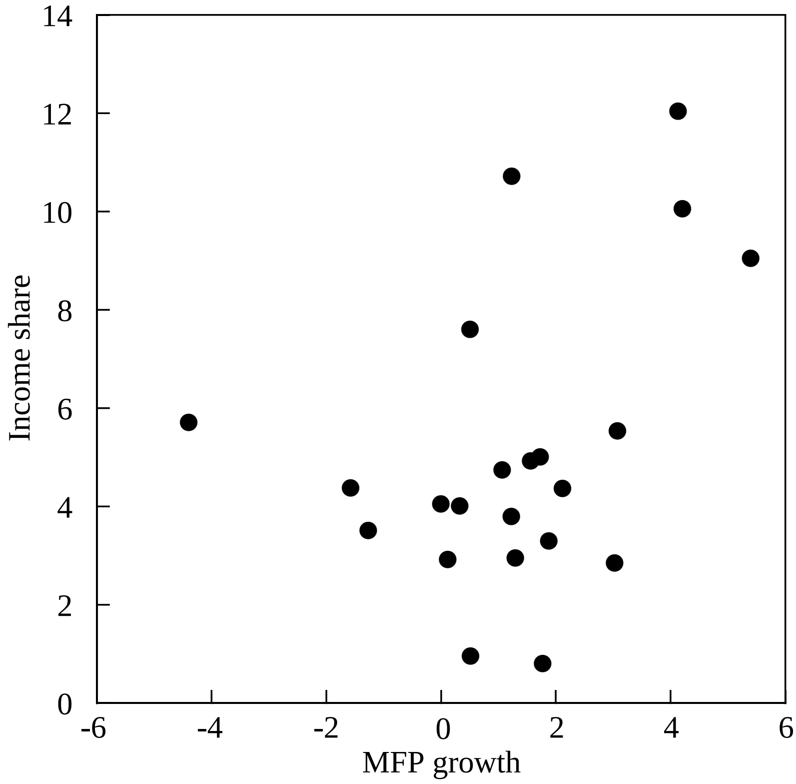
Finally, firms may have overinvested in computer capital. That is, firms were swayed by the hype surrounding the 'new economy' and undertook excessive investment in computers. In this case, the output from computers would be lower than the price paid for them. If this were the case one might expect to see a negative correlation between IT use and MFP growth.

To examine if any of these problems may be present we look at the industry-level data for Australia to see if there is any correlation between computer use and MFP growth across industries. We present two figures to examine this question. The first shows MFP growth and IT income shares for each industry (except agriculture) for the periods 1989/90–1994/95 and 1995/96–2000/01.[16] It suggests that higher computer use may be associated with higher MFP growth.

---

[16] Agriculture is excluded from the figure due to the large fluctuation in MFP associated with weather patterns. It is possible to use other measures on the vertical axis, such as IT's contribution to growth; changing measures has little effect on the results.

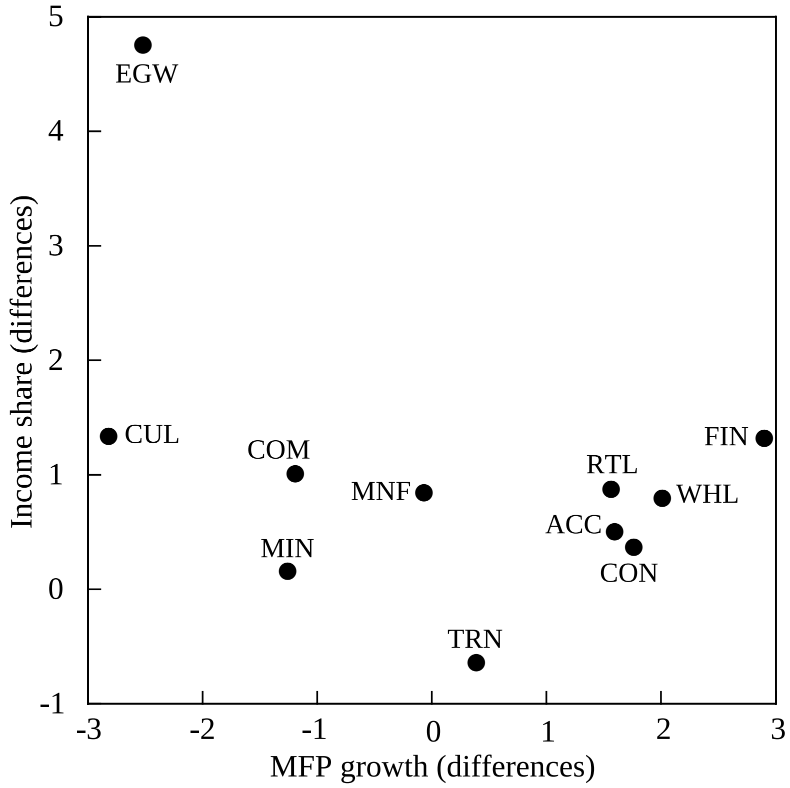
Figure 6: MFP Growth vs IT Income Share



This figure shows some suggestion of a positive correlation. Nonetheless, the correlation is dominated by a few industries that experienced strong growth in MFP and had high computer use, most notably communications. There are many reasons one might question this approach. Different industries may grow at different rates for reasons other than computer use. Alternatively, there may be distortions to these results due to deregulation. Some of the best performers are service industries. Telecommunications, for example, was deregulated in 1991 and might have been expected to experience higher productivity as a result. To control for this we present a figure showing the change in MFP growth between 1990/91–1994/95 and 1995/96–2000/01 against the change in computer usage. This allows for industry fixed effects, in other words, that some sectors may have a higher rate of growth independently of their computer usage.

The results from this transformation of the data suggest that there is no obvious MFP spillover. With the exception of the one outlier (EGW), there is no obvious correlation in Figure 7. This suggests that the relation seen in Figure 6 reflects factors other than IT usage. However, the lack of correlation also provides no evidence that there has been over-investment in computers.

Figure 7: MFP Growth vs IT Income Share (Differences)



Notes: ACC: Accommodation; COM: Communications; CON: Construction; CUL: Cultural; EGW: Electricity, gas and water; FIN: Finance; MIN: Mining; MNF: Manufacturing; RTL: Retail; TRN: Transport; WHL: Wholesale

The fact that EGW is such an outlier suggests that its results have been significantly affected by industry deregulation. Thus, it would be wise to wait for more data before drawing any general conclusions about the effect of IT on the EGW sector.

Notwithstanding the results in Figure 7, it is still possible that there is a correlation between productivity and computer usage. The ABS, in constructing its estimates, does not assume that rates of return are equalised across industries. Instead it calculates an internal rate of return for each industry such that all its other estimates are consistent. That is, the internal rate of return for each industry becomes the residual and absorbs all the errors made in the process. If the internal rate of return is higher in industries that use computers more intensively this may be a sign of spillovers from computer use to broader productivity growth. We have, unfortunately, been unable to ascertain if this correlation exists.

7. Discussion

Before considering the implications of these results it is worth reiterating the lack of precision in these estimates. Capital stock estimates are notoriously difficult to construct as are the estimates of income shares for computers. This combined with the treatment of tax in the underlying data mean that there is inevitably a range of error around the estimates. That being said, the estimates are the best available based on the best available data.

The estimates obtained in this paper are larger than previous estimates of the benefit from computer use both in Australia and in the US. Table 4 below compares the estimates from these previous studies and recalculates the results from Table 1 over the shorter sample period that has been used in previous studies.[17]

There are enough differences between the studies that one should be cautious about drawing too much out of the precise figures. Between the Australian results the sectoral coverage is different as are the underlying capital data. The US results are based upon aggregate economy-wide results whereas ours are based upon industry-level data. Additionally, there is a difference in the treatment of labour inputs. Oliner and Sichel's results for the US include an estimate of quality adjusted labour inputs – generated by looking at changes in education and experience of the labour force. The ABS is currently working on an experimental labour quality adjustment but full results are not yet available. The preliminary results suggest that over the period 1994/95 to 2000/01 the contribution to growth of quality improvements in labour was only 0.15 per cent per annum.[18] Due to the preliminary nature of these estimates no adjustment is included in Table 4. Consequently the MFP estimates for Australia include any 'residual' effect from improved labour quality. However, using the preliminary estimates as a guide, subtracting 0.15 per cent per annum from MFP growth would not change any substantive features of the comparison with the US.

---

[17] Wilson (2000) looks at the contributions to labour productivity growth so the results are not directly comparable. The results in Table 4 also differ slightly from those originally reported in Gruen (2001). This is a result of minor revisions to the method, error checking, and some changes in the data. None of the differences change the story in any significant way.

[18] See the feature article in the September quarter 2001 National Accounts, ABS Cat No 5206.0, p 15.

Table 4: Comparison of Results

	Australia(a)				US	
	This paper		Toohey		Oliner and Sichel	
	1991–95	1996–99	1991–95	1996–99	1991–95	1996–99
Growth rate of output	1.78	4.47	2.47	4.35	2.75	4.82
Contribution from:						
IT capital	0.89	1.20	0.54	0.74	0.57	1.10
Hardware	0.42	0.87	0.25	0.36	0.25	0.63
Software	0.47	0.33	0.21	0.24	0.25	0.32
Communications	–	–	0.08	0.13	0.07	0.15
Other capital	0.15	0.76	0.86	1.10	0.44	0.75
Labour	–0.37	0.35	0.40	0.87	1.26	1.81
MFP	1.11	2.16	0.67	1.64	0.48	1.16
Income shares:						
Hardware	1.8	2.4	1.3	1.4	1.4	1.8
Software	2.4	2.6	1.2	1.4	2.0	2.5
Growth rate of inputs:						
Hardware	22.0	41.6	18.9	25.7	17.5	35.9
Software	18.8	13.9	17.8	17.4	13.1	13.0

Notes: (a) Dates used are financial year periods, e.g., 1991–95 indicates 1990/91–1994/95.
Results for Toohey were obtained from the author and include some results not originally published.

Notwithstanding these points, this table highlights the difference between the experience of Australia and the US over the 1990s. While GDP growth rates in the market sector were broadly similar, the US achieved this expansion by employing more labour while Australia has seen little change in the contribution from labour. Instead, most of the gains have been made through MFP growth.

There has also been a slightly larger contribution from capital, and in particular computer capital, to growth in Australia. Given that most of the 'new-economy' innovations originated in the US, this seems a surprising result. It may be that Australia achieved higher computer-capital contributions to growth over the 1990s by gradually 'catching-up' to the US. But it is hard to be sure. There are enough differences in statistical treatment that it is difficult to make confident statements about the relative contributions of computer capital to growth in the two countries.

What is most remarkable in Australia is the rate of MFP growth. Results from Section 6.2 suggest that we cannot clearly attribute this to our higher use of computers. In the absence of other candidates we can only suggest that the microeconomic reform of the 1980s and 1990s has paid handsome productivity dividends in the late 1990s.

Our decomposition in Section 6.1 allows us to consider some implications for the future. Production methods are in the process of being reorganised towards greater use of computer inputs. This change is reflected in their increasing income share. To the extent that this is a transitional feature we would expect the income share of computers to stabilise at some time in the future. When this occurs, the rising income share will no longer make a contribution to growth. Our estimates suggest that this contribution may be up to 0.6 per cent per year.

The other half of our decomposition highlights the benefits from the rapid technological advances that have occurred. These have added about 5 per cent to output over the course of this decade. Should technological progress or price reductions slow then this contribution to growth would also fall. Nonetheless, despite recent weakness in the industry, there are few signs that the pace of technological improvement or price falls passed on to users are declining. This gives us reason to believe that computers will continue to make a significant contribution to output growth for the foreseeable future.

8. Conclusion

This paper investigated the historical gains from the use of information technology in Australia. Our analysis suggests that Australia has done well out of the 'new economy'. Its use of computer technology is amongst the highest in the world with Australian business investment in computer and related equipment growing rapidly since the early 1990s. Furthermore, we find that around one-half of the gains from the use of IT can be attributed to price falls while the other half can be attributed to higher expenditure on computers. We arrive at the conclusion that Australia has experienced significant output growth related to computer use and that, as a user of IT, we will continue to gain significantly in the future provided that technological growth in the industry remains as rapid as it has been previously.

Appendix A: Industry-level Contributions to Growth

Table A1: Industry-level Contributions to Growth

	Agriculture		Mining		Manufacturing		EGW		Construction		Wholesale trade	
	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001
Output growth	–1.51	6.40	4.10	4.89	0.71	2.46	2.28	2.00	0.43	1.64	1.91	4.56
Contributions from:												
IT capital	0.15	0.25	0.18	0.20	0.65	1.10	0.72	1.54	0.61	0.57	1.06	1.11
Hardware	0.11	0.18	0.06	0.16	0.32	0.91	0.42	1.39	0.31	0.37	0.36	0.67
Software	0.04	0.07	0.12	0.04	0.33	0.19	0.30	0.15	0.30	0.20	0.70	0.44
Other capital	–0.78	–0.53	2.27	2.74	–0.08	0.66	–0.09	0.14	–0.06	0.09	–0.43	–0.35
Labour hours	–0.54	0.14	–0.66	–0.49	–1.38	–0.54	–1.32	–0.88	0.00	2.08	–0.23	0.22
MFP	–0.34	6.54	2.31	2.44	1.52	1.24	2.97	1.20	–0.12	–1.10	1.51	3.58
Income shares:												
Hardware	0.63	0.63	0.25	0.45	1.35	2.44	1.80	3.71	1.15	1.58	1.45	2.20
Software	0.19	0.31	0.54	0.55	1.66	1.71	1.27	1.49	1.34	1.48	3.18	3.44
Other capital	55.33	55.21	71.38	73.47	33.05	34.30	61.66	68.67	19.02	18.89	23.85	19.93
Labour	43.85	43.85	27.83	25.53	63.94	61.55	35.27	26.13	78.49	78.05	71.52	74.43
Growth of inputs:												
Hardware	22.75	28.52	14.62	47.61	24.46	41.10	21.63	36.08	24.72	25.11	21.40	35.87
Software	21.44	22.01	21.40	16.13	21.22	16.42	21.52	12.58	22.10	15.96	21.29	16.14
Other capital	–0.56	–0.87	3.28	3.88	–0.46	1.20	–0.25	0.64	0.93	0.24	–2.17	–2.76
Labour	–1.36	0.42	–2.36	–1.93	–2.06	–0.85	–3.76	–2.71	–0.13	2.61	–0.33	0.28

Table A1: Industry-level Contributions to Growth (*continued*)												
	Retail trade		**Accommodation**		**Transport**		**Communications**		**Finance**		**Cultural**	
	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001	1991–95	1996–2001
Output growth	2.23	3.82	2.63	3.97	3.19	3.49	9.09	10.32	1.43	4.91	2.65	4.10
Contributions from:												
IT capital	0.96	1.05	0.80	0.80	0.95	0.90	1.68	2.44	2.15	3.60	1.11	1.25
Hardware	0.51	0.81	0.38	0.64	0.52	0.63	0.55	2.07	0.89	1.66	0.49	1.08
Software	0.45	0.24	0.42	0.16	0.43	0.27	1.13	0.37	1.26	1.94	0.62	0.17
Other capital	0.08	0.13	0.18	0.91	0.13	0.25	1.19	2.22	–0.35	–0.13	1.83	3.78
Labour hours	0.91	1.04	2.88	3.16	0.23	1.20	0.94	1.61	–1.59	0.91	2.14	1.01
MFP	0.28	1.60	–1.23	–0.90	1.88	1.14	5.28	4.05	1.22	0.53	–2.43	–1.94
Income shares:												
Hardware	1.59	2.62	1.21	1.91	2.56	2.39	2.62	3.63	4.56	4.75	1.69	2.67
Software	2.17	2.02	2.18	1.80	2.15	2.06	5.56	5.58	5.60	6.98	2.82	2.48
Other capital	16.39	11.83	18.78	19.77	30.46	29.59	38.72	41.42	29.90	27.40	38.18	35.11
Labour	79.85	83.53	77.83	76.52	64.83	65.96	53.10	49.36	59.94	60.87	57.31	59.74
Growth of inputs:												
Hardware	31.21	33.20	33.04	37.07	20.94	26.91	21.69	58.38	17.15	34.41	27.57	45.35
Software	21.42	16.16	20.61	15.61	21.14	14.13	20.96	11.59	21.83	27.41	22.30	14.43
Other capital	–0.54	–3.05	2.15	5.50	0.31	1.96	2.04	4.95	1.70	–0.34	5.78	11.28
Labour	1.15	1.23	3.69	4.12	0.41	1.84	1.83	3.29	–2.66	1.53	3.72	1.68

Note: Dates used are financial year periods, e.g., 1991–95 indicates 1990/91–1994/95.

Appendix B: Total Requirement Coefficients

Table B1: Total Requirement Coefficients[(a)]

Using input-output tables for 1996/97

Requirement by industry:	For communications	For business services
Agriculture	2.6	12.6
Mining	2.6	14.5
Manufacturing	3.3	19.8
Electricity, gas and water	2.4	13.0
Construction	2.4	21.7
Wholesale trade	6.8	40.4
Retail trade	7.3	31.2
Accommodation, cafes and restaurants	4.5	24.9
Transport and storage	4.5	21.6
Communication services		15.1
Finance and insurance	3.3	13.2
Cultural and recreational services	5.0	23.4

Note: (a) Calculated inclusive of imported inputs, and with competing imports allocated indirectly.

References

Bakhshi H and J Larsen (2001), 'Investment-Specific Technological Progress in the United Kingdom', Bank of England Working Paper No 129.

Carmichael J and N Dews (1987), 'The Role and Consequences of Investment in Recent Australian Economic Growth', Reserve Bank of Australia Research Discussion Paper No 8704.

Cooper MJ, O Dimitrov and PR Rau (1999), 'A Rose.com by Any Other Name', *Journal of Finance*, 56(6), pp 2371–2388.

Gordon RJ (1999), 'US Economic Growth Since 1870: One Big Wave?', *American Economic Review*, 89(2), pp 123–128.

Gordon RJ (2000), 'Does the "New Economy" Measure Up to the Great Inventions of the Past', NBER Working Paper No 7833.

Gruen D (2001), 'Australia's Strong Productivity Growth: Will it be Sustained?', Reserve Bank of Australia *Bulletin*, February, pp 62–69.

Hall RE (1988), 'The Relation Between Price and Marginal Cost in US Industry', *Journal of Political Economy*, 96(5), pp 921–947.

Jorgenson DW and KJ Stiroh (2000), 'Raising the Speed Limits: US Economic Growth in the Information Age', *Brookings Papers on Economic Activity*, 1, pp 125–235.

Kiley MT (1999), 'Computers and Growth with Costs of Adjustment: Will the Future Look Like the Past?', Federal Reserve System Finance and Economics Discussion Series, No 1999-36.

OECD (2001), 'The New Economy: Beyond the Hype', Final report on the OECD Growth Project, OECD, Paris.

Oliner SD and DE Sichel (1994), 'Computers and Output Growth Revisited: How Big is the Puzzle?', *Brookings Papers on Economic Activity*, 2, pp 273–334.

Oliner SD and DE Sichel (2000), 'The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?', *Journal of Economic Perspectives*, 14(4), pp 3–22.

Parham DJ, P Roberts and H Sun (2001), 'Information Technology and Australia's Productivity Surge', Productivity Commission Staff Research Paper.

Solow RM (1957), 'Technical Change and the Aggregate Production Function', *Review of Economics and Statistics*, 39(2), pp 312–320.

Toohey T (2000), 'Information Technology and Productivity', ANZ *Economic Outlook*, October.

Whelan K (2000), 'Computers, Obsolescence and Productivity', Federal Reserve System Finance and Economics Discussion Series, No 2000-06.

Wilson D (2000), 'Australian Productivity: Catching a "New Economy" Wave', Goldman Sachs Global Economics Working Paper No 50.