NOIE

The National Office for the
INFORMATION ECONOMY

Contribution of ICT to economic growth

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This paper provides the Steering Committee with information setting out the contribution that ICT makes to economic growth. In so doing, it touches on the methodological debates about the importance of ICT. It also briefly covers some of the comparative country studies that underlie the macroeconomic analysis of economic growth and the role of ICT in achieving that growth. Key points covered include:

- The question of just how important ICT is for productivity improvements and economic growth has been hotly debated by economists for some time.

- Earlier contributions to this debate have found limited evidence of any relationship between ICT and productivity. However, this counter-intuitive finding has triggered a sustained debate over several years.

- These earlier studies have been criticised on the grounds of limitations arising from their underlying assumptions and use of models which were inadequate to explain the impacts of diffusion and take-up of technology within industry and across economies.

- In more recent years, attempts are being made to develop models which incorporate the more complex relationships among the players in the innovation system.

- Recent work by the OECD (in which Australia has been a major contributor), the Reserve Bank and NOIE (particularly the Ovum consultancy) all indicate a much more positive relationship between diffusion and take-up of ICT and economic growth than economists had earlier thought.

- However, the impact of the technologies clearly varies widely between firms, between industries and, significantly, between countries. Australia appears to have been one of the better performing countries in using ICT to achieve sustained productivity improvements.

- At least some of the debate about the importance of ICT for economic growth has centred on the question of whether it is more important to be a producer or a user of these technologies.

- This simplistic either/or question is of little real use to policy makers, since it is clear that both are important. In addition, in the case of Australia, such an approach (as exemplified by some of the OECD's judgements) fails to recognise the development of major applications in user industries as a significant form of ICT production in their own right.

- It is clear that having a high degree of national ICT capability is increasingly important to underpin the development of the ICT industry itself, its key user industries, and hence, economic growth more generally.

- It is important to be aware that all of this is very much a work in progress, and that the debate amongst economists continues, although a consensus is emerging.

- However, there is broad recognition among those countries (G8, Sweden, Australia) who recognise the importance of the transition to the information economy that better

performance metrics need to be developed— to measure both the impact of ICT on industry performance and the contribution made by ICT to broader economic growth.

The pervasiveness of ICT

ICT is now part of the fabric of developed economies. Over a relatively short time span of 30 years or so, ICT has become an intrinsic part of everyday life to the extent that, like electricity, modern society could not function in its absence.

The heavily interconnected nature of a developed economy with long and complex value chains highlights the pervasiveness of ICT as a general purpose technology. Even if some businesses or economic sectors of activity do not yet use these technologies in critical business applications, their suppliers, customers and competitors increasingly do so. Thus, over time, fundamental parameters such as the cost of key inputs like labour and capital are changing for everyone through the increasing diffusion of these technologies.

Growth in adoption of ICT by business in Australia has been very strong in the last decade. The ABS has conducted four surveys on the use of IT by Australian businesses. The first of these covered 1993–94, while the last covered 2000–01. These surveys demonstrate the increasingly pervasive nature of ICT. The 1993-94 survey found that computer use in non-agricultural businesses occurred in:

- about 49% of those employing one or more people;
- 46% of those employing one to 19 people; and
- 99% of those employing 100 or more.

By 2000–01, 84% of all businesses and virtually all businesss employing over 20 people used computers. Among these businesses, 69% had access to the Internet and 22% had a web presence.

However, these global figures hide the great variations in take-up of ICT between various sectors of the Australian economy. As the Ovum Consultancy report (see Attachment A) demonstrates, the Australian economy is disproportionately large in traditionally non-ICT using areas, such as mining and, to a lesser extent, agriculture.

ICT and productivity—the economic debate

While there is widespread take up of ICT and a presumption that the technologies will provide clear productivity benefits, there has been, and continues to be a lot of debate amongst economists as to just how important ICT really is for economic growth and transformation.

In 1987, economics Nobel laureate Robert Solow said ‘‘You can see the computer age everywhere but in the productivity statistics’’. There has been debate about the contribution of ICT to productivity and economic growth since that time, the same time over which ICT has been increasingly embraced by developed economies worldwide.

The debate reflects the complexity of the relationship between technology and the economy and the unsatisfactory nature of growth models (such as Cobb Douglas). These models not only abstract from the complexity of the growth process in capturing scale and embodied

technological change, but also abstract from the time and path independence observed in real-world technological transformations on business, government and social organisations.

OECD research of the 1990's found that the nature of growth in lead economies was changing. Using a measure of economic growth called the ''growth accounting identity'' (for an explanation of what this is, see Attachment B) to explore relationships between national statistical aggregates, the OECD found that the traditional industry experience of diminishing returns from capital deepening (increasing the capital used per worker) had changed in recent years to one of increasing returns and a trend to increasing capital productivity[1].

In Australia, the Productivity Commission analysed ABS market sector productivity estimates up to 1997–98 using an extended growth accounting identity and showed that ICT investment had a significant but fairly minor role, through capital deepening (i.e., more capital per worker). Following the release of its 1999 research report[2], the Productivity Commission stated in a media release that 'The recent surge in Australia's productivity growth is directly linked to past microeconomic reforms'. It judged that the more critical and significant surge in multi-factor productivity growth (MFP - which encompasses the technology effect) was not associated with ICT take up, but rather microeconomic reform.

Recent United States, Australian, and OECD research findings, however, indicate that economic and social transformations associated with the movement to a knowledge economy are driving productivity growth in advanced economies, and that ICT plays a central role in that transformation. The common emerging view in Australia is that productivity growth in Australia in the 1990s was precipitated by microeconomic reform, but subsequently was sustained by the significant investment in ICT that was in itself a response to the competitive pressures unleashed by microeconomic reform.

The bursting of the technology bubble exposed the hype and unrealistic expectations of the recent technology stock market boom. However, labour productivity has continued to grow strongly in the US so that, over the last 12 months the growth rate has been more than 5%. Chairman of the US Federal Reserve Bank, Alan Greenspan, has commented[3] that there is a strong suggestion that US productivity growth, fuelled by ICT, is sustainable and will continue. And for Australia, which has experienced productivity growth over the 1990's at a rate greater than that of the US (although starting from a lower base), the potential exists to also continue to see high rates of ICT generated productivity growth.[4]

In the aftermath of the bursting of the technology bubble, the OECD's support for ICT as a growth driver did not reverse. In fact, subsequent cross-country research confirmed that the on-going transformation could deliver continued productivity growth.

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[1] The increase in capital productivity is inconsistent with the neoclassical growth model under which the greater the capital deepening the lower the productivity of the additional capital.

[2] *Microeconomic Reforms and Australian Productivity: Exploring the Links,* Productivity Commission 1999

[3] *Productivity*, remarks at the U.S. Department of Labor and American Institute Conference, Washington, D.C., October 23, 2002, (http://www.federalreserve.gov/boarddocs/speeches/2002/20021023/default.htm)

[4] *Productivity Growth in Australia*, Dean Parham, Productivity Commission Staff Working Paper, April 2002 and *Australian Use of Information Technology and its Contribution to Growth*, John Simon and Sharon Wardrop, Economic Research Department, Reserve Bank of Australia, Research Discussion Paper 2002-02.

Using growth accounting estimates, OECD research has shown that ICT investment accounted for between 0.5 and 1.3 percentage points in GDP growth per capita per annum over a number of economies in the 1995–2000 period. In Australia, the growth was 1.3% per annum over 1996-00. More detailed statistics are set out in the following Table[5].

The impact of ICT investment on GDP growth – results from national studies

	GDP growth		Labour prod. growth		Contribution of ICT		Notes
Country	90-95	95-00	90-95	95-00	90-95	95-00	
	Percent						
United States							
Oliner and Sichel	--	--	1.6	2.7	0.5	0.9	91-95; 96-99
(2000)	2.5	4.0	1.4	2.7	0.5	1.0	90-95; 95-99
Jorgenson, et al. (2002)	--	--	1.5	2.7	0.4	0.9	90-95; 95-00
BLS (2002)							
Japan							
Miyagawa, et al. (2002)	--	--	2.2	1.4	0.1	0.4	90-95; 95-98
Germany							
RWI and Gordon (2002)	2.2	2.5	2.6	2.1	0.4	0.5	90-95; 95-00
France							
Cette, et. al (2002)	0.5	2.2	1.6	1.1	0.2	0.3	90-95; 95-00
United Kingdom							
Oulton (2001)	1.4	3.1	3.0	1.5	0.4	0.6	89-94; 94-98
Canada							
Armstrong et al	1.5	4.9	--	--	0.4	0.7	88-95; 95-00
(2002) Khan and	1.9	4.8	--	--	0.3	0.5	91-95; 96-00
Santos (2002)							
Australia							
Parham, et al. (2001)	--	--	2.1	3.7	0.7	1.3	89/90-94/95; 94/95-99/00
	1.8	4.9	2.2	4.2	0.9	1.3	91-95; 96-00
Simon and Wardrop (2001)							
Belgium							
Kegels, et al. (2002)	1.5	2.8	1.9	1.9	0.3	0.6	90-95; 95-00
Finland							
Jalava and Pohjola (2002)	--	--	3.9	3.5	0.6	0.5	90-95; 96-99
Korea							
Kim (2002)	7.5	5.0	--	--	1.4	1.2	91-95; 96-00
Netherlands							
Van der Wiel (2002)	--	--	1.2	1.3	0.2	0.2	91-95; 96-99

[5] *ICT and Business Performance – Empirical Findings and Policy Implications*, OECD, intended for discussion at the workshop on ICT and business performance on 9 December 2002, p22.

Note that, while the growth accounting identity is useful, it has shortcomings and limitations, particularly in the identification of causality and arising from application of a static model to a dynamic situation. Attachment B contains a more complete analysis of the deficiencies of the growth accounting identity.

Widespread awareness of the e-transformations occurring in industry and society does not necessarily indicate that the evidence of these changes will be readily apparent in Statistical Bureau National Accounts Aggregates[6] that describe the economy. Similarly, analysis by industry sectors of productivity and growth related to ICT take-up suffers from concerns about the validity of the statistics, questions about the precise identification of ICT and uncertainty about the implications of the research. Nevertheless, recent empirical evidence to support the economy-wide transformations associated with ICT is compelling.

Use v Production

While the contribution of ICT to productivity and economic growth has increasingly been acknowledged, there has also been much economic debate about the respective contributions from ICT production and ICT use. Early US research on US productivity growth found the source in ICT production. Subsequent research contradicted this finding and found a significant contribution from ICT use.

In 2001, the OECD published the findings of its two-year long research into economic growth and the 'New Economy'. In drawing policy implications from the findings, the OECD unambiguously supported inclusion of ICT as a central plank of growth-oriented policy, but cautioned against a policy to promote ICT production. It considered that the benefits of ICT could come from use alone, and not all countries could successfully engage in ICT production. (It is noteworthy that Greenspan's comments concerning sustainable US productivity growth noted above relate mainly to productivity gains from applying ICT, not to producing it.)

The OECD position was strongly influenced by Australia's circumstances. In the OECD's estimation, Australia stood apart from other small economies that demonstrated high productivity growth in the 1990s. Sweden, Ireland, and Finland all had significant ICT manufacturing sectors, Australia did not. Research into Australia's productivity surge by the Productivity Commission provided empirical support for the OECD's production versus use dichotomy.

In the then exemplar US economy of the late 1990s, the impact of ICT and the consequent 'New Economy' finding was not without controversy. However, subsequent research has led to a consensus that productivity growth in the IT manufacturing sector and economy-wide productivity gains from the use of IT contributed equally to the US growth surge over the late 1990s. A consensus is emerging in Australia that Australia's productivity surge has been due to the synergistic effects of microeconomic policy reform and ICT takeup.

The simplistic either/or question of production versus use is of little real use to policy makers, since it is clear that both are important. In addition, in the case of Australia, such an approach (as exemplified by some of the OECD's judgements) fails to recognise the

[6] This statistical deficiency is being addressed by the Australian Bureau of Statistics through the development of satellite accounts for ICT.

development of major applications in user industries as a signficant form of ICT production in their own right. It is clear that having a high degree of national ICT capability is increasingly important to underpin the development of the ICT industry itself, its key user industries, and hence, economic growth more generally.

Transformation of the economy

ICT technologies are already having a role in driving productivity improvements and innovation in sectors such as financial services, as well as in some aspects of mining, agriculture. They are also transforming the delivery of key government services (including health and education). Extensive research in Australia and in other OECD countries has been documenting these impacts.

The new technologies are also used for valuable applications in government service delivery, increasing the efficiency of government service delivery and decreasing the costs of business and citizens in interacting with government agencies. There is significant potential to further transform government services by effective use of new technology.

Less well known is the impact of these technologies on the non-commercial and non government sectors. ICT is beginning to transform Australia's not-for-profit sector. Groups as diverse as the Smith Family, service clubs, parent associations and sporting clubs are enjoying savings, increased efficiency, and improved service delivery.

These technologies are also providing the basis for connecting Australia's rural and regional communities into national life, and expanding the opportunities for economic and social participation of Australians of all ages and backgrounds.

ICT research and innovation and linkage of Australian researchers and enterprises into the global networks of development and commercialisation of ICT products and services have been accelerated by investments made in *Investing for Growth* (1997) and *Backing Australia's Abilities* (2001) initiatives. Linkages between these innovators on the technology front and advanced users of the technologies are increasingly critical to the early adoption of applications crucial to the competitive advantage of Australian firms.

Information and communications technologies do not drive transformation – that comes from the policy environment, strategic challenges and change strategies embraced by individuals, firms and governments. Effective implementation and management of ICT in support of process efficiencies and innovation in processes, products and markets is required. The Ovum Report, which is based on 18 recent case studies of ICT implementations in a wide range of public, private and not-for-profit sector agencies noted that:

- 'There is a mounting body of evidence supporting the hypothesis that mere ICT investment alone does not necessarily yield ICT productivity gains, and that the environment in which the investment is made is just as important in many situations as the nature of the technology itself. Case study evidence suggests that in some situations productivity gains from certain ICT investments can routinely exceed 5% per annum.'

Technology capabilities provide enabling tools for successful transformation – a platform for competitiveness, security, social inclusiveness and creativity in the 21st century. They will be an integral and essential part of the achievement of the government's whole of government policy priorities for the next year and beyond.

The transforming effect of ICTs will also drive new opportunities for Australian businesses. The widespread adoption of ICTs—particularly in areas that have so far been slower in their uptake—will open niches for innovative businesses to develop ICT applications and services. The broad innovation infrastructure in Australia will be critical in supporting these opportunities.

The Ovum Report suggests that should the productivity impacts of ICT increase in traditionally non-ICT using sectors, such as agriculture and mining, then the Australian economy, overall, would benefit to an even greater extent from ICT productivity in future, and would do so proportionately more than most other developed countries under the same circumstances. In particular, the impact of ICT on Australia's export performance would become more apparent

This view is supported by a 2002 macro-level study conducted by the Allen Consulting Group,[7] which indicates that substantial economy wide gains are in prospect from the involvement of Australian business in the Information Economy.

The study predicts that by 2004–05 Australia will enjoy:

- higher underlying growth—increasing GDP by up to 2.6% over the levels that would otherwise obtain; and

- more jobs—employment to be higher than otherwise by around 1.2%, or about 110 000 jobs.

Economic debate and policy issues

Although research has led to a much greater understanding of the importance and role of ICT in generating productivity and economic growth, much closer analysis of the government's ICT strategy to compare its impact with those of specific microeconomic reform (MER) measures is needed to clarify policy issues. More complex models, including industry models, are useful (e.g. see research by C J M Paul 2001). However, the data requirements for realistic modelling can seldom be met in Australia, particularly given the confidentiality restrictions on official statistics.

- There is a pressing need for better performance metrics that encompass the contribution of ICT to the economy.

Better policy models are also needed to provide an appropriate research base for ICT technology policy. In particular, models that endogenise technological change are advocated by economists[8]. Some endogenous growth models hold promise, but in their current state have been found wanting in empirical research. Attachment C is an analysis of the shortcomings of endogenous growth models.

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[7] Allen Consulting Group 2002, *Australia's Information Economy: The Big Picture,* Report commissioned by The National Office for the Information Economy, April 2002.

[8] See, for example, *The Conceptual Basis of Technology Policy*, Lipsey and Carlaw, 2001, forthcoming, Fig. 2, p.44

Conclusion

Information and communications technologies and services have become pervasive, general purpose enablers of economic and social transformation. Given the right policy settings, they provide the platforms on which growth in productivity, innovation and social well-being can be constructed. This was the basis for the adoption by the Coalition Government in 1999 of a *Strategic Framework for the Information Economy*, and is expected to be a central focus of the *ICT Framework for the Future* report.

National Office For The Information Economy
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Attachment A

THE OVUM CONSULTANCY STUDY

NOIE commissioned Ovum Consulting and Tasman Research to examine the ways in which organisations seek to obtain maximum benefit from their ICT programs both in terms of overall approach and for particular ICT projects. The Ovum draft report was received on 10 December. The report examines case studies of organisations in a number of different sectors in the Australian economy including the not-for-profit sector. The study aims to better understand the ways in which certain types of organisational behaviour might advance the process of maximising the results of ICT implementation. Individual case study analysis seeks to shed light on the way in which each organisation has improved the delivery of benefits from the introduction of ICT into its operations through the organisational processes it adopted for implementation. The study also compares ICT productivity in Australia with that of overseas countries.

CONCLUSIONS

DOMESTIC TRENDS

- Numerous factors affect the way in which productivity and transformational effects at the level of the firm impact at the sectoral or whole of economy levels. Most notable is the nature of the technology and whether it provides absolute benefits above and beyond any competitive advantage it provides.

- The productivity gains from technologies that provide absolute benefits are ongoing, whereas the productivity gains from technologies that *only* provide a competitive edge are smaller to begin with and tend to be lost when the competition catches up.

- Productivity gains are more apparent and more sustainable when the markets in which firms operate are variable (that is, are growing or capable of growth), such that an increase in activity for one firm is not matched by a decrease in activity of another.

- Australia has invested heavily in ICT, with expenditure on ICT now representing more than 8% of GDP. Sectors that have invested most heavily in ICT include finance, communications and utilities (electricity, gas, water), while ICT investment has been smallest in mining and agriculture.

- At the firm level, the level of ICT investments is influenced by a range of factors. Firm size and area population density are both positively correlated with the level of ICT investment.

- There is a growing consensus in Australia that ICT is responsible for an increase in productivity at firm, sectoral and whole of economy levels. Across the economy, ICT has contributed to up to 1.26% growth in labour productivity and a slightly lower figure for TFP. Modelling results indicate that it is currently responsible for 1.66 % growth in Australian GDP.

- There is a mounting body of evidence supporting the hypothesis that mere ICT investment alone does not necessarily yield ICT productivity gains, and that the

environment in which the investment is made is just as important in many situations as the nature of the technology itself. Case study evidence suggests that in some situation productivity gains from certain ICT investments can routinely exceed 5% per annum.

- Indeed, the sectoral and economy wide productivity observations that are available are significantly less than 5% per annum, indicating that the management of ICT investments and results outlined in these case studies is atypical and better than normal. The case studies reveal examples of less-than-perfect ICT management, despite them being selected as exemplars, or at least above average. This suggests great scope for productivity improvements.

- If more and more organisations begin to apply the lessons from the case study research, then one would expect the overall productivity growth contributed by ICT to improve. A 25% increase in ICT productivity across all sectors (beyond what they are currently achieving) would yield a 0.41% increase in national GDP in 2003, or $2.68 billion. A 50% increase in productivity gain would yield a 0.81% increase or $5.31 billion. These outcomes assume that the rest of the world achieves the same increase. Similar increases are evident across a number of macroeconomic indicators, such as real wages, real consumption, investment levels, imports and exports.

INTERNATIONAL TRENDS

From the analysis of Australian industry in this report, we conclude that:

- Despite having a small ICT production sector relative to many countries in the developed world, Australia is an intensive ICT user, with investment levels in ICT amongst the highest in the world.

- As a proportion of total ICT investment, Australia invests heavily in software more so than hardware or communications equipment.

- In terms of productivity gains from ICT usage, the evidence suggests that Australia is a world leader along with the United States. The unique aspect of Australia's ICT productivity performance is that it is achieving such high ICT productivity gains without having a large ICT production sector.

- The structure of the Australian economy is not the source of overall high productivity gains from ICT relative to other countries. In fact, relative to many countries the Australian economy is disproportionately large in traditionally non-ICT using areas, such as mining and, to a lesser extent, agriculture. A proportionately very large communications sector partly offsets this.

- Should the productivity impacts of ICT increase in traditionally non-ICT using sectors, such as agriculture and mining, then the Australian economy, overall, would benefit more from ICT productivity in future, and would do so proportionately more than most other developed countries under the same circumstances. In particular, the impact of ICT on Australia’s export performance would become more apparent.

ATTACHMENT B

Use and misuse of the growth accounting identity

The identity

Econometric measures of the contribution of ICT to output and labour productivity growth use a growth accounting identity. Following is an example of this identity used in an International Monetary Fund study of the Australian economy (*Australia: Selected Issues and Statistical Appendix, IMF Country Report No. 01/55, April 2001,* Washington).

$$\Delta \ln Y_t = \alpha_t \Delta \ln K_t + \beta_t \Delta \ln L_t + \Delta \ln A_t$$

Based on a constant returns to scale production function ($\alpha + \beta = 1$) and perfect competition in the goods and labour markets, output ($\boldsymbol{Y_t}$) growth can be accounted for by increasing use of capital, (K_t) and labour (L_t) inputs, each weighted by their share of total income (α and β), and by a residual (A_t), commonly named total factor productivity (TFP), which captures any growth that is not associated with input usage, that is, any disembodied technical change.

A first set of refinements to this equation can be made by distinguishing between ICT and non-ICT capital stocks, replacing labour input with a quality-adjusted index (q), and expressing all variables in per capita terms (lower-case variables indicate rates of growth of each variable less the rate of growth of unadjusted labour), resulting in the following equation:

$$\Delta \ln \gamma_t = \alpha_{\pi,t} \Delta \ln \boldsymbol{k}_{IT,t} + \alpha_t \Delta \ln \boldsymbol{k}_t + \beta_t \Delta \ln \boldsymbol{q}_t + \Delta \ln \boldsymbol{A}_t$$

A further refinement of the basic equation can be made by splitting the TFP growth into three components. First, a spillover effect related to the usage of ICT capital (θ) is introduced in order to single out 'super-normal' returns, that is, the returns associated with this type of capital which are not paid to anyone and thus are part of TFP. Second, following Domar (1961), TFP growth can be disaggregated between growth in the ICT-producing sector and in the rest of the economy, using the two sectors' shares of total gross output as weights:

$$\Delta \ln \gamma_t = \alpha_{IT,t} \Delta \ln \boldsymbol{k}_{IT,t} + \alpha_t \Delta \ln \boldsymbol{k}_t + \beta_t \Delta \ln \boldsymbol{q}_t + [\alpha_{IT,t} \theta \boldsymbol{k}_{\pi,t} + \mu_{IT,t} \Delta \ln \overline{\boldsymbol{A}}_{IT,t} + (1 - \mu_{IT,t}) \Delta \ln \overline{\boldsymbol{A}}_t]$$

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This equation allows us to distinguish three channels through which ICT affects output and labour productivity growth: 1) via its role as a capital input; 2) via the TFP increase in the ICT-producing sector; and 3) via the TFP increase associated with the spillover effects related to the usage of the new technologies.

Shortcomings and limitations

The growth accounting identity is useful in identifying the emergence of broad transformations, but is not a basis for determination of causality.

As the OECD has itself pointed out, growth accounting can be a useful historically-based tool for measuring, explaining, understanding, and perhaps even benchmarking technology-driven growth, if the shortcomings and limitations of growth-accounting methodologies are appreciated. The OECD (2001a) manual on productivity emphasises the complications that beset the stimulation and interpretation of MFP growth. These include:

- The annual snapshots of the dynamic growth processes taken by the use of a comparative-statics-based growth accounting method do not model the underlying mechanisms. Interpreting a dynamic process with static equilibrium-based methods is fraught with conceptual and measurement issues.

- Cross-border flows of capital, finance, know-how and services have complex impacts on Australia's production and innovation that are not all captured by the model. (Imports of business computers are effectively treated as consumption goods. The benefit of falling overseas computer prices at an unchanged exchange rate is reflected only as a terms-of-trade gain, ie Australia's exports buy more imports. Essentially the productivity benefits of the embedded technological improvements are treated as (i) being equivalent to the price deflators, (ii) being identical for all users, and (iii) not generating any cross-sectoral impacts. The issue is addressed in the more sophisticated Capital, Labour, Energy Material (CLEM) productivity model).

- Flows between the market and non-market sectors are also not captured by the methodology in estimating the cross-sectional distribution of MFP growth. Of particular importance would be the Computer services industries that are included in the non-market Property and business services (PBS) sector.

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- The simple growth accounting approach can mislead as to real-world interactions and synergies. As argued by the OECD, it is only with the support of detailed case studies and other analyses, that they can provide reliable insights. More complex models with hard-to-meet data requirements are needed to explore the interaction between sectors, and distinguish between issues such as separation of embodied and disembodied technical change, change in scale economies, increasing returns, etc.

Data problems severely limit more complex studies into ICT technologies in Australia. These include interaction/bundling between supply of ICT capital and services, and between different parts of the ICT sector, as well as ABS confidentiality restrictions.

The shortcomings of endogenous growth modelling

There is a tendency for sector-based research to use endogenous growth models to determine cause. Reservations have been expressed about the use of such models.

Aghion and Howitt (1998) catalogue the diverse range of models falling in this class, each providing a partial explanation of the growth process by theoretically examining a particular growth phenomenon. The authors demonstrate how to combine features of different models, ie capital accumulation with the boom/bust cyclical experience, as well as impacts on trade, education, etc, to better introduce real-world complexity. The diversity of models suggests that the choice of endogenous growth model can strongly influence research findings.

A study of technologically based growth by Katz (1998),'*Structural Reforms and Technological Behaviour*', points to possible inadequacies in the use of this class of model to explore how to benefit from technological investment. Katz finds that:

> 'Although modern growth theory (P. Romer, 1987, 1992; R. Barro and Salas i Martin, 1996; Helpman and Grossman, 1992; Mankiew, 1996, etc.) has successfully modelled endogenous forms of learning, 'creative destruction' processes, sectoral externalities and increasing returns to scale, and imperfect competition mechanisms that facilitate the private appropriation of R&D expenditure, neoclassical models still have a long way to go before grasping the institutional and 'cultural' complexity of innovation and technology that economists have been struggling to describe over the past two decades. As noted by R. Nelson (Nelson, 1996), progress in this direction has been taking the form of 'appreciative theorizing' that is well ahead of what modern neoclassical growth theory has managed to incorporate formally. This is particularly true in relation to the behaviour of institutions, the complexity of the way in which production is organized and the ultimate nature of learning processes at the level of the firm and to the way such factors relate to how firms build up a pool of technical capabilities.'

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