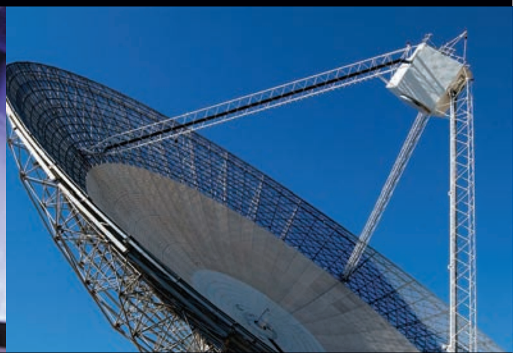
Australian Government

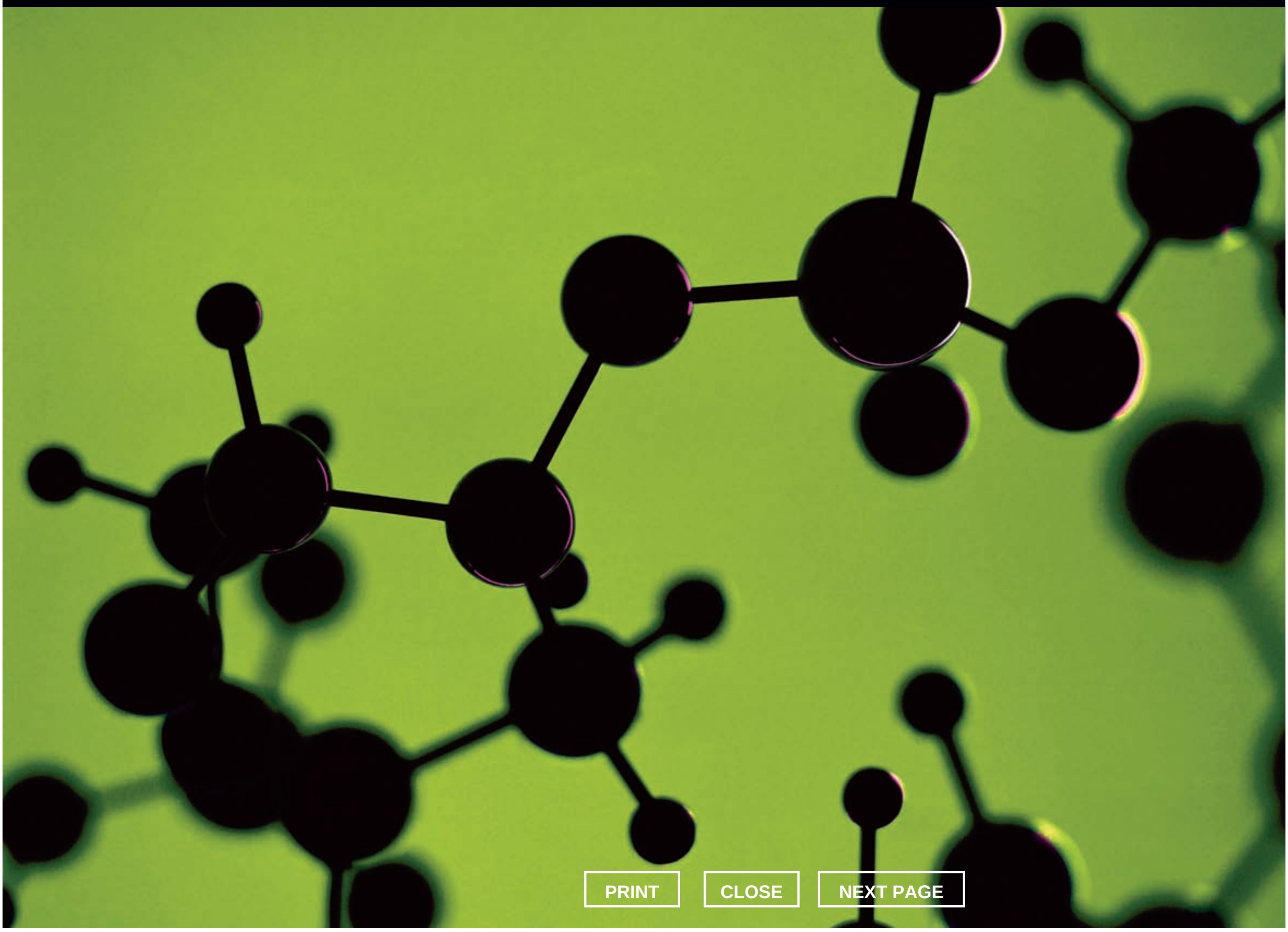
Department of Communications, Information Technology and the Arts

FORECASTING PRODUCTIVITY GROWTH 2004 TO 2024

Occasional economic paper







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Forecasting productivity growth: 2004 to 2024

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Foreword

This research paper is part of ongoing research by the Department of Communications, Information Technology and the Arts (DCITA) on the factors driving productivity growth in Australia and the role of information and communications technology (ICT) in this growth.

Research into productivity is fraught by complex conceptual and data issues, with alternative theories and methodologies offering different perspectives. The DCITA research into the relationship between ICT and productivity seeks to exploit the benefits of these differing perspectives by using a range of different approaches in both in-house and contracted research. It is seen as adding value and depth to the public discussion of important albeit complex issues and providing a sounder foundation for policy development.

This report, the latest member of the series, approaches the issue through the development of productivity forecasts for the next two decades. Clearly past productivity trends and relationships bear upon the future, and the historic relationships found in earlier DCITA and Productivity Commission research provide this grounding. This has been supplemented by technology road maps and analysis of major foreign and Australian organisations and by the comments and insights of various government agencies with expertise in particular fields and industries.

Many of the predictions assume a continuation of past trends. This is not intended to imply that the underlying processes are purely technological in nature. Nevertheless, the evolution and diffusion of ICT as a general purpose technology is enabling a wide range of other changes throughout the economy involving complementary investment, experimentation and positive feedback.

A number of Australian Government departments and agencies provided helpful comments on individual industry/technology sections or the entire draft report. They are the Department of Industry, Tourism and Resources, the Department of Agriculture, Fisheries and Forestry, Australian Bureau of Statistics, CSIRO Resource Futures Program, Productivity Commission, Australian Bureau of Agricultural and Resource Economics and the Bureau of Transport and Regional Economics. The assistance provided by these departments and agencies in the course of drafting does not imply their endorsement of the report. Naturally, responsibility for the content rests with the authors of the report.

DCITA is grateful for referee comments on the entire report provided by Professor Phil Lewis from the University of Canberra.

Internal referees were Mr David McGeachie of the Research and Analysis section, Mr Greg Gurr of the ICT Innovation Branch and Mr Chris Williams from the Communications Research Unit.

The report was prepared in the Information Economy Division by Mr John Revesz under the direction of Dr Lee Boldeman. Mr Harvey Anderssen provided valuable advice. The projections from the MONASH general equilibrium model were prepared by Professor Philip Adams from the Centre of Policy Studies in Monash University.

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Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACR	Accommodation, Cafes and Restaurants
AI	artificial intelligence
AMT	advanced manufacturing technology
ANZSIC	Australia and New Zealand standard industrial classification
CAD	computer aided design
CAM	computer aided manufacturing
CD-ROM	compact disk – read only memory
CNC	computer numerical controller
CoPS	Centre of Policy Studies
CRS	cultural and recreational services
CSC	Computer Science Corporation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCITA	Department of Communications, Information Technology and the Arts
EGW	electricity, gas and water
GDP	gross domestic product
GNI	gross national income
GNP	gross national product
GMO	genetically modified organism
GPS	global positioning system
GPT	general purpose technology
IT	information technology
ICT	information and communications technologies
LAN	local area network
LP	labour productivity
MFP	multi-factor productivity
MEMS	micro-electromechanical systems
NDSP	National Dryland Salinity Program
NOIE	National Office for the Information Economy
OECD	Organisation for Economic Co-operation and Development
PBPS	property, business and professional services
PDA	personal digital assistant
PLC	programmable logic controller
R&D	research and development
RDM	remote disease management
RF	radio frequency

RFID	radio frequency identification device
RNNDI	real net national disposable income
VA	value-added
Wi-Fi	wireless fidelity

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Executive summary

Scope and purpose

This report presents forecasts of productivity growth in major sectors of the Australian economy between 2004 and 2024. The main objective is to inform policy makers and the interested public on the likely impact of technological change on productivity growth. On the basis of quite conservative assumptions, indications are that information and communications technology (ICT) will remain the main driver of productivity growth over the next 20 years.

One of the main reasons for looking at sectoral rather than aggregate productivity forecasts is to highlight expected changes in technologies, a subject that is easier to analyse at the sectoral level. Apart from technological progress economic growth will also depend on factors such as workplace relations, competitive conditions, social environment, population ageing, rising education standards, overseas economic conditions, oil prices and other possible energy-related problems. While these factors receive some attention in this report the emphasis is on technological progress, mainly because of its critical importance in driving productivity growth. Moreover, it is difficult to predict the impact on productivity of changes in non-technological factors. Particularly serious forecasting difficulties arise because of the large uncertainties concerning future greenhouse gas abatement measures and the cost of energy supplies.

The main interest in this report is on labour productivity growth defined in accordance with national accounting conventions as constant price value-added divided by total working hours. The report also looks at expected changes in the sectoral composition of the economy (structural change) and the growth in real GDP per capita.

The forecasts are derived from the extrapolation of trends in the last two decades, modified intuitively in the light of information about emerging technologies that are likely to become economically important within the next 20 years. All forecasts are presented in terms of a mean and associated 80 per cent confidence interval.

In many respects this report is a sequel to earlier publications by the Department on productivity growth in manufacturing (NOIE 2004) and services (DCITA 2005a). While these previous studies used national accounting data over the last two decades in order to analyse the drivers of national productivity growth in the past, the present study uses almost the same historical data in order to derive predictions about the future.

The predictions follow a standard growth accounting framework. They cover labour productivity (LP) growth, multifactor productivity (MFP) growth and capital deepening (that is, change in the capital-labour ratio) in broad ‘market sectors’ of the economy. MFP growth is the portion of economic growth that cannot be explained by changes in labour and capital inputs under conditions of constant return to scale in aggregate production. The forecasts separate LP growth into two components, that is, MFP growth and growth due to capital deepening. These variables are linked by the formula:

$$LP\ growth = MFP\ growth + \frac{capital\ income}{total\ income} * capital\ deepening$$

A number of recent Australian economic forecasts cover the period from 2004 to 2024. The unique features of the present study are that it examines individually 15 sectors, is based on a growth accounting framework and takes into account emerging technologies that are likely to play an important role in the next 20 years.

Technological trends

Before proceeding with extrapolations, the report reviews in a non-technical manner a number of technological futures studies published by the European Commission and major USA research agencies. Conducting technological forecasts 20 years ahead is difficult but not necessarily unrealistic. Most of the new technologies that will be adopted in the next 20 years are already in development stage. In this situation, the aim of the exercise is to predict which of the existing new technologies will evolve to become important in the marketplace.

A number of overseas and Australian economic studies (including NOIE 2004 and DCITA 2005a) highlighted the central role that ICT played in the economic development of technologically advanced countries in the last couple of decades. That this trend is likely to continue in the coming years is a characteristic of a general purpose technology (GPT), such as ICT.

The contribution of ICT to productivity growth was spurred by unparalleled technological progress in this area. The capacity of digital processing and memory units improved over 10 million times between 1950 and 2000, resulting mainly from advances in microelectronic technology. This spectacular progress led to improved automation in virtually all areas of the economy, including offices, shops, factories, warehouses, farms, mines, schools, hospitals and telecommunication networks.

Much of the expected contribution of ICT to productivity improvements in the future will result from the continuation of these trends, but in many areas radically new innovations will assume increasing importance. Emerging productivity enhancing technologies include, for example, radio frequency identification devices (RFID) replacing barcode scanners and having wide potential to raise productivity in many areas of storage, distribution and trade. Another important new innovation stream is represented by micro-electromechanical systems (MEMS) which can improve the performance and ‘intelligence’ of industrial, transport, agricultural, construction, medical and telecommunications equipment.

Impediments to wider diffusion of computer-controlled machinery/equipment in the next two decades will probably be related mainly to software development, which is still

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largely a craft industry where capabilities have lagged behind the new opportunities created by rapid technological advances in hardware.

Other emerging GPTs will play an increasing role over the next two decades. Biotechnology, broadly defined to cover DNA modifications and more traditional organic technologies, will contribute to improving human health, food production and environmental protection. But while the impact of ICT through improved automation and information flows affects all sectors of the economy, the impact of progress in biotechnology is more limited, restricted mainly to agriculture, medical care and organic material processing in manufacturing. These sectors cover around 13 per cent of GDP.

Nanotechnology is another GPT with many promising applications. Its main impact will be on manufacturing, particularly the production of ICT equipment, MEMS, materials for drug delivery and materials with unique properties. Over 15 per cent of manufacturing output might incorporate some nano-materials by 2020.

Summary of forecasts

Based on historical productivity growth rates and technological forecasts, this study produced predictions for upper, lower and mean growth rates. Table 1 presents the mean predictions for individual sectors.

Table 1 shows detailed growth accounting estimates for 12 ‘market sectors’. The summary figures for the ‘market sector’ and for ‘all sectors’ are weighted averages. Only LP growth predictions are presented for non-market sectors. These are based on the MONASH general-equilibrium forecasting model of the Australian economy.

Notice that higher productivity growth rates are expected in sectors that are heavily exposed to evolving new technologies. This is ICT in the case of communications, biotechnology in agriculture and a combination of advances in ICT, materials science, nanotechnology and biotechnology in manufacturing. On the other hand, productivity growth in accommodation and restaurants, a sector not closely linked to new technologies, is predicted to be low.

Table 1 Average predictions: annual growth rates 2004 to 2024

	LP growth	*MFP growth*	*due to capital deepening*
	%	%	%
Agriculture	2.3	1.4	0.9
Mining	2.2	-0.4	2.6
Manufacturing	2.6	1.5	1.1
Electricity, gas, water	1.5	-0.5	2.1
Construction	1.9	1.1	0.8
Wholesale trade	1.9	1.2	0.7
Retail trade	1.7	1.1	0.6
Accommodation and restaurants	0.7	0.4	0.4
Transport and storage	1.5	0.5	1.0
Communication services	6.1	2.7	3.3
Finance and insurance	2.3	0.8	1.4
Cultural and recreational	0.8	0.2	0.6
Market sector mean	**2.2**	**1.0**	**1.2**
Property and business services	0.9		
Government services	0.0[a]		
Education	1.6		
Health and community services	1.4		
Personal and other services	0.8		
Imputed rent on dwellings	1.6		
All-sectors mean	**1.78**		

[a] LP growth is set to zero in government services because according to national accounts conventions real output in this sector is proportional to labour inputs, hence by definition LP growth is zero.

From the LP growth predictions it is possible to derive predictions for the growth in real GDP per capita. The all-sectors LP growth rates from the three sets of predictions are shown in the second column of table 2. The third column shows annual growth rates after adjusting for changes in effective labour supply per capita. These are based on forecasts by the Productivity Commission that effective labour supply per capita (in terms of average working hours per person) will be reduced by four per cent over the next 20 years as a result of population ageing.

Table 2 Calculating predicted growth in real GDP per capita: 2004 to 2024

Predictions	*All-sectors annual LP growth rates*	*Adjustment for 4% less working hours*	*Final predicted annual growth rates*	*Increase in real GDP per capita 2004 to 2024*
	%	%	%	%
Mean	1.78	1.57	1.57	36.6
Upper	2.30	2.09	1.83	43.7
Lower	1.15	0.95	1.26	28.4

The fourth column shows the final predictions of annual growth rates of real GDP per capita. The aggregate upper and lower predictions have been brought closer to the mean, in recognition of the fact that not all optimistic and pessimistic sectoral outcomes will occur together. Note, the predicted mean growth rate in column four is lower than the over two per cent annual real GDP per capita growth rates recorded in the last decade. The final growth rates yield the predicted increase in real GDP per capita between 2004 and 2024, shown in the last column.

Structural change

The national accounts information used for extrapolating productivity trends can be also used to make predictions by extrapolation about the likely future sectoral composition of the economy. These structural change predictions are based on less detailed considerations than the predictions related to productivity growth.

The intuitive predictions presented in table 3 indicate that the shares in national employment of property and business services, health care, accommodation and restaurants and personal services are expected to increase significantly over the next 20 years, while the employment shares of manufacturing, agriculture, construction, wholesale and retail trade and education are expected to decline. The increase in the share of property and business services assumes that the trend to outsource more business and professional activities to this sector from other sectors will continue.

Table 3 Distribution of employment between sectors
In terms of total working hours

	Actual 1983–84	*Actual 2003–04*	*Predicted 2023–24*	*Change 04 to 24*
	%	%	%	%
Agriculture	7.3	4.3	3.5	-0.8
Mining	1.7	1.3	1.4	0.1
Manufacturing	18.5	12.8	10.1	-2.7
Electricity, gas, water	2.2	0.8	0.6	-0.2
Construction	7.1	9.3	8.7	-0.6
Wholesale trade	6.8	5.1	4.6	-0.5
Retail trade	12.8	12.7	11.4	-1.3
Accommodation and restaurants	3.0	4.5	5.1	0.6
Transport and storage	5.6	5.2	5.7	0.5
Communication services	2.2	1.9	1.7	-0.2
Finance and insurance	3.9	3.7	4.0	0.3
Property and business services	6.3	11.8	15.0	3.2
Government services	4.7	4.3	4.3	0.0
Education	6.2	7.2	6.5	-0.7
Health and community services	7.2	9.0	10.6	1.6
Cultural and recreational services	1.5	2.1	2.1	0.0
Personal and other services	3.0	4.0	4.6	0.6
Total working hours	100.0	100.0	100.0	0.0

Major conclusions

Some of the major conclusions presented in this report are:

The main sources of productivity growth

The report suggests that the main sources of productivity growth will be capital deepening (that is, more capital per worker) combined with technological progress in ICT and to a lesser extent biotechnology and nanotechnology. Productivity growth will be also strongly influenced by changes in workplace relations, competitive conditions and the social environment.

The effect of population ageing on income per capita

According to Productivity Commission predictions, population ageing will reduce effective labour supply per capita by four percent over the next 20 years. This study has not sought to validate this prediction. Based on this estimate, the mean prediction of this study suggests that as a result of ageing the mean annual rate of growth in real GDP per capita will be reduced from 1.78 per cent to 1.57 per cent during the forecast period.

Some policy issues

While policy issues are outside the scope of this report, it should be noted that in order to realise the predicted productivity benefits it will be necessary to support an appropriate level of investment in skill formation and in ICT related R&D. Falling international ICT prices are not sufficient by themselves to ensure strong economic growth. The introduction of new ICT technologies involves an extensive learning process that generates significant knowledge and innovation related externalities to the Australian economy, which are reflected mainly in MFP growth.

1. Introduction

1.1 Scope and purpose

This report presents forecasts on productivity growth in major sectors of the Australian economy between 2004 and 2024. The main interest is in macroeconomic forecasts that follow national accounts conventions. The predictions cover expected growth in labour productivity, multifactor productivity (MFP) and capital deepening in broad 'market sectors' of the economy.[1]

One of the main reasons for looking at sectoral rather than aggregate productivity forecasts is to highlight expected changes in technologies, a subject that is easier to analyse at the sectoral level. Sectoral productivity predictions are presented in terms of upper and lower bounds that are expected to cover future outcomes at the 80 per cent probability level. The study also looks at expected changes in the sectoral composition of the economy (structural change) and growth in real GDP per capita.

Clearly past productivity trends and relationships bear upon the future, and the historic relationships found in earlier DCITA and Productivity Commission research provides the foundations for the predictions presented here. This has been supplemented by technology road maps and analysis of major foreign and Australian organisations and by the comments and insights of various government agencies with expertise in particular fields and industries.

Many of the predictions assume a continuation of past trends. This is not intended to imply that the underlying processes are purely technological in nature. Nevertheless, the evolution and diffusion of ICT as a general purpose technology is enabling a wide range of other changes throughout the economy involving complementary investment, experimentation and positive feedback.

The historical data that forms the basis for the extrapolations comes from Productivity Commission (2005a) estimates of the growth in LP, MFP and capital-labour ratios of 12 market sectors over the last 20 years. These estimates are based on ABS data.

A study by Diewert and Lawrence (2005) (commissioned by DCITA) arrived at higher aggregate productivity growth estimates than the ABS. The Diewert and Lawrence (2005) estimates could not be used in this report because they cover the entire market sector and not individual industries.[2] Diewert and Lawrence (2004b) question the accuracy of industry

1 Market sectors exclude all government services and some private services where it is difficult to measure the value of output in constant price terms.

2 MFP growth between 1964-65 and 2003-04 in the 'extended market sector' (covering also education, health and some other public services) according to Diewert and Lawrence (2005) averaged 1.47 per cent per anum, whereas the corresponding estimate for the 'market sector' by the ABS was 1.17 per cent per annum.

level MFP data, suggesting that there are significant measurement errors in sectoral inputs and outputs. DCITA shares these concerns. However, this report uses the Productivity Commission/ABS historical estimates because adjusted sectoral data are not yet available. The likely effect of these differences is to understate the impact of ICT on productivity growth.

Apart from historical data, the report also considers technology futures studies. Many of the emerging technologies reviewed in this paper are the leading edge technologies of today that might become the standard technologies of tomorrow. The aim of reviewing technological futures studies is to describe in broad terms technological changes that are likely to occur in the marketplace and to ensure that predictions are not based solely on historical trends.[3]

In addition to technological-commercial factors, economic development also depends on more unpredictable changes in terms of trade, the global economic environment and government policies. This study does not attempt to make predictions about changes in these factors, although the extrapolations pick up some of the impact of historical changes in these areas.

The main objective is to inform policy makers and the interested public on the likely impact of technological changes on productivity growth, stressing the central role that ICT is expected to play in Australia's economic development over the next two decades. Given that the forecasts cover the entire economy, it is impossible to avoid touching on non-ICT related subjects such as biotechnology, environment and energy, but the discussion on these topics is limited. There are other Australian studies that deal with expected developments in these areas in more detail.

Some of the issues that will be addressed in this report are listed below.

- The main sources of productivity growth
- The impact of technological progress in offsetting the effect of an ageing population on real GDP per capita
- Uncertainties concerning the impact of energy-related problems on GDP and productivity growth in the next two decades
- Sectoral changes in the economy that are likely to occur during that time

Some brief answers will be provided in section 6.3. A few policy implications will be also discussed.

1.2 Productivity measures

The basic productivity measure used in this report is labour productivity (LP), which is defined as value-added (expressed in constant price volume index terms) divided by employment in each industry (measured in terms of working hours).

3 Technology forecast studies also touch on issues such as renewable energy sources and conservation of the environment.

The projections include in addition to LP growth also multifactor productivity (MFP) growth and capital deepening (that is, change in the capital-labour ratio).[4] These time-dependent variables are linked through the mathematical formula:

$$LP\ growth = MFP\ growth + \frac{capital\ income}{total\ income} * capital\ deepening \qquad (1.1)$$

Appendix B explains the reasoning behind this growth formula and some statistical issues related to the measurement of capital deepening and MFP growth. The second term in the right hand side of eq. (1.1) represents the contribution of capital deepening to LP growth. MFP growth is the portion of economic growth that cannot be explained by changes in labour and capital inputs, assuming a constant return to scale aggregate production function.

By examining the two components of LP growth, one obtains a better understanding of the factors that drive productivity growth.

1.3 Sectoral coverage

Due to the limited availability of ABS time-series data on value-added volume indices, detailed productivity growth predictions from the in-house study are presented only for a sub-set of major industries, referred to as the 'market sector' of the economy.

The market sector industry grouping relates broadly to marketed activities for which there are satisfactory estimates of the growth in the volume of output. Historically, output for the non-market industries has been measured using hours worked, which being a measure of input rather than output is not suitable for productivity measurement. Direct estimates of output volumes for health and education were introduced into the National Accounts in 2001. The measures cover private and public sector output of these services. However, in respect of measuring MFP, capital service data are unavailable for these two industries and difficulties remain in capturing quality changes in these measures. For the other primary non-market sector industry, government administration and defence, output measures are still based on labour inputs.

Property and business services (PBPS) output measures were previously based on labour inputs. However, value added is now measured using the double deflation method and data are available from 1995–96. For measuring the MFP of PBPS capital measures are not yet developed.

The productivity growth estimates for 'market sector' industries are available in most cases only at the broad ANZSIC division level. There are 12 'market sector' industries with MFP measures.

- Agriculture
- Mining
- Manufacturing

[4] In the ABS/Productivity Commission statistics change in the capital-labour ratio refers to capital services imputed from financial measures (depreciation and imputed capital costs) rather than capital stocks.

- Electricity, gas and water supply
- Construction
- Wholesale trade
- Retail trade
- Accommodation, cafes and restaurants
- Transport and storage
- Communications[5]
- Finance and insurance
- Cultural and recreational services

The ANZSIC division 'non-market' service industries excluded from in-house productivity forecasts due to lack of suitable historical data are listed below.

- Property, business and professional services (PBPS)
- Government administration and defence
- Education
- Health and community services
- Personal and other services[6]
- Imputed rent on dwellings

For the purpose of projecting growth in real GDP per capita, this study adopted the projections from the MONASH general-equilibrium forecasting model for non-market sectors.

Because of the potentially significant contribution of ICT to improving difficult-to-measure productivity in education and health, promising technological innovations in these sectors are analysed in chapter 5, notwithstanding the fact that these sectors do not belong to the 'market sector' covered by the in-house productivity forecasts. The purpose of the discussion on education and health is not to predict productivity outcomes but rather to highlight technological opportunities for productivity improvements.

1.4 Other Australian forecasts

Before entering into forecasting and analysis, it might be appropriate to mention a number of other medium to long-term Australian forecast studies that have been published recently. None of these other studies follows the methodology or has the scope of this report. Nonetheless, there are significant overlaps in certain areas.

The Treasury published a report in 2002 on the expected effect of population ageing on the (aggregate) Australian economy, with particular emphasis on government spending on aged care and health. The forecasting period in Treasury (2002) extends over 40 years to 2041–42. The report covers both demographic and GDP projections. Section 6.2 will

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[5] Covers telecommunications and postal services.

[6] Personal and other services also include some public services such as police and fire brigades.

compare this study's predictions of real GDP per capita growth and the projections from Treasury (2002) for the period from 2004 to 2024.

The Productivity Commission (2005b) report on the expected implications of population ageing in Australia presents more detailed economic and demographic projections than Treasury (2002). Section 6.2 will compare the Productivity Commission (2005b) projections of real GDP per capita growth between 2004 and 2024 with the respective predictions of this study. Section 6.2 will also discuss the Productivity Commission's views about expected changes in labour force participation and the productivity of an ageing workforce.

The future size and age distribution of the population is discussed in Treasury (2002), ABS (2003) and Productivity Commission (2005b). These demographic projections are not covered in the present report. On the other hand, the present study extends to sectoral forecasts, whereas Treasury (2002) and Productivity Commission (2005b) deal only with the aggregate economy (that is, GDP).

The main reason for focussing here on sectoral forecasts in contrast to the more aggregated approach adopted in most other economic forecasts is because, by virtue of their more detailed coverage, sectoral forecasts are better suited to highlight the expected impact of technological changes on the economy. In addition, sectoral forecasts provide much other useful information.

In regard to environmental issues, Foran and Poldy (2002) from the CSIRO published a detailed study on likely future trends in the Australian physical economy, including material and energy stocks and flows across the economy and their association with population, technology (industry, infrastructure), resources (natural and man made) and the environment (land, water, air). Their report presents quantitative forecasts on natural resource usage (energy, water and land) and greenhouse gas emissions under three population scenarios, however, it does not present financial (that is, national accounts based) forecasts. The present study will touch on some of the projections of Foran and Poldy (2002) when discussing agriculture, energy and water supplies.

Akmal et el (2004) present ABARE's views on Australia's energy outlook from 2001–02 to 2019–20. Some of these projections will be reviewed when examining possible productivity changes in mining and electricity.

Finally, the Business Council (2004) has published some qualitative views about possible developments to 2025 from a panel of commentators, including business and union leaders, academics and representatives of community groups. These predictions cover a broad range of social, economic, demographic, political and environmental issues affecting Australia. The qualitative comments expressed by the panel represent a different approach to assessing medium-term prospects than the quantitative predictions presented in this report.

1.5 Predictions from the Monash model

Alongside the in-house predictions, this report also presents projections from the well known MONASH general equilibrium model in regard to average annual growth rates in labour productivity from 2003 to 2024.

Since 1993 the Centre of Policy Studies (CoPS) in Monash University has developed MONASH, a dynamic computable general equilibrium model of the Australian economy designed for forecasting and policy analysis. Like its predecessor, ORANI, MONASH has a high level of microeconomic detail. Unlike ORANI, it has a forecasting capability. This is due to:

- a more detailed specification of intertemporal (that is, dynamic) relationships;
- greater use of up-to-date data; and
- enhancements which allow the model to take on information from specialist forecasting organisations and from recent historic trends.

The key to generating credible forecasts is to use detailed information available from expert groups specializing in the analysis of different aspects of the economy. MONASH forecasts incorporate a wide variety of information.

- Input-output data from the ABS
- Macro forecasts from the Treasury and other macro analysts
- Export volume and price forecasts from ABARE
- Forecasts of tourist numbers from the Bureau of Tourism Research
- Forecasts of tariff rates from the Productivity Commission
- Forecasts of changes in technology and consumer tastes derived from trends calculated at CoPS in Monash University

Using this information, the model can generate forecasts for 113 industries and 115 commodities. Among other applications, MONASH is used by state government and Australian Government departments requiring detailed employment forecasts.

The interested reader can find a general description of the MONASH model in Dixon and Rimmer (2002). Appendix C presents detailed forecasts from MONASH for 112 industries. Among other things, these forecasts indicate expected labour productivity (LP) growth rates. More aggregated LP growth forecasts from MONASH for 12 market sectors and five non-market sectors are presented in the sectoral sections in chapter 4.

1.6 Structure of the report

The report is divided into six chapters.

Chapter 2 examines definitional, methodological and forecasting issues related to national accounts data. A brief discussion is presented on the methodology used in the national accounts to establish constant price volume indices and the limitations of these methods. Attention is given to the reliability of forecasting future productivity growth on the basis of historical trends, by examining how accurately one could have predicted in the past the growth in real GDP per capita 20 years ahead by looking on trends in the previous 10 or 20 years. Comparisons between actual and predicted outcomes are based on observations from 1949–50 to 2003–04. Another subject taken up is the role of non-technological factors in driving productivity growth. The final section in chapter 2 examines the combined share of energy sectors in GDP, because in this area there are greater uncertainties about the future than in other sectors.

Chapter 3 reviews in a non-technical manner some of the technological futures literature. Much of this literature is from the European Commission and USA research agencies. The emphasis in this literature review is on new ICT technologies that are likely to be implemented in the next 20 years. Attention is also given to other dynamic fields, such as biotechnology, new materials and nanotechnology.

Chapter 4 presents forecasts for productivity growth in the 12 broad market sectors listed earlier. As indicated earlier, these predictions are based on extrapolating productivity growth rates from the last 20 years and making some intuitive adjustments in the light of expected developments in technologies and energy markets. The predictions cover labour productivity (LP) growth, MFP growth and capital deepening (change in the capital-labour ratio). In addition, the MONASH model's sectoral projections for labour productivity growth are also presented. A brief sketch is provided on expected technological developments in each market sector. The in-house study does not deal in detail with non-market sectors. For these sectors only LP growth predictions are presented, based on projections from the MONASH model.

Note, the forecasts from the in-house study are referred to as predictions rather than projections. The term projection in the economic literature usually refers to forecasts based on mathematical-statistical models, such as the MONASH model. However, the forecasts from the in-house study are essentially intuitive extrapolations based on historical data combined with additional information on technological trends and natural resource constraints. Consequently, it seems more appropriate to refer to them as predictions.

Chapter 5 examines opportunities for productivity improvements in the non-market sectors of health and education. The purpose of the discussion is not to present quantitative predictions for productivity growth but rather to highlight emerging technological opportunities.

Chapter 6 combines the sectoral forecasts in chapter 4 to derive aggregate predictions for LP growth in the economy. After some adjustments the LP growth predictions yield the predicted growth in GDP per capita. The predictions are not extended to total real GDP, because this paper does not contain population projections. Demographic forecasts have been covered in a number of other Australian economic studies.

Chapter 6 also presents predictions on expected changes in the sectoral composition of the economy (that is, structural change) in the light of historical trends and predicted productivity growth rates in different sectors. The final section presents some brief answers to the issues raised in section 1.1.

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2. Methodological and forecasting issues

As indicated earlier, most of the productivity forecasts presented in this report follow national accounting (that is, GDP) conventions. To understand better the meaning of these forecasts it is necessary to clarify what is measured in the national accounts, how it is measured and in particular what methods are used to estimate changes in sectoral outputs over time.

Other issues examined in this chapter include the reliability of national accounts forecasts, non-technological drivers of productivity growth and the relative importance of energy production in GDP, a subject of some importance in forecasting given the exceptionally large uncertainties in this area.

2.1 The scope of national accounts

A major purpose of national accounts is to estimate total national output, commonly referred to as gross domestic product (GDP). In addition, national accounts present estimates for the output of different sectors as well as the allocation of output and consumption between households, government, investment and exports. Apart from GDP, national accounts reports gross national income (GNI), which is GDP plus or minus total net income from abroad. Also reported is real net national disposable income (RNNDI), calculated by taking real gross domestic income and deducting real incomes payable to the rest of the world, adding the real incomes receivable from the rest of the world, and deducting the volume measure of consumption of fixed capital. The main focus of attention in this report is on forecasting output per hour at the sectoral level and real GDP per capita. The terms constant price GDP and real GDP are used interchangeably in this report.

Needless to say that national output covers a multitude of items. Monetary units are the common denominator used in all national accounting measures. Sectoral output is measured in terms of value-added and these value-added estimates in the national accounts are based on the aggregation of financial (accounting) results of private and public enterprises and government agencies. Provided sufficient information is available from enterprise surveys and taxation statistics, the aggregation of financial data does not pose major conceptual difficulties in current prices. The same, however, does not apply when trying to estimate changes in constant price value-added, a subject that will be discussed in the next section.[7]

Given that national accounts are based on accounting (financial) aggregates, there are some important limitations involved in forecasts that follow national accounting definitions. Much of the recent forecasting literature deals with issues not properly covered in the national

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[7] GDP, GNI and RNNDI growth estimates can be established without reference to sectoral data by aggregating information on incomes (labour and capital) across all sectors (say, by using taxation statistics) and deflating the totals by an aggregate price deflator, based largely on the consumer price index. Diewert (2004) expresses the view that constant-price aggregate GDP estimates are much more reliable than the corresponding sectoral value-added estimates. This view is also echoed in Diewert and Lawrence (2005a).

accounts, such as sustainable development and the environment. Major issues in this area include climate change, deforestation, soil degradation and the depletion of natural resources such as crude oil and ocean fisheries. These changes are reflected in the national accounts only if they have a measurable impact on current economic performance. Otherwise, these environmental changes are not reflected in current national accounts statistics, though some future consequences of resource depletion might be picked up in the national accounts in later years.[8]

For that reason, the present forecasts do not deal with natural resource and environmental issues, apart from soil degradation in agriculture and the uncertain outlook in regard to oil and other energy sources over the next 20 years.

Also, no attempt will be made to forecast a number of important economic variables (some of them included in the national accounts), which do not contribute much to the understanding of productivity growth in the market sector. These include exports, imports, balance of trade, exchange rate, unemployment, taxation, government expenditure and the like. Forecasts from the MONASH general equilibrium model reported in this paper do take into account expected changes in these other economic variables.

There are other economic factors besides resource depletion and the environment that are not covered in the national accounts. Perhaps the most significant among these is the changing pattern of income distribution. The substantial productivity growth in the last two decades was accompanied by increasing income disparities and a rising proportion of casual workers in the workforce (Watson et al 2003 and AMP.NATSEM 2004). Whether these trends will likely to continue in the next 20 years is outside the scope of this study.

It should be noted that maximising national income (GDP or RNNDI) per capita is not the only valid socio-economic objective. There are other important and sometimes conflicting social aims, such as promoting freedom, raising cultural standards, improving social harmony, reducing income inequalities, reducing stress and uncertainty, reducing environmental pollution and protecting natural flora and fauna. Notwithstanding the presence of other socio-political objectives, national income provides a reasonably good indication about the level of output in the economy.[9] How this output is used depends on consumer preferences and political choice, a subject outside the scope of this forecasting report.

2.2 Volume value-added measures used by the ABS

This section examines the methodologies used by the ABS to estimate sectoral volume changes in the national accounts. Following the adoption by the ABS of supply and use table to benchmark the national accounts estimates of GDP, annual double deflated measures of output volumes are available for all industries on a comparable basis from 1995–96 onwards.

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[8] This subject is discussed in more depth in Eckersley (1998).

[9] Eckersley (1998) and McNeill (1999) examine the relationship between GDP and some other social welfare measures.

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Prior to 1995–96, and still on a quarterly basis, the ABS uses three volume indicators to estimate volume value-added at the industry level:[10]

- the output indicator method;
- double deflation; and
- the input indicator method.

The output indicator method is the most widely used. It deflates value-added according to estimated volume changes in a fixed price weighted basket of products or uses a direct physical quantity such as tonnes of coal produced. The double deflation method is restricted to the agricultural sector in the quarterly estimates. The input indicator method is used in 'non-market' sectors, most particularly for government, and, prior to 1995–96, for property and business services (PBPS) and personal services. Estimates of health and education output are based on direct volume indicators from 1984–85 onwards and prior to that on labour input. The quarterly data compiled using these various techniques are benchmarked to the supply and use table results from 1995–96 onwards to ensure that the best estimates of 'real' value-added are compiled on both a quarterly and annual basis. Further detail on these methods is presented in the ABS National Accounts: Concepts, Sources and Methods (ABS 2000, chapter 24).

In most industries with tangible products, the output indicator method is based to a large extent on changes in physical quantities. The value-added volume index of mining is based on ABS and ABARE estimates of the quantity of output of various mining products. In industries such as electricity, gas and water supply, telecommunications, and transport, physical measures are combined with financial indicators to estimate changes in the real value of output over time. For example, in transport passenger/km and freight/km and in electricity kWhr consumed. Due to the large heterogeneity of manufactured goods, for manufacturing the estimates are based on the dollar value of sales of manufactured goods deflated by appropriate price indexes.

In service industries with less tangible outputs various indirect measures are used to estimate 'real' changes in value-added. In wholesale and retail trade the output estimates are based on inflation-adjusted turnover. In finance and insurance the estimated volume of output is based on financial service charges, premiums and capital income. In accommodation and restaurants the estimates are based on tourist guest-nights and inflation adjusted turnover estimates for clubs, pubs, cafes and restaurants. In cultural/recreational services the output indicators include the revenue of commercial TV and radio stations, expenditure on government supplied cultural/recreational services (broadcasting, libraries, museums, parks) and estimates from household surveys concerning expenditure on gambling and entertainment.

The double deflation method is used on a quarterly basis only in agriculture, where volume indexation of value-added covers both outputs and inputs. The changing volumes of farm outputs and inputs are estimated from ABS and ABARE agricultural surveys.

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[10] As noted earlier, annual estimates are based largely on double deflation.

The input indicator method is used in industries where it is very difficult to estimate volume indices of output. These include government administration and defence some elements of personal and other services, and prior to 1983–84 health and education. Since 1983–84 output indicators have been used for health and education volume measurement although issues regarding the measurement of quality change remain.

Where no other volume methods can be applied, the volume value-added estimates in the national accounts are based on total labour inputs (that is, working hours). That means that in these sectors (which still include government administration and defence) LP growth, defined as the change in the ratio of constant price value-added to working hours, is by definition zero. Therefore, these sectors are excluded from national accounts based productivity forecasts, though this study will examine likely changes in their output (based on total labour hours) when projecting changes in the sectoral composition of GDP (section 6.3). For other non-market sectors, where only partial historical productivity estimates are available, the productivity forecasts from the MONASH model are used.

2.3 Quality-adjusted price indexation problems

One of the major methodological difficulties in forecasting at the sectoral level is related to the measurement and prediction of changes in the volume of aggregate output. Each sector analysed in this paper covers thousands of different products and/or services. Given perpetual changes in the composition of output and the quality of products, the appropriate volume indexation of value-added is a challenging problem.

Commenting on productivity growth in the USA, the president of the Federal Reserve Bank of St. Louis (Poole 1999) raised the question whether the measurement of productivity is distorted. He quoted one of the pioneers of productivity research, Griliches, who argued that the part of the USA economy he calls ‘reasonably measurable’ has declined from about half to less than 30 per cent since World War II.

The problem is that much of the economy produces things that are extremely difficult to measure and the share of this sector—services, broadly speaking—keeps growing. Griliches’ bottom line is that outside of sectors like agriculture and manufacturing, where it is more or less possible to count things in order to measure output, one should be extremely suspicious of productivity numbers. This qualification also applies to Australian productivity estimates.

Volume indexation difficulties are aggravated by tumbling ICT equipment prices as a result of continuing rapid technological progress in this area, which is a central topic in this report. DeLong (2000) cites a USA economic study, which found that a computer in 2000 cost one–ten thousandth as much as a computer with the same performance capabilities in 1960. This implies that the quality-adjusted price of a computer at the beginning of a decade was 900 per cent higher than at the end of a decade.

This magnitude of price changes raises serious indexation problems. Even if performance for the same price increased tenfold over a decade, the economic value of the output from the equipment did not increase 10 times, because the equipment became applied less efficiently as its performance improved exponentially. The decrease in price increased the quantity sold, but computers became less intensively used in terms of working hours and the operating system employed for running them required much more processing time and memory.

Moreover, the equipment became employed in applications that would have been uneconomic with more expensive computers; such as Internet communications, video games, CD-ROM reading, e-commerce, control of spark plug ignition in cars or factory automation. For example, reading CD-ROMs was technically feasible already 25 years ago, but reading at the same speed as modern personal computers would have required computer hardware costing millions.

Obviously, the quality-adjusted 'hedonic' price and volume indexation of ICT equipment raises many difficult issues. Not only is it difficult to estimate accurately constant-price quality-adjusted values for computers sold to consumers, but there are even greater difficulties in estimating the real constant-price value of the ICT capital stock deployed by industry. These problems carry over to forecasts involving constant price volume changes in ICT using industries.

A related issue is that a significant portion of falling ICT prices are reflected in the national accounts in capital deepening (that is, increase in the capital-labour ratio) rather than in MFP growth. According to estimates in DCITA (2005a) around 30 per cent of capital deepening represents not real investment but the effect of tumbling ICT prices on the quality-adjusted constant-price valuation of capital services. This subject is discussed in more detail in section B.4 in the appendix.

A recent research report on productivity growth, commissioned by DCITA and prepared by Diewert and Lawrence (2005b), estimated higher rates of output and MFP growth over the period from 1965 to 2003 than the estimates reported by the ABS. Part of the difference arises as a result of different approaches in estimating the quality-adjusted value of capital services.

Partly due to the ICT revolution, the product composition in the economy is changing rapidly. According to Diewert and Lawrence (2004), two per cent of the price quotes by a typical statistical agency in one month are no longer available in the following month. The rapidly changing composition of output raises serious difficulties in establishing robust measures for changes in quality-adjusted constant-price sectoral value-added.[11] In addition, possible large scale expansion in the future of pollution control measures may pose major difficulties to the quality-adjusted valuation of national output.

2.4 The reliability of extrapolations

The introductory chapter in Cooper and Layard (2003) outlines a number of methodologies used in forecasting studies, including extrapolations, the construction of scenarios and searching for consensus views among experts. In this report the emphasis is on the

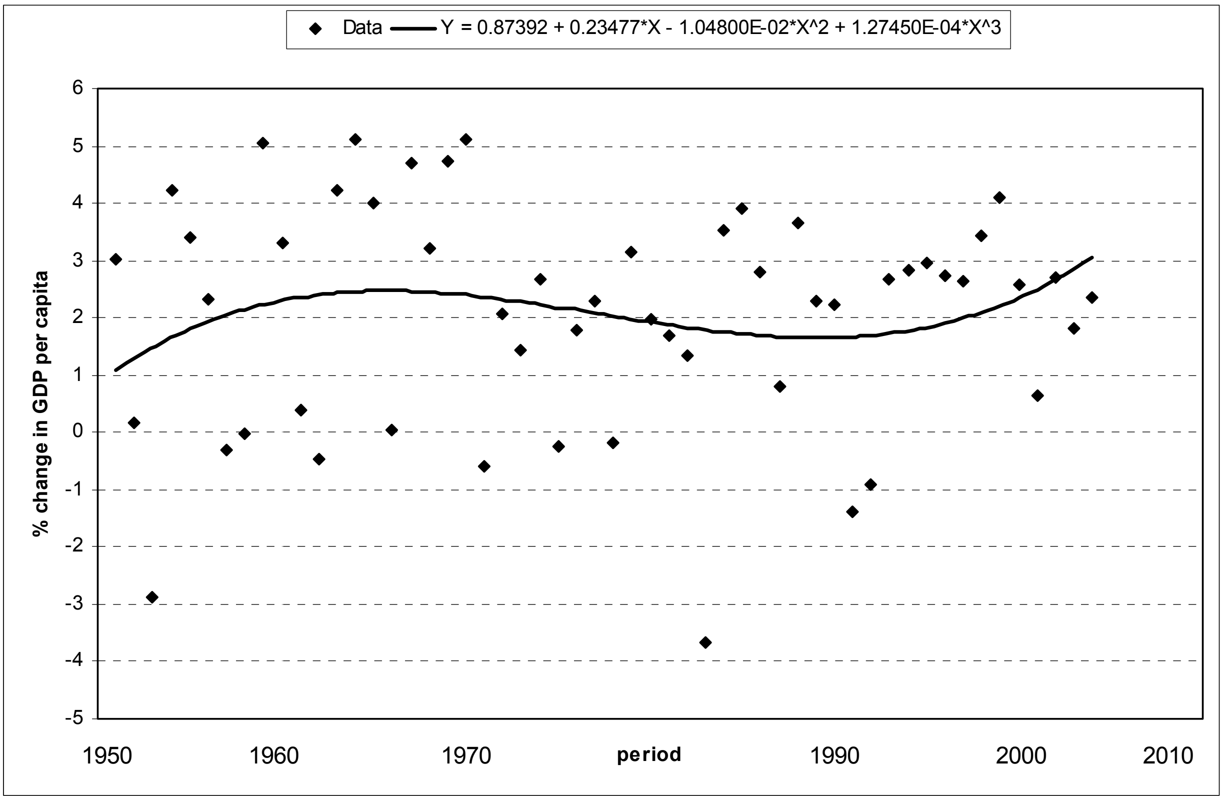
11 Diewert (2004) presents a fairly comprehensive review of various indexation problems related to national accounts based productivity measures with special reference to Australia.

extrapolation of historical trends of productivity growth. This raises the issue of the reliability of statistical extrapolations in the productivity area. To the extent that productivity growth in the past followed a fairly smooth and predictable pattern, this would increase one's confidence in being able to predict reasonably well future trends.

For the purpose of examining productivity trends in the past, this report uses real GDP per capita as a proxy productivity measure. While it is not the same as labour productivity (related to the number of persons employed or working hours) the real GDP per capita statistics has the advantage of going back further in time.[12] Using information from Foster (1996) and recent ABS data, it is possible to construct a time series of real GDP per capita from 1949–50 to 2003–04. Table A.1 in the appendix shows the data over 54 years.

Figure 2.1 illustrates the variations in annual real GDP per capita growth rates. Clearly, annual growth rates vary significantly. Yet the long-term growth rate is fairly steady.

Figure 2.1 Annual percentage changes in real GDP per capita: 1949–50 to 2003–04



The formula of the regression is shown in the upper panel. None of the coefficients is significant at the 5 per cent probability level and R^2 is only 0.04. The time variable (x) in the regression starts from 1950 = 0.

Source: Foster (1996), ABS Cat. No. 5204.0.

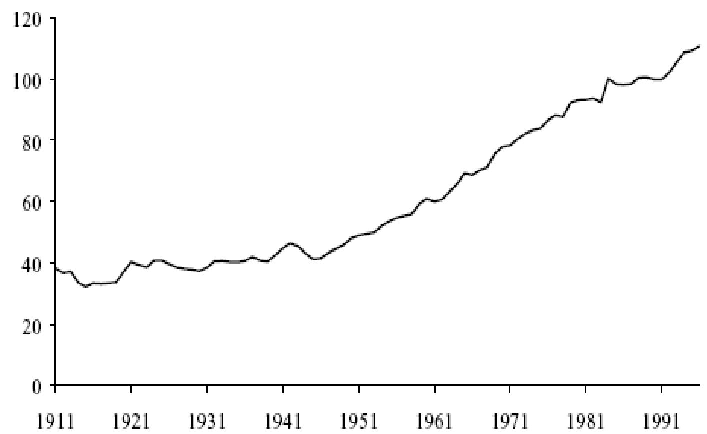
Figure 2.1 shows a third order polynomial regression line fitted to the data. This curve illustrates that smoothed growth rates averaged around 2 per cent per annum over 54 years with some moderate fluctuations between decades. Since the late 1980s there has been an

12 The predicted relationship between LP growth and GDP per capita growth is discussed in section 6.1.

upswing in real GDP per capita growth rates. Figure 2.1 suggests that by using for extrapolation purposes not annual growth rates but rather historical growth rates over 10 or 20 years, one might be in a reasonable position to predict the growth in real GDP per capita over the next 20 years.

The Industry Commission (1997) report on productivity looked at a longer time-series of aggregate productivity growth from 1911 to 1996, using real GDP per worker as the productivity indicator. Figure 2.2 displays the long-term trend. The growth rates before World War II were negative or low, but picked up after the war and maintained a fairly steady trend since then. The pre-war experience suggests that long-term extrapolations may not always be reliable.

Figure 2.2 Real GDP per worker, 1910–11 to 1995–96 (index 1989–90=100)



Growth rates[b]	
1910s	-0.9
1920s	-0.3
1930s	0.9
1940s	0.4
1950s	2.4
1960s	2.7
1970s	1.8
1980s	0.9
1990s	2.0

Source: Industry Commission (1997).

Regarding overseas aggregate productivity trends, an American economist (Baily), in commenting on some medium-term productivity projections presented in Gordon (2003), noted the striking regularity of USA aggregate productivity growth over the 20th century. From 1899 to 1999 GNP per capita in the USA grew at 2.1 per cent a year on average. Over the first half of the century growth averaged 2.0 per cent a year and over the second half it was 2.2 per cent. There was some variation over sub-periods, notably during the great depression. But there was less variation during the second half of the century. GNP per capita grew at an average rate of 2.4 per cent a year over 1948–73, at 1.9 per cent over 1973–90 and at 2.1 per cent over 1990–99. Some American economists dubbed this finding as the ‘2 per cent solution’ to forecasting.

Despite the considerable regularity of Australian and American real GDP per capita growth rates over the second half of the 20th century, long term extrapolation based on past performance is still risky even at the aggregate level. Table 2.1 uses the Australian real GDP per capita data from 1949–50 to 2003–04 to test how average growth rates in the preceding 20 years compared with growth rates in the following 20 years. Data are available for 20 years on both sides only for 14 financial years from 1969–70 to 1983–84.

The figures in table 2.1 indicate significant differences between prior and posterior productivity growth rates, depending on the position of the reference year on the long-term productivity cycles depicted in figure 2.1. During most of the period examined, real GDP per capita growth in posterior years was lower than in prior years, reflecting the effect of the productivity boom of the 1950s and 60s. However, toward the mid 1980s, real GDP per capita in posterior years exceeded that in prior years due to poor productivity performance in the 1970s and 80s and the upswing in the 1990s.

Reducing the time horizon in prior years from 20 to 10 years will tend to widen the differences between prior and posterior growth rates, as shown in table A.2 in the appendix.

Table 2.1 Comparison of average real GDP per capita growth rates in prior and posterior 20 year periods

Year ended June	*Average annual growth rate prior 20 years*	*Average annual growth rate posterior 20 years*	*Ratio of growth rates in posterior over prior years*
	%	%	
1970	2.44	1.63	0.67
1971	2.26	1.59	0.70
1972	2.36	1.44	0.61
1973	2.58	1.50	0.58
1974	2.50	1.51	0.60
1975	2.32	1.67	0.72
1976	2.29	1.71	0.75
1977	2.42	1.73	0.71
1978	2.41	1.91	0.79
1979	2.32	1.96	0.84
1980	2.25	1.99	0.88
1981	2.32	1.94	0.83
1982	2.41	2.00	0.83
1983	2.01	2.29	1.14
1984	1.93	2.23	1.16

Source: Foster (1996), ABS Cat. No. 5204.0.

The initial evidence used in this report to gauge the future are average sectoral productivity growth rates in the previous 20 years, which are then moderated intuitively by views about how technological developments may affect productivity prospects. The figures in table 2.1 give some indications about the appropriate confidence interval. The largest difference between prior and posterior figures is minus 42 percent in 1973 and plus 16 per cent in 1984. These figures suggest that in 20 year extrapolations a suitable confidence interval at the 80 per cent probability level may lie between 35 per cent below and 25 per cent above the projected aggregate mean productivity growth rate.[13] In chapter 4 this confidence interval is used to define the upper and lower predictions for sectors where no exceptional uncertainties are identified. Wider confidence intervals are used in sectors where there are

[13] This implies a skewed probability distribution with the lower tail being longer than the upper tail.

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reasons to expect larger uncertainties. These sectors include agriculture, mining, electricity, water and transport.

Needless to say, if there were reasons to believe that the momentum of technological progress will slow down in the next 20 years, then productivity projections based on extrapolations ought to be revised downward. However, as discussed in chapter 3, there are no signs for slowdown in the current major dynamic technological fronts, that is, ICT, biotechnology and nanotechnology.

2.5 Non-technological factors behind productivity growth

The predictions in this study are heavily influenced by expected technological developments. But there are other important factors behind productivity growth that should be noted.

According to estimates from Productivity Commission (2005a), over 52 per cent of labour productivity growth in the 'market sector' of the economy from 1983–84 to 2003–04 was the result of capital deepening (that is, increase in the capital-labour ratio). The remaining 48 per cent was due to MFP growth, which is the residual that represents technological and organisational progress and increase in 'human capital'. The quality-adjusted constant-price value of capital services per working hour (that is, capital deepening) has nearly doubled during this period. Capital deepening is expected to remain a major driver of labour productivity growth in the next 20 years as well. It is taken explicitly into account in the sectoral predictions in chapter 4.

According to estimates in DCITA (2005a), around 30 per cent of capital deepening in the last two decades was the result of tumbling ICT prices rather than increased capital spending per worker.[14] The effect of tumbling ICT prices on capital deepening is likely to continue, but perhaps at somewhat slower pace than in the past. Consequently, this study usually adopted lower capital deepening estimates than those indicated from historical data[15].

Expected changes in the economic-institutional environment and their impact on sectoral productivity growth rates are not analysed explicitly in this report, however, the effect of past changes in the economic environment are reflected in the historical productivity growth rates on which the predictions are based. According to the analysis presented in NOIE (2004) and DCITA (2005a), between 30 and 60 per cent of MFP growth since the mid 1980s

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[14] According to unpublished ABS capital stock data expressed in current prices, since the early 1980s the stock of computer hardware and software grew over three times faster than the net capital stock of machinery and equipment.

[15] In 2002-03, ICT capital (including software and electrical equipment) accounted for 21.5 per cent of the estimated total value of capital equipment deployed in market sector industries (ABS Cat. No. 5204.0, Capital Stocks unpublished data). The true figure could be higher, because much ICT equipment and software incorporated into various industrial and transport equipment is not recorded as ICT capital in the ABS statistics. Around a third of the ICT capital recorded was software and the proportion of software has been increasing steadily in recent years. Given the growing importance of 'smart' equipment and devices in various production activities, investment in software will likely to account for an increasing share of capital stocks.

can be attributed to changes in institutional-economic factors, including globalisation, micro-economic reforms and rising education standard of the workforce.

NOIE (2004) and DCITA (2005a) present statistical evidence in support of the view that technological progress, particularly in ICT, was more important in driving labour productivity growth in the last two decades than changes in the economic environment. The principal observation supporting this argument is that productivity growth tended to be much higher in ICT intensive sectors than in others. However, both these studies acknowledge that microeconomic reforms had some non-estimable indirect effects on productivity growth by stimulating investment and the adoption of new technologies and by improving economic efficiency.

On this issue the Productivity Commission places more emphasis on the importance of micro-economic reforms. The weight to be given to various influences is difficult to estimate. More detailed analysis of this subject can be found in Productivity Commission (1999), Parham (2004a), Parham (2004b) and DCITA (2005a).

There are two important points that should be noted from the discussion above. First, MFP growth cannot be equated exclusively with technological progress. Changes in the economic environment may have a significant impact on MFP growth. Second, the effective takeup and efficient utilisation of new technologies requires institutional change. Such changes could have a major impact on capital deepening and MFP growth.

Other factors that may affect productivity growth in the next 20 years include possible changes in the climate that could affect agricultural productivity and possible supply problems in energy markets, particularly that of oil, which could affect transport and other sectors in the economy. These factors are discussed briefly in this report. Their future scale and impact on productivity is very hard to predict.

2.6 The share of energy production in GDP

The range of uncertainties in the energy sector is wider than in most other sectors of economy. One reason is connected with global efforts to reduce greenhouse gas emissions; the other is related to the gradual depletion of crude oil reserves around the world.[16]

Both factors might have a significant negative impact on national productivity growth in the next 20 years, although it is far from certain that such an impact will actually occur. Given the wide uncertainties surrounding energy supplies, it is of some interest to examine the share of energy production in GDP, in order to gauge the potential impact of significant changes in energy markets and technologies on national productivity.

[16] The source of the uncertainty is not so much that existing crude oil reserves are gradually being depleted, but that new reserves are not being developed fast enough to keep up with the growth in world oil consumption—so oil prices are becoming more volatile. According to British Petroleum (2004) estimates, known world oil reserves can satisfy world demand for another 40 years at current consumption level. However, the growth in world oil consumption and the rate of discovery of new reserves is hard to predict.

The primary energy sectors comprise of coal mining, oil and gas extraction, electricity generation and gas distribution. From the latest ABS mining statistics and national accounts, the share of energy production value-added in GDP (at factor prices) in 2002–03 was 5.27 per cent; its composition is shown in table 2.2:

Table 2.2 The share of energy production in GDP in 2002–03

	%
Coal mining	1.09
Oil and gas extraction	2.34
Electricity	1.61
Gas distribution	0.22
Total primary energy	5.27

Source: ABS Cat. No. 8415.0 and ABS Cat. No. 5204.0.

Due to confidentiality reasons, the ABS does not publish value-added and sales statistics on oil extraction separately from gas. From information on foreign trade and the quantities produced and traded, it appears that oil (including liquefied petroleum gas) accounted for 72 per cent of oil and gas extraction value-added in 2002–03, with the remainder being natural gas. This implies that the value-added of crude oil production in that year was 1.68 per cent of GDP. In 2002–03 total petroleum exports (including liquefied petroleum gas) amounted to 1.06 per cent of GDP, while corresponding imports amounted to 1.26 per cent.

Some studies (for example, Kümmel et al (2002) and Ayres et al (2003)) argue that the energy sector makes a much larger contribution to the economy and to economic growth than its 5 per cent share of GDP in industrialised countries. There can be no question that energy supplies are vital to modern economies. This is evidenced by the fact that short-term disruptions to energy supplies caused by events such as oil price shocks or accidental disruptions to electricity, oil or gas supplies can result in economic losses well beyond the direct costs incurred.

But from a long-term perspective, the critical point in relation to energy is not the non-marginal contribution of energy supplies to the economy (in terms of consumer and producer surplus) but rather the replacement cost of current energy sources by non-fossil fuels and by substitutes for crude oil.

Indications are that with currently known technologies much of fossil fuel based electricity generation could be replaced by alternative energy sources such as nuclear fission, wind power and biomass with probably less than 50 per cent extra cost imposed on users. Some cost estimates are discussed in the (USA) Energy Information Administration (2001) report and in Abt (2003). Various substitutes for crude oil such as bio-ethanol, liquefied gas and high grade shale oil can already compete commercially against crude oil products in niche markets. Much larger supplies might come into the market in the long-run if the oil price stays or rises above its current high level.[17]

[17] Electric vehicles driven by batteries or hydrogen using fuel cells are more expensive petroleum substitutes. Section 4.10.3 presents more information on this subject. Synthetic petroleum from

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In the light of these estimates and given the 5.3 per cent share of energy production in GDP, it is possible (but far from certain) that in the long-run (well beyond the 20 year time horizon of this report) major changes in Australian energy supplies, to ensure long-term sustainability, could be implemented at an annual cost of less than 2.7 (= 5.3*0.5) per cent of GDP. The effects on GDP of short-term disruptions in energy supplies could be larger than that as will be discussed shortly.

ABARE's projections for the Australian energy market to 2019–20, reported in Akmal et al (2004), do not foresee major changes in energy sources or technologies before 2019. In the light of these projections and the relatively small share of the energy sector in GDP, it appears that even substantial increases in oil prices or greenhouse gas abatement measures will unlikely to reduce GDP by more than 3 per cent in the next 20 years compared with the level that would prevail without these problems.

Given the long life span of energy using/producing equipment (about 15 to 20 years for cars, 40 to 50 years for power stations) extensive transformation of the Australian energy system is unlikely to happen in the next 20 years, since preparations for major changes are not yet under way. To the extent that energy sources in Australia will change over this period (such as the partial replacement of coal by gas in power generation) the costs of these relatively small compositional changes will probably amount to less than one per cent of GDP. However, short term supply disruptions or instability in international energy markets could have a larger impact on real GDP, due to macroeconomic adjustment difficulties in Australia and abroad.[18] Possible events in this area are hard to predict, neither is it possible to estimate probabilities.

Taking three per cent of GDP as the probable upper limit of the annual cost of energy related problems assumes reasonably good mobility of resources over the forecast period. In the absence of strong mobility of resources, the effects of shocks in oil markets or the reallocation of resources to greenhouse gas abatement could be considerably larger than that suggested by GDP shares alone.

Compared with expected growth in real GDP per capita of between 28 and 44 per cent over the next 20 year (see section 6.1) a possible fall of three per cent in aggregate productivity due to energy related problems appears to be relatively small. The mean and pessimistic predictions in this report assume some negative energy-related effects on real GDP growth, but these are excluded from the optimistic predictions. A discussion on the possible effects of oil and other energy problems on mining productivity is presented in section 4.3.3, on electricity in section 4.5.3 and on road transport in section 4.10.3.

This report touches on energy issues in order to derive predictions for productivity growth in energy-related sectors that constitute part of GDP, however, it does not enter into this

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coal is another expensive crude oil substitute. It was used in Germany during World War II and in South Africa in more recent times.

[18] Note, the impact of higher oil prices on the Australian economy is partially offset by higher export prices of natural gas and coal. Such changes are reflected in the terms of foreign trade rather than GDP or sectoral productivity data. By virtue of national accounts definitions, changes in the terms of trade affect real national disposable income (RNNDI) but not GDP.

subject in great depth. A number of government agencies including the Australian Greenhouse Office, CSIRO, ABARE and the Bureau of Transport and Regional Economics are looking into future prospects in energy production and consumption. The predictions in chapter 4 take into account comments received from these agencies.

3. Technological futures studies

3.1 Methodology and information sources

This chapter reviews some recent literature on emerging technologies that are likely to become commercially important in the next 20 years. Further discussion about new technologies will be presented in chapter 4, in the context of sectoral forecasts. The purpose of this literature review is to ensure that the predictions presented later are not based solely on the extrapolation of historical trends but also take into account expected changes in technologies.

There is an extensive literature on emerging technologies. Some of this literature is intended to serve science and technology policy formulation while other publications serve the general public. The following discussion relies primarily on technological forecasts presented in RAND (2000 and 2001), European Commission (1999, 2000 and 2004), CSC (2002 and 2003), Tegart (2002) and OECD (2004b).[19] TIME (2000) presents a collection of articles about future technologies for non-technical readers. The Futurist magazine (published by George Washington University) also addresses non-technical readership.

Conducting technological forecast 20 years ahead is difficult but not necessarily unrealistic.[20] Many of the technologies that will be adopted in the next 20 years are already beyond the prototype stage. Generally, there is no need to consider untested ‘wild card’ technologies. In fact, predicting the diffusion of new technologies over the next 10 or 20 years is more closely related to commerce than to engineering, given that the aim of the exercise is to predict which of the existing leading-edge technologies will evolve to become important in the marketplace.

The diffusion of technological innovations tends to be gradual. For example, a study by David (1990), which traces the adoption of the electric motor in the American economy, shows that it took decades until the application of this important general purpose technology was approaching its true economic potential. Similar time lags have been observed in the historical diffusion of other major innovations (Grubler 1997). It takes many years until the benefits of the innovation become widely recognised and until the necessary economic infrastructure (including standards and regulatory framework) is established for its effective utilisation. Similar gradual diffusion could be expected with new technologies that only recently started to penetrate the market or have not yet been commercialised.

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19 European Commission (1999) summarises a number of foresight studies carried out in individual European countries.

20 The introductory chapter in Cooper and Layard (2003) outlines methodologies used in forecasting studies, including extrapolations, the construction of scenarios and expert panels. OECD (2002) presents a sarcastic review of numerous blunders in long-term technological predictions (usually more than 50 years ahead). A 20 year time horizon is more predictable, but major surprises are not entirely unexpected.

This chapter reviews some promising innovations in ICT, biotechnology, new materials and nanotechnology that are likely to have a significant impact on Australia's economic development over the next 20 years. The purpose of the discussion is to provide the reader some idea about the likely shape of technological progress, which will be reflected through MFP growth in the 'market sector' of the national accounts.

3.2 Information and communications technologies (ICT)

3.2.1 A historical perspective

There is a broad consensus emerging in the economic literature that ICT has been a major driver of productivity growth in developed countries in the last couple of decades. Recent overseas economic studies that highlight the central importance of ICT in driving productivity growth include David (2000), Schreyer (2000), Stiroh (2001), Colecchia and Schreyer (2001), Jorgenson et al (2002), Oliner and Sichel (2002), Bassanini and Scarpetti (2002), Gordon (2003), Inklaar et al (2003) and OECD (2004a).

Australian macro-productivity studies that point to the same conclusion include DeLong (2000), the Ovum Report (2002), Diewert and Lawrence (2005a and 2005b), NOIE (2004) and DCITA (2005a and 2005b). Parham (2004a) agrees that ICT had a major influence on productivity growth but places greater emphasis on micro-economic reform. Parham (2004b) recognises more clearly the importance of ICT but adopts a 'semi-sceptical' position.

Judging by recent technological futures studies, ICT will remain a major driver of productivity growth in advanced industrialised countries in the next two decades. An important contribution of ICT to productivity growth will be in improving automation in virtually all areas of the economy including offices, factories, shops, warehouses, schools, hospitals, farms and mines and in facilitating information search and flow.

The contribution of ICT to macro-economic productivity growth was spurred by unparalleled technological progress in this area. The capacity of digital processing and memory units improved over 10 million times in 50 years (European Commission 1999). This spectacular progress was caused mainly by the miniaturisation of microelectronic circuits. It is illustrated in the rule-of-thumb commonly referred to as 'Moore's Law', stating that the density of transistor circuits on a piece of silicon chip doubles every eighteen months. While the cost of computing was tumbling the cost of telecommunications was also decreasing at a rapid albeit slower pace, as a result of the introduction of optical fibre cables, satellite transmission and digital signalling and switching equipment.

The contribution of ICT to productivity growth in recent decades came through such innovations as the computerisation of accountancy, costing and stock control functions, electronic banking, barcode scanners and electronic commerce through the Internet and other channels. Information processing became much easier with the help of databases and spreadsheets. Electronic information archiving and retrieval can be carried out at a fraction of the cost of paper-based systems.

In addition, small computers (CNCs, PLCs and dedicated microprocessors) combined with sensors and actuators have been incorporated into various manufacturing, transport, farm and mining equipment, enabling improved control, machine diagnostics and reduced labour, material and energy requirements. Much of the expected contribution of ICT to productivity gains in the future will result from the continuation and intensification of these trends, but in many areas radically new innovations will assume increasing importance and these will be reviewed briefly in the following sections.

The following discussion concentrates on the effect of ICT on production sectors in the national accounts rather than ICT consumer goods.

3.2.2 Ubiquitous computing and communications

Ubiquitous computing and communications is a vision of widely used distributed computing, connected through broadband services. This vision sees a world within the next decade or two in which almost everything around us has computers built in and interconnected (Tegart 2002). Apart from consumer electronic goods, these include computerised controllers and micro electro-mechanical systems (MEMS) incorporated into cars, machines and many home appliances. Low energy radio frequency identification devices (RFIDs) can be attached to a plethora of inexpensive devices including: cameras, microphones, accelerometers and gyroscopes in cars, blood pressure meters and various medical and environment monitoring instruments. Generally, the trend is toward 'smarter' machines, equipment and appliances.

Ubiquitous computing/communications require the development of systems, including input-output and power components, which can be embedded into non-computer devices. ICT devices will become smaller, lighter and 'smarter'. Intelligent interconnections between digital devices raise many new challenges in software development.

Ubiquitous computing and communications will likely to permeate the consumer electronics market. As explained in section 3.2.8, dedicated microprocessors, CNCs, PLCs, MEMS and RFIDs will also play a key role in productivity enhancing innovations in various sectors of the economy.

Ambient intelligence

Ambient intelligence refers to the convergence of three key technologies: ubiquitous computing, ubiquitous communication and intelligent user friendly interfaces. Again, this concept refers to prospective developments in both consumer and industrial markets. In regard to industrial applications, the evolution of ambient intelligence will heavily depend on the speed of diffusion of new software to provide machine intelligence to a multitude of applications in various production and service activities. More will be said on that subject later.

Gartner's vision

The international ICT consulting group Gartner (2004) identifies four technology areas that will be crucial in creating and supporting ubiquitous computing/communications.

Sensor networks—will provide new ways to measure and monitor physical environments in minute detail. Everything will be connected and its location known. Sensor networks will be used to increase efficiency, reduce costs and gain a better picture about the immediate future.

Ever present connectivity—involving PDAs, smart phones, portable computers, compact music/video players, security systems and the like, all connected through wireless communication technologies.

Data storage and access—will improve so rapidly that the cost of keeping everything will be cheaper than the cost of deciding what to keep. This will result in a phenomenon called 'perfect recall', that is, digital trail that capture people's every move and which can be reclaimed when needed.

Real time infrastructure—will use sensor network management and event driven technologies to build distributed mega-systems capable of capturing, storing and analysing trillions of transactions.

The following nine sections describe some productivity implications of ubiquitous computing/communications and ambient intelligence in more detailed and concrete terms.[21]

3.2.3 The expansion of broadband

All technological forecasts indicate a very large increase in broadband communications over the next two decades, driven by rapidly falling prices, increasing equipment capabilities and conversion from analogue to digital signals. The expansion of 'second generation' Internet, digital cable TV and video phones is expected to fuel a massive increase in demand for broadband communications.[22]

Many businesses are already connected to the Internet through high-speed broadband and ADSL connections to households are increasing rapidly. In the future high-speed broadband to households will provide unified access to cable (digital) TV, conventional and video telephones, the Internet and digital devices inside the home.[23] The user will be able to navigate between various applications with relative ease.

Broadband will help to raise business productivity through wider diffusion and better quality services in e-commerce, e-banking, e-government, e-education and e-health. In addition, broadband is essential for the expanding field of 'distributed computing', which involves

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[21] Kurzweil (2005) presents some provocative thoughts on the possible impact in the long run of new developments in ICT and nanotechnology on human health and cognitive abilities. Given that these long-term predictions are unlikely to be realised on a significant scale within the next 20 or even 40 years, they are not reviewed in this report.

[22] Second generation Internet provides an integrated channel for data, voice and video communications. It is possible that in the next 20 years telephone and fax numbers will be gradually replaced by Internet-type addresses (Australian Communications Authority 2005).

[23] According to CSC (2002) it is not certain that broadband lines to households will consist only of optical fibre cables. Radio communications is likely to provide some competition in 'last mile' broadband connections.

sharing processing power and memory between a large number of computers located in different places (CSC 2003). The ICT network in e-research (discussed in section 3.2.10) represents a distributed computing network. It can be used to access remote databases and high speed computing in research applications. Much of the expanded broadband will serve the consumer market, by offering more diverse and higher quality entertainment and personal communication services.

RAND (2000) predicts the introduction within the next decade of ultra high speed optical telecommunication networks based on optical switching equipment, which will replace the currently used electronic switches. Such optical equipment could switch signals many times faster than electronic switches.[24] Their diffusion could lead to a major shakeup of the telecommunications equipment industry worldwide.

3.2.4 Portable ICT devices

Portable information devices combining the computing power of the personal computer, the networking of the Internet, the vivid images of TV and the convenience of telephone are expected to be used by over half the population by the next decade. The recent growth in the Internet and mobile phones can be seen as further steps toward a 'networked society' (or ubiquitous communications), in which people will expect to be able to communicate electronically anywhere and anytime in full motion multi-media.

Due to the scarcity of radio spectrum, radio communications will be confined mainly to short distance signals while most long distance transmission in mobile networks will be carried through optical fibre cables, which already have enormous capacity. Satellite based mobile telecommunications is expected to expand with low orbiting satellites and high altitude drones.

The recently developed 'Bluetooth' and 'Wi-Fi' technologies allow wireless communications within short distances using low energy radio signals at more than one megabit per second. Bluetooth is usually suitable for a distance of less than 10m and Wi-Fi for less than 100m. Such capabilities permit many appliances and devices in the home, office or factory to 'talk' to each other. This creates new possibilities for many novel applications in warehouses, shops, factories, hospitals and other workplaces.

A promising innovation among mobile personal devices is a type of high-resolution medium screen laptop computer that can be read like a book or journal. In some of these devices inputs can be written on the screen rather than typed or alternatively given by voice.

Like fixed broadband, portable ICT devices are likely to serve mainly the consumer market (that is, entertainment and personal communications). However, there are some important new business applications that should be noted. Global positioning system (GPS) devices

[24] Optical switches (such as controlled tilting nano-mirrors) could remove the delays currently caused by having to convert from light to electricity in electronic communication switches used in optical fibre networks.

are already being used to track accurately the position of trucks and cars on the road.[25] They can be also used to track within a radius of a few meters the location of workers carrying GPS devices. Even more accurate location tracking is possible through RFIDs carried by workers in an area populated by a dense network of RFID readers. While such capabilities may contribute to improved productivity, they raise issues about supervision and privacy.

Personal digital assistant (PDA) portable devices represent another productivity improving innovation that is likely to be widely used in the future. The PDA is a personalised information storage and retrieval system. PDAs offer a powerful memory aid to knowledge and managerial workers that can be used instantly anywhere.

3.2.5 Radio frequency identification devices (RFID)

The rapidly falling cost of microcircuits opens the way for the development of various inexpensive digital signalling devices that can transmit short wave radio signals to a nearby computer terminal. Some of these are being referred to as 'microlocator tag with communications' or 'RF identification tags'. The principle is similar to that of a cordless phone, but these wireless devices are usually much smaller and cheaper. They can use the Bluetooth technology mentioned earlier as well as other short distance communication protocols. The power source for transmission comes from radiation energy absorbed from the signal receiving unit (the RFID reader).

RFIDs have many promising applications in commerce, industry and consumer goods. To avoid a cacophony of simultaneous signals from many RFIDs transmitting to the same computer (RFID reader) at the same time requires a sophisticated transmission protocol. OECD (2004b) sees the lack of standardised RFID communications as one of the major barriers to wider diffusion of RFIDs.

The application of short distance wireless communications integrated into local area networks (LAN) in offices, factories, warehouses, hospitals and nursing homes could lead to major productivity improvements. For example, a dense network of RFID readers can be used to monitor the location and movement of materials in warehouses and factories. This opens the way for computer controlled movement of materials by means of robotic palletizers and trolleys or the provision of locational guidance to the operators of forklift trucks. RFIDs can also improve stock control, supply chain management and just-in-time delivery. RFID tags could displace barcode labels in many shops and warehouses, though barcode labels will continue to be used widely in the next 20 years.[26] RFIDs worn by patients in hospitals and nursing homes can enable computer aided monitoring of their condition and location. Other possible applications of radio signal emitting/receiving chips will be discussed in later sections of this report. In many instances, such devices obviate the need for wired connection to a moving object that is controlled or monitored by a computer.

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[25] Location tracking devices, using GPS, can be also used to monitor the movement of pets, children and people with disabilities.

[26] According to OECD (2004b) some 'passive' RFID tags cost now less than 5 cents a piece. At this price range RFIDs are commercially competitive with barcode labels, since RFIDs can provide much more information than labels and the information stored inside the RFID can be modified.

3.2.6 Micro-electromechanical systems (MEMS)

MEMS integrate a small computer with mechanical elements, sensors and/or actuators on a single chip. It is one of the major achievements of the new field of nanotechnology (section 3.5).

MEMS enable the development of smart products by augmenting the computational ability of microelectronics with the perception and control capabilities of micro-sensors and micro-actuators. The micro-sensors measure the environment, while the microelectronics process the information and direct the actuators to respond accordingly. In a sense MEMS are a microscopic version of traditional computerised control systems used in industry. The application of computerised controllers and MEMS in production activities will be examined in more detail in section 3.2.8, dealing with advanced automation.

MEMS are truly microscopic – some incorporate electrically driven motors smaller than the diameter of the human hair. Other mechanical elements commonly used include small levers, gears and electrical power switches. Due to their low cost, minute size and increased functionality, MEMS have the potential to impact virtually every product category.

In the last decade the MEMS technology made its way into a handful of applications, most notably in the automotive industry, where MEMS are used to monitor and improve fuel efficiency, tire pressure, air conditioning, brakes, suspension and airbag deployment. Other applications include optical switching in telecommunications (to replace electronic switches), biomedical applications (lab-on-a-chip, assay-on-a-chip) and RF MEMS for mobile phones (RAND 2001 and CSC 2002).

In a similar manner to their application in motor vehicles, MEMS can be incorporated into various parts of machinery and equipment used in manufacturing, construction, agriculture and mining, to control and coordinate the operation of different machine components. They can lift productivity by improving the 'intelligence' of machinery and equipment.

3.2.7 New software technologies

The fast rollout of ubiquitous computing and communications with the implicit pervasive applications across all industries and activities and the complexity effects of interconnecting all these devices could pose significant challenges in software development.

On the one hand, over the past 50 years hardware has achieved over 10 million times increase in performance (in terms of processing speed and memory size), while software is still largely a craft industry (European Commission 1999). Thus, it is not surprising that software related innovations were repeatedly at the top of the priority lists of ICT technologies in European foresight studies. The fact that large programs extend over thousands and even millions of machine code instructions makes it very difficult to develop new software error free.

Most technological foresight studies identified the crucial role of new software construction methods, with emphasis on formal software modeling, object orientation and reusable libraries. While these software methods require more coding than traditional programming, they enable modular development of new software incorporating self-contained program

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segments (objects) or entire programs developed elsewhere. Efforts are being made toward automation of software production by creating self-generating and self-updating software. Perhaps the most significant achievement in this area would be the development of virus ‘vaccines’, which could detect unauthenticated program segments and might become operational within the next decade.

On the general applications side, new software development efforts are directed at:

- improving security protection from viruses and hackers;
- improving authentication procedures to identify the sender;
- reducing coding errors through program segmentation and improved testing;
- improving interoperability between different operating systems (platforms);
- improving and developing new digital communication protocols;
- improving ‘middleware’ software used in distributed computing;
- improving data search capabilities and the manipulation of large databases;
- developing better voice recognition and visual pattern recognition capabilities;
- improving computerised language translation;
- developing ‘artificial intelligence’ programs for various applications;
- improving three-dimensional visual representations; and
- improving PDA software to help organise personal and business affairs and assist memory.

In each of these areas substantial progress is expected in the next 20 years.

It should be noted that further development of e-commerce, e-banking, e-government and e-health require the resolution of security and authentication problems on the Internet and increased public trust in the system. Currently, private system developers and government agencies are working to resolve these issues. Reducing network security problems and increasing public confidence in the Internet is a challenging problem. A recent article in the Australian National Security Review (2004) draws attention to the rapid obsolescence of current security measures in the face of emerging new technologies, such as distributed applications through LANs.[27]

The high cost of software development and the shortage of programmers (particularly those with engineering skills) are unlikely to delay by much further development of major software applications where the cost of new software can be defrayed among millions of users. The high cost of software is more likely to delay the development of a myriad of product-specific applications in machine control, where the customer base is much smaller.

Hence, despite the availability of suitable ICT equipment, CNCs, PLCs, MEMS, RFIDs, electronic sensors and electro-mechanical actuators, progress in computerised automation in various fields might be delayed due to the high cost of software needed to put the new

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[27] For the time being, the best defence is to remain constantly on the alert and upgrade the security software.

hardware components into operational use. In addition, skill bottlenecks might delay the diffusion of truly user-friendly and bug-free software. Yet, over the next 20 years additional resources will be drawn into these activities and the extent of future bottlenecks is highly uncertain.

3.2.8 Expert systems and advanced automation

Advanced automation is one of the most promising applications of ICT. Theoretically, any rule based activity can be computerised. Rule based activities include calculations, bookkeeping, playing chess and card games, playing musical instruments, phrase-based information search, positioning tools or materials, setting up and/or monitoring machine operation, driving a car, navigating a plane and so forth.

Apart from work involving imagination, synthetic thinking or emotion, virtually all other work activities could be computerised, at least in theory. An expert could specify the rules to follow in response to various instructions and feedback from sensory devices. These rules then can be programmed into a computer controlling appropriate actuators to carry out the required activity (at a much greater speed than humans). Machines and equipment controlled by computers according to rules specified by experts are commonly referred to as 'expert systems'.[28]

So much in theory. In practice computer controlled automation of many tasks is constrained by the cost and difficulty of computerisation, because of the extensive programming effort required and the high cost of the electro-mechanical and sensory system that has to be interfaced with the computer.

Early computerised automation outside data processing concentrated on equipment where only a few elements (such as valves, switches, levers or motor) had to be controlled by the computer [so-called computer numerical controller (CNC) or programmable logic controller (PLC)] subject to inputs from a few sensory devices (indicating for example, location, proximity, alignment, speed, pressure, temperature and the like). Such applications include the control of metal cutting machines, welding machines, spark plug ignition and fuel injection in cars, the flow of liquids and gases in chemical plants, pick-and-place robots and the like. In many of these applications the spatial configuration of the equipment determines possible movements of the computer controlled element(s) (NOIE 2004).

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[28] More sophisticated controls involving 'learning' or 'adaptation' are referred to as artificial intelligence (AI). In some AI systems the program is not entirely pre-determined, but modifies its responses to the same input(s) in the light of accumulated information. By contrast, an expert system relies entirely on the knowledge of the expert and does not acquire knowledge by itself. AI is unlikely to assume a major role in machine and robotic controls in the next 20 years, which will continue to be based mainly on 'expert systems'. On the other hand, some elements of AI are already being used in applications such as information screening, medical diagnostic, language translation and PDA software.

More advanced automation requires coordinated control of many actuators subject to input from many sensors and frequent polling of the sensors.[29] It may also involve coordinating a large number of MEMS. This requires much more extensive programming with all the attendent problems regarding costs and unexpected errors.

Moreover, many routine tasks that are performed without difficulty by humans are very difficult to computerise. Many of these are related to eye-hand coordination. Three dimensional visual sensors currently require massive computational capability and are not particularly good in pattern recognition. Consequently, mimicking eye-hand coordination by computer controlled equipment is usually very costly and unreliable.

In other applications requiring coordination between various elements of a system extensive programming may be needed, which could render such application uneconomical. While in principle ICT devices, RFIDs and MEMS embedded into various parts of a production system could 'talk' to each other; to ensure 'intelligent talking' may require in practice a very large programming effort. It is often more economical to computerise narrow tasks and leave higher level coordination to human operators.

Notwithstanding the impediments to computer-controlled automation, in many respects this field is still in its infancy and further significant productivity enhancing innovations are expected in the next 20 years in manufacturing, warehousing, transport, construction, farming and health care.[30] The sectoral sections in chapters 4 and 5 will discuss some of these prospective developments.

In many service activities more advanced automation aims at providing higher quality services by relying on self-service rather than other persons. This trend is already evident in shopping and banking. It will likely to become increasingly important in the coming years in areas such as education, health care, tourism, eating out, real estate transactions and equipment fault finding.

3.2.9 Possible slowdown in silicon technologies

A number of studies foresee the end of 'Moore's law' within the next fifteen years (see RAND 2000). As mentioned earlier, according to this rule-of-thumb the density of microelectronic circuits on a piece of silicon chip doubles every 18 months. As the conductors in these circuits approach only a few dozen atoms in width, electrical conduction becomes unreliable. Consequently the silicon micro-etching technology might be approaching its limits within the timeframe of this report.

There are some more powerful computing technologies currently under investigation, including molecular, optical and quantum computing, which are based on different scientific

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[29] Modern computerised controllers can check the status of sensors many thousand times per second. Currently, inputs from many sensors combined with the control of many actuators is mainly used in process control applications involving the regulation of liquid or gas flows or the distribution of electric power. In these applications it is relatively easy to implement computer controls.

[30] In many industries the application of computerised controllers and MEMS is expected to lead to further increase in the size of machinery and equipment and their multi-functionality.

principles. So far these technologies are only at an experimental stage and it is unknown if and when they will enter the marketplace. Currently, molecular computing appears to be the approach closest to commercialisation, as indicated in the discussion about nanotechnology in section 3.5.[31]

Even if advances in silicon technology slow down, it will have little impact on the adoption of new ICT technologies in production and service industries.[32] Currently, the main bottleneck in ICT development is on the software rather than hardware side. Hardware usually costs much less than software in new ICT applications outside the mass consumer market and this trend is likely to accentuate in the coming years.

In the next 20 years the major impediments to the diffusion of expert systems, smart machines, interconnected smart devices and other specialised ICT applications will be mainly due to the high cost and imperfect reliability of complicated software rather than as a result of slower decrease in the cost of hardware. Advances in knowledge management and Internet search capabilities are being impeded by semantic and ontological problems that have not yet been adequately resolved. Progress in artificial intelligence software might help to overcome some of these difficulties.

3.2.10 ICT and science

Some of the early applications of computers were in scientific research and since then the links between ICT and scientific research have become firmly established. In recent years these links have become much stronger and this trend is expected to intensify in the coming years. ICT is now regarded as a fundamental enabling technology in scientific research. Much biological and bio-chemical research, including the mapping of genomes, would not have been feasible without the intensive use of computers. The pervasive application of computers in virtually all fields of research, including biotechnology, material science, nanotechnology and cognitive sciences and the increasingly inter-disciplinary nature of research, led some observers to the notion of converging technologies (CT).[33] Computer-based simulation and modelling techniques extend human discovery into areas where practical experimentation is impossible or extremely costly.

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[31] Whether a technological slowdown is really on the horizon is unclear. According to a report in an Internet bulletin (vnunet 2005), Hewlett Packard have developed a 'groundbreaking design' for next-generation crossbar structured nano-electronic circuits on silicon that can deliver near-perfect manufacturing yields with equipment 1 000 times less expensive than currently available. Kurzweil (2005) is optimistic about the ICT potential of three-dimensional carbon nano-tubes.

[32] Some important areas of ICT do not depend much on silicon technologies. These include optical communications and external magnetic or optical data storage units. The same applies to the application of nano-materials (such as carbon nanotubes) in ICT equipment.

[33] Kurzweil (2005) suggests that virtually all technologies are gradually becoming 'information technologies'. Currently, this trend is most evident in scientific research. Kurzweil implies a broad definition of 'information technologies' including robotics and computerised controllers incorporated into various types of machinery and equipment and in some cases even the human body.

Development in ICT in relation to distributed computing, by way of very large peer-to-peer networks of computing resources, are providing the foundations for the e-research network, a powerful and natural complement of the existing world-wide-web. The e-research network is a distributed computing system that enables the sharing of computer resources (processing time and memory) among the large number of machines connected to it. This network allows the efficient manipulation of vast amounts of information, massive simulations and data mining (that is, data analysis, screening and matching). The powerful infrastructure provided by this computing network will enable the emerging discipline of e-research to achieve distributed global scientific collaborations, using very large data collections, massive computing resources and high performance three-dimensional visualisations.

The e-research network will provide a major boost to the efficiency and effectiveness of scientific research and the dissemination of information. Access to common scientific databases through the network is expected to reduce duplications in research and diminish uncertainties and disagreements due to different observations as a result of minor differences in experimental methods and/or data collections.

3.2.11 The learning process in applying ICT

The contribution of ICT to productivity growth depends not only on the emergence of new applications and technologies. It also involves extensive learning and adaptation in user industries. Similar learning process occurs with other new innovations but it tends to be stronger with ICT applications.

DeLong and Summers (1991 and 1992) made a major contribution to the economic understanding of learning-by-doing in industries. They found from a cross-country econometric study that investment in new machinery and equipment (such as ICT equipment) tend to contribute more to real GDP growth than equal investment in structures or transport equipment. This implies that the 'social' rate of return to investment in different applications is not the same. They explain this by the learning-by-doing process associated with investment in modern equipment. This 'intangible' investment in human capital helps to raise productivity but is not recorded in national accounts capital expenditure data. The importance of learning-by-doing is even greater with ICT than with most other types of production equipment.

Diewert and Lawrence (2005b) econometric study on productivity growth in Australia reached a similar conclusion. They found that ICT inputs are worth around 40 per cent more to producers in other sectors in terms of marginal product than the prices paid. They explain the undervaluation of ICT inputs by a combination of the following factors:

Tumbling ICT prices leave the market in an ongoing state of disequilibrium. If users do not correctly anticipate the true benefits from ICT, they will lag behind in acquiring the most appropriate technologies and, at any given point of time, the marginal product of the ICT technology purchased will tend to exceed its marginal cost.

There may be innovation related externalities associated with investment in ICT technologies. In this context it should be noted that currently over a third of business R&D carried out in Australia is ICT-related.

There may be intangible investment in human capital associated with the acquisition and operation of ICT in the business sector, as indicated by the DeLong and Summers thesis about learning-by-doing.

Diewert and Lawrence (2005b) findings are supported by USA firm-level studies by Brynjolfsson and Hitt (1996) and Dewan and Min (1997). These USA studies, based on a large sample of firms, found excess return to IT investment relative to labour input and also excess return relative to ordinary capital. Brynjolfsson and Hitt (1996) also found that a dollar spent on IT labour generates more output than a dollar spent on non-IT labour or expenses.

It is well recognised that continuing technological breakthroughs embedded in ICT hardware can only deliver progress if combined with a host of complementary innovations, large and small, in business and society. It is in this 'middle ground' of entrepreneurial opportunity that users and producers together determine the most promising commercial innovations (DCITA 2005b). Here technological competition is driving change, as ICT service firms work with businesses to convert tacit business practice into codified routines that, in turn, become business systems built around information systems. These activities involve substantial intangible investment in human capital and organisational change and are likely to lead to significant learning-by-doing related indirect contributions to real GDP growth.[34]

The continuing evolution of (often less than perfect) software systems and the need to develop (and learn) in-house new software applications are major elements in the ICT-related learning-by-doing process.

3.2.12 Cross-border outsourcing

Another important economic issue related to ICT is the growing trend to outsource activities to outside suppliers and even to suppliers from abroad. The shift toward outsourcing is driven by declining inter-firm transaction costs, mainly as a result of decreasing data processing and communications costs. This motivates companies to seek the best and cheapest external suppliers to replace peripheral internal tasks and retain only core activities inside the firm (so-called vertical disintegration).

The shift toward outsourcing has been most noticeable in the last two decades in manufacturing, reflected in rising inter-firm transactions and intra-industry foreign trade (NOIE 2004). However, in recent years there has been a noticeable increase in outsourcing in service industries as well, in activities such as computer system maintenance, software development, data processing, accounting and clerical work, advertising, marketing, wholesale trade, transport, storage, cleaning, building maintenance, engineering, staff training and the like (see section 4.14.3).

Moreover, the trend to outsource services is becoming increasingly globalised. India has emerged as one of the leading software developers in the world, with much of the programming done for large transnational corporations. Apart from software, other service

[34] Gregor et al (2005) is a relevant Australian firm level survey. It was commissioned by DCITA to explore the management and assimilation of new ICT technologies.

activities that are gravitating toward low-wage countries include telephone call centres, telemarketing, bookkeeping and data processing, clerical work, non-core R&D, engineering design and remote monitoring of ICT systems.[35]

Gartner (2004) notes that one of the most significant shifts caused by ICT is the reality of off-shore or global sourcing. Increasingly companies will leverage technology, investment and connectivity to access lower-cost, high quality labour around the world. This could lead to economic gains through improved (international) allocation of resources.

3.3 Biotechnology

Biotechnology is expected to be one of the most important and decisive technologies for the coming years. Biotechnology will contribute in many ways to improving human health, food production and environmental protection. It is likely to be a major contributor for the future development of both health care and agriculture. This report refers to biotechnology broadly defined, covering all manipulations of organic matter, and not only DNA modifications.

While the impact of ICT through improved automation and information flows affects all sectors of the economy, the impact of progress in biotechnology is more limited, restricted mainly to agriculture, medical care and some segments of manufacturing. According to national accounts figures the value-added of agriculture (at factor prices) accounted for 3.65 per cent of GDP in 2003–04—the corresponding share of health and community services was 6.37 per cent. Manufacturing industries that will be strongly affected by biotechnology include pharmaceuticals, paper and plastics, specialty chemicals, some food processing and engineering equipment related to bio-sensors and waste treatment (both solid and water). These industries cover around a quarter of manufacturing output and 3 per cent of GDP. All in all, sectors directly affected by the rapid progress in biotechnology represent around 13 per cent of GDP.[36]

3.3.1 Health care

Biotechnology is likely to lead in the coming years to new approaches for fighting the major diseases of today, such as cardiovascular disease, cancer, neuro-degenerative diseases and viral diseases (European Commission 1999, RAND 2001). This will lead to further increase in life expectancy.[37] Most of the progress will occur as a result of better understanding of genetic dispositions and bio-chemical mechanisms. Briefly, some of the major advances expected within the forecast period include:

Cardiovascular diseases—

- Identification of genes related to hypertension and arteriosclerosis.

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[35] OECD (2005) reports that an increasing proportion of R&D is outsourced to countries where highly skilled researchers can be hired at lower wages, such as Ireland and Hungary.

[36] There are a few other sectors that might be marginally affected by advances in biotechnology, including certain mining activities (see section 3.3.3).

[37] Biological constraints related to the process of ageing might curtail the rate of increase in life expectancy despite rapid progress in medical technologies (Productivity Commission 2005b).

- Improved treatment for arterial occlusion and myocardial infarction.
- Treatment of heart disease via the growth of functional tissue.[38]

Cancer—

- Identification of multiple genes related to cancer.
- New drugs to prevent the occurrence of cancer in susceptible persons.
- Treatment to block the multiplication of carcinogenic cells.
- Effective methods to halt the spread of cancer cells.
- Better understanding of environmental factors contributing to cancer.

Neuro-degenerative diseases—

- Treatment for Alzheimer's disease and possibly other late onset neuro-degenerative disease(s).
- Genetic/biochemical tests for schizophrenia and depression.

In addition, some progress is expected in treating arthritis and other joint diseases.

The main contribution of biotechnology to health care will be in improving the effectiveness of diagnostics and drugs. New developments in ICT, materials science and nanotechnology will also contribute to improvements in health care, particularly in areas such as less invasive surgery, artificial implants, tele-medicine and tele-nursing. Some promising contributions of ICT are reviewed in chapter 5, which surveys potential labour saving technologies in health care.

An important contribution of ICT will be in improving record-keeping about a person's medical history and diagnostic results and possibly, in few years time, also information about his/her genome. Such database could be used to prepare customised drugs to remedy a cluster of problems in individual patients. Custom made drugs are very expensive and are unlikely to be widely used within the next 20 years—their consumption will be restricted mainly to wealthy patients (TIME 2000).

Selective drug carriers that release the drug only if certain pattern of DNA has been detected could be useful in the treatment of cancer. The general trend is toward increasing reliance on drug therapy and less invasive surgery at the expense of traditional surgery.

Politically and ethically controversial medical innovations, such as culturing replacement organs from embryonic stem cells or using replacement organs from animals, might assume some importance during the forecast period, but much less so than advances in diagnostics and pharmaceuticals.

3.3.2 Agriculture

Modern biotechnology, which is founded on new knowledge of molecular biology and genetics, involves a set of applied techniques for the genetic selection and genetic

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[38] This is part of the new field of tissue engineering, which relies heavily on stem cells.

modification of organisms. The former uses biotechnology to enhance selective breeding techniques and the latter actually changes the organism's DNA so as to introduce new traits and characteristics in a more targeted manner.

These two technological streams will lead to further development in agriculture. These include more precise genetic screening for crop and livestock production, genetically modified (GMO) crops with enhanced nutritional value and stress/disease resistance and transgenic animals (combining genes from different species) for improved productivity. Some of these technologies remain controversial and this may impact on the rate of diffusion of GMOs.

Under the Gene Technology Agreement struck by the Commonwealth and the States, organisations must be licensed by the Federal Gene Technology Regulator before intentionally releasing GMOs into the environment. Organisations must be licensed to:

- grow a GM crop in a field as part of a field trial; or
- grow a GM crop commercially.

The Regulator assesses applications on the basis of the environmental or health and safety risks raised by cultivation of the GMO. However, several States/Territories have placed moratoria on the commercial use of some GMO crops, primarily in response to marketing concerns. While some GMO crops continue to be grown, it is unclear how much impact these technologies will have on Australian agriculture over the next 20 years.

Even without GMO crops, further improvements are expected in disease, pest and drought resistance through selective breeding techniques. Section 4.2.3 examines these and other possible productivity enhancing innovations in Australian agriculture.

3.3.3 Industrial biotechnology

Biotechnology has significant applications in manufacturing. According to predictions cited in European Commission (2000), within the next five years 35 per cent of pulp and paper will rely on some biotechnological process in production; 20 per cent of pharmaceuticals and fine chemicals, but less than 4 per cent of processed food, textiles and leather. Enzymes extracted using biotechnology could replace less effective catalysts in many chemical processes.

Modern biotechnology is turning crops into plant-cell factories that produce high value-added products mainly as secondary metabolites. GMO crops could be used to produce novel and/or foreign proteins, polymers and medical bio-materials. Plant produced polymers are suitable for the production of biodegradable plastic packages. It is expected that polymers and other chemicals from plants will account for up to 20 per cent of bulk chemicals by 2010 (European Commission 2000).

Apart from its impact on organic material industries (such as pharmaceuticals, complex organic chemicals, paper, wood processing, plastics and to a lesser extent food processing and textiles) biotechnology has a major impact on several engineering industries. These include equipment for treating solid waste and wastewater, sensory devices for biological applications (bio-sensors) and more broadly the medical instruments and equipment industry (UK Industrial Biotechnology Task Force 2004). OECD (2001) estimated that the 'core' industrial and environmental biotechnology industry (mainly end-of-pipe waste treatment equipment) could be worth US$ 600 billion globally by 2010. Meanwhile, switching to biotechnology as manufacturing plants are replaced would increase the figure to US$ 1500 billion. Altogether, around a quarter of manufacturing output is expected to be significantly affected by the progress in biotechnology. This represents around 3 per cent of GDP in Australia.

Bioming is another promising area. Certain bacteria are well suited to concentrate metals in sulphide ores. This technology is already widely used in leaching copper and it could be also applied in the extraction of gold and other metals near mining sites. The CSIRO is actively researching this field and new applications might be commercialised within the next 20 years (CSIRO 2004).

3.4 Advanced materials

Material science is another dynamic area of research. The following sections will review three major strands of research:

- New materials with improved strength and other properties.
- New materials for health care.
- New materials for ICT and nanotechnology.

3.4.1 Materials with improved properties

Many new materials have been developed in recent years with improved mechanical, thermal and photo-electronic properties. Much of recent research is concentrated on 'composite' materials, where the final product is made up of a controlled mixture or interwoven matrix of two or more separate materials. These include metallic, ceramic and polymeric composites as well as hybrid composites made up of a combination from different groups.

New composites and alloys

Much research is directed at finding materials that combine lightness with strength. Composites incorporating microscopic 'carbon nanotubes' represent a promising innovation, but the cost is still high and the same applies to carbon fibres. Some new metal alloys are showing superior properties in combining strength, light weight and corrosion resistance, for example, certain types of high tensile steel. In addition, new light and strong polymers (the raw material of plastics) have been developed, but the combustibility and low temperature resilience of plastics remains a problem.

Some progress has been made in ceramic and metallic-ceramic composites that remain strong at high temperatures. This is crucial for the development of more thermodynamically efficient turbines and engines.

Ceramic superconductors that can operate at liquid nitrogen rather than liquid helium temperature have been developed and could be used within the next decade in electric motors, transformers and underground cables.

As a result of the rapid progress in the development of composites, polymers and engineering ceramics, European Commission (1999) predicts that in the early 21th century the share of composites, plastics and ceramics in total material consumption will increase at the expense of metals.

Nano-materials

Nano scale materials, that is, materials with properties that can be controlled at sub-micrometer ($<10^{-6}$) or nanometer ($<10^{-9}$) level, are an increasingly active area of research, because properties in these size regimes are often fundamentally different from those of ordinary materials (RAND 2001). Examples include carbon nanotubes, quantum dots and isolated biological molecules. These materials can be prepared either by purification or by tailored fabrication methods.

These materials are referred to in the literature as nano-material and nano-particles. Much of this type of research can be classified either as material science, biochemistry or nanotechnology.[39] Nano-materials and nano-particles are likely to provide some of the most important commercial applications of nanotechnology in the coming years (see section 3.5).

3.4.2 New materials for medical use

A wide range of new biocompatible materials have been developed for medical applications (RAND 2001). These include:

- ‘Smart’ cloths that can deliver medicines.
- Some nano-materials can be used for non-injected drug delivery.
- New polymeric shells can be used for controlled release of drug molecules.
- New materials and designs for vesicle and tissue support can reduce surgical invasiveness. New scaffolding materials have been developed for tissue engineering.
- Hydrogells with controlled swelling behaviour can be used for drug delivery or as templates to attach growth material for tissue engineering.
- Strong ceramics are used for bone replacements.
- Fluorinated colloids can be used as blood substitutes in surgery and for drug delivery.

There are many more new innovations in this dynamic field.

[39] European Science Foundation (2005) notes that nano-materials with medical applications cover several scientific disciplines including: molecular biology, colloidal chemistry, surface chemistry and membrane biophysics. The many interfaces between nanotechnology and biotechnology are not surprising given that both disciplines are involved in manipulating matter at a microscopic or nanoscopic level.

3.4.3 New materials for ICT applications

A variety of new materials have been developed for ICT applications. These include:

- 'Smart' cloths that monitor health signs and interface with ICT systems.
- New materials that can encode information for personal identification and security systems.
- Small batteries with very high energy densities.
- Sensory devices that utilise optical, magnetic or thermal responses of certain new materials.
- Non-linear optical materials for ultra-violet lasers used in sensory devices and to enable finer microlithography of computer chips.

3.5 Nanotechnology

The science of nanotechnology, or molecular manufacturing, involves the creation of tiny structures and materials through the manipulation of individual atoms or molecules (OECD 2004b). The term nanotechnology has been applied to products with at least one dimension measuring less than 100 nanometres in size (typically a couple of hundred atoms).

Carbon nanotubes are one of the most commonly used building blocks of nanotechnology. They are easily rolled sheets of carbon atoms, which are valued for their remarkable structural strength and ability to conduct heat and electricity. The properties of individual carbon nanotubes vary as a result of differences in their size and structure, thereby making them suitable for diverse uses.

Nanotechnology has uses across a broad spectrum of industries. Specialty coatings developed through nanotechnology are commonly employed to make existing products stronger and more durable. Nanoscale materials are incorporated into a wide range of products including spacecraft and industrial equipment, machine tools, coating for computer disks, stain resistant fabrics, surgical equipment, sporting goods and cosmetics (RAND 2001).

Nanotechnology's relevance to ICT lies in its potential to decrease dramatically the size and increase the capacity of data processing, transmission and storage devices by utilising the improving ability of certain materials to conduct electricity at the molecular level Computer manufacturers are working to develop molecular-sized microprocessors to replace silicon etching techniques (see section 3.2.9 on molecular computing). MEMS can be classified either as ICT or nanotechnology products.

The successful generation of electrically controlled infrared light from carbon nanotubes may be applied in optical communications and in light sensing ICT equipment. Health researchers are working on nano-products that could be used to repair and deliver medicine to targeted cells, with implications for the treatment of cancer and other diseases. It is widely held that nanotechnology will eventually affect in some way all material fabrications and applications (including pollution control, electricity generating solar panels and hydrogen using fuel cells), though this will likely to happen well beyond the 20 year horizon of this report (Kurzweil 2005).

According to estimates by Lux Research cited in Nanowriter.com (2005), nanotechnology products will be incorporated into around 15 per cent of world industrial output by 2014. These applications will include around 50 per cent of electronic products, 16 per cent of goods in healthcare and life sciences and 4 per cent of general manufactured goods. However, sales of basic nano-materials like carbon nanotubes and quantum dots will amount to only a tiny fraction of the applications market. The main applications of nanotechnology in the next 20 years are expected to be in computer processing and memory units, flat screen displays, MEMS, materials for non-injected drug delivery, specialty chemicals, aerospace, machine tools and special purpose coatings.

Safety concerns related to the many unknowns in nanotechnology have been cited as one of the main inhibitors to investment and development. There are potential health risks from the use of nanotechnology, such as inhaling nano-components or releasing them into the environment in large quantities. These health risks are currently under investigation. Standards will need to be set for the production, use and disposal of nano-products (OECD 2004b).

3.6 Final comments

The above brief survey of prospective technological developments gives some confidence that the statistical predictions provided later are based on observations of on-going innovation activities. Which of the technologies surveyed will become more or less important in the marketplace is not a critical issue in the context of highly aggregated statistical projections. The important point to note is that many new productivity enhancing innovations are under development across a very broad front.

4 Sectoral forecasts

4.1 The general approach

The forecasts for 12 market sector industries in the following sections cover labour productivity (LP) growth and its two components, that is, MFP growth and capital deepening. The relevant formula is presented in eq. (1.1) in chapter 1 and is explained in appendix B. The forecasts for non-market sectors are restricted to LP growth and are based on projections from the MONASH general-equilibrium model.

Three sets of predictions are presented—a mean prediction plus associated upper and lower bounds. Using the confidence interval estimates discussed in section 2.4, the upper productivity growth estimate were usually put at around 25 per cent above the mean and the lower productivity growth estimate at around 35 per cent below the mean. Based on the outlier numbers in table 2.1, there is over 80 per cent chance that the actual outcome will be located between these upper and lower bounds. In sectors subject to larger uncertainties, such as mining, agriculture, transport, electricity and water supply, wider confidence intervals are used.

In conjunction with this study's forecasts, the report also presents predictions from the MONASH model regarding expected average annual growth rates from 2003 to 2024 in output, labour supply and capital in the respective sectors. The annual growth in output minus the growth in labour supply yields the predicted annual change in LP. Appendix C presents detailed forecasts from the MONASH model for 112 industries.

In addition to forecasts, this chapter also presents supporting historical information for market sector industries on:

- Average annual productivity growth rates over 20 years from 1983–84 to 2003–04.
- Average annual productivity growth rates over 10 years from 1993–94 to 2003–04.
- The share of each sector in GDP in 2003–04 and in 1983–84.
- The share of capital income in total sectoral value-added in 2002–03 and in 1982–83. This parameter is required for calculating the effect of capital deepening on MFP growth.
- Information on the value-added (or sales) composition of principal sectors by their major constituents. Due to the absence of adequate historical data, the predictions do not extend to sub-sectors, nonetheless, their shares in sectoral output provide useful background information.

As indicated earlier, the forecasts are based on the extrapolation of past trends modified intuitively in the light of expected technological changes in each sector. Some brief indications about the nature of technological changes are presented. Attention is also given to possible energy related problems.

4.2 Agriculture, forestry and fishing

The following three tables present some relevant historical data on agriculture. Using extrapolations, these data underlie the predictions presented in table 4.5.

4.2.1 Historical data

Table 4.1 Average annual productivity changes in agriculture

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	3.13	2.67	0.46	0.62
10 years from 93–94 to 2003–04	4.25	4.04	0.20	0.24

Source: Productivity Commission (2005a).

Table 4.2 Share of agriculture in GDP and the share of capital income in agricultural value-added

	%
Share of agriculture in GDP in 2003–04	3.65
Share of agriculture in GDP in 1983–84	4.84
Share of capital income in value-added 2002–03	65
Share of capital income in value-added 1982–83	67

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.3 The composition of agricultural sales in 2001–02

	%
Wheat	14.6
Other cereal crops	6.8
Fruits, grapes, nuts	8.5
Vegetables	5.2
Sugar, cotton and other crops	14.0
Cattle and milk	25.0
Sheep and wool	11.1
Pigs, poultry and eggs	5.7
Forestry	2.9
Fishing	6.2
Total	100.0

Source: ABS (2004b).

4.2.2 Forecasts for agriculture

Table 4.4 Forecasts for agriculture from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	3.1
Employment growth	1.5
Capital growth	-1.3
LP growth (= production – employment)	1.6

Table 4.5 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	2.3	1.4	0.9	1.3
Upper prediction	3.1	1.7	1.3	1.9
Lower prediction	1.0	0.6	0.4	0.6

4.2.3 Comments on agriculture

Labour productivity in agriculture grew at the rate of 3.13 per cent a year in the 20 years to 2003–04, despite the fact that 2003–04 was a drought year in many regions. In the 10 years to 2003–04, LP growth averaged an impressive annual rate of 4.25 per cent. Most of the productivity rise was the result of MFP growth rather than capital deepening (table 4.1).

The strong productivity performance in agriculture has been driven mainly by developments in three technological fronts:

- biotechnology,
- farm mechanisation, and
- improved soil management.

Section 3.3.2 examined some promising applications of biotechnology on agriculture and this subject will not be repeated here. In the present context, biotechnology refers both to DNA modifications as well as more traditional agricultural techniques involving selective breeding, hybridisation, pesticides, weed control and the like.

Apart from biotechnology, agriculture has benefited and will likely to continue to benefit in the coming years from substantial progress in farm mechanisation. With the incorporation of small computers and electronic sensors into various machine components, farm machinery is becoming larger and more versatile. Computerised controllers and MEMS enable more precise and coordinated control over the operation of different machine components and broader multi-functional performance.

A particular innovation in farm mechanisation that received some attention recently is 'precision farming' assisted by satellite-based global positioning system (GPS). Precision farming is the computerised management of crops to suit variations in land characteristics. It is based on assembling data from satellite and aerial surveillance as well as field scouting through soil and vegetation samples. As the tractor moves across fields, it receives satellite data on its precise location, which can be combined with other geographically referenced information on soil composition, water levels, infestations and other crucial factors. The tractor's computer then delivers varying amount of irrigation water, seed, fertiliser and pesticides to optimise the production of the land as its condition varies meter by meter (Halal 2000). Farm equipment manufacturers are already selling precision farming systems on standard tractors.

On the livestock side, there are already robotic milking machines on the market that are accessed by cows who wish to be milked. Experimentation with robotic sheep shearing equipment started in Australia in the 1980s, but has not yet been commercialised. RFID tagging of farm animals is becoming more widely used in order to facilitate monitoring and shipment.

The strong productivity growth in recent years has been supported by large investment in agricultural R&D and in public information services to farmers. There is continual development of the science of agricultural production by 14 rural R&D corporations (jointly funded by industry and the Australian Government*)* working in partnership with research providers such as the CSIRO, Cooperative Research Centres, universities and others. There is a strong focus on adapting technologies to Australian conditions. In 2003–04, the rural R&D corporations invested over $460 million in agricultural R&D and the CSIRO invested some $482 million in relevant areas.

Agricultural technologies developed through R&D that increase productivity are many and varied, including vaccines to control disease, adoption of integrated pest management, improved weed control, soil conservation, reductions in inputs such as chemicals and fuel and improved animal husbandry. Farmers learn about new technologies through education and information 'extension' services.

The sources of productivity gains in Australian agriculture in the last couple of decades have been diverse, ranging from simple management changes such as the replacement of one animal breed by another to the introduction of direct drilling of cereal crops resulting from developments in both mechanisation and biotechnology (in this case herbicide and plant breeding). This diverse pattern is likely to continue.[40]

There are good opportunities on the horizon for further productivity improvement through the judicious use of biotechnology and mechanisation combined with continued broad development of the science of agricultural production under Australian conditions and the dissemination of the information needed to improve the productivity and sustainability of farms. In addition, more efficient functioning of markets, including the market for water, may contribute to better resource allocation and increased productivity.

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40 Possible improvements in medium-term weather forecasting (at least a few months ahead), based on increasingly sophisticated computer models could substantially improve farming productivity. This may be particularly useful in Australia, which is subject to high variability in rainfalls. Already some progress has been made in medium/long term weather forecasting.

On the other hand, there are a range of possible negative developments that could reduce productivity growth. For one, the recent drought might portent declining rainfall in Australia's major agricultural regions. While natural resource management is improving, with techniques such as minimum tillage now widely adopted, soil degradation will not disappear for a long time, including soil salinity, acidity, soil erosion, loss of soil structure, declining microbiological activity and exhaustion of trace elements, resulting from past actions that cannot be ameliorated quickly nor easily (Foran and Poldy 2002 and Dunlop et al 2004). Indeed, concerns that land degradation may prove to be the most significant factor limiting farm productivity over the next couple of decades have resulted in this issue becoming a major focus for policy makers and R&D providers.[41]

In regard to biotechnology, the introduction of GMO foods could be halted or substantially delayed due to public opposition. Several States/Territories have placed moratoria on the commercial use of GMO crops, primarily in response to marketing concerns. While some GMO crops continue to be grown, it is unclear how much impact these technologies will have on Australian agriculture over the next 20 years.

Given these uncertainties, the mean prediction for LP growth in agriculture in this study is below the historical LP growth rate. The upper prediction is in line with LP growth recorded in the last 20 years. The lower prediction suggests little LP growth in the event that significant negative developments will eventuate. Most LP growth is expected to come through MFP growth (that is, technological change) rather than as a result of capital deepening, following the same pattern as in the recent past.

4.3 Mining

4.3.1 Historical data

Table 4.6 Average annual productivity changes in mining

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	3.78	1.32	2.47	3.31
10 years from 93–94 to 2003–04	2.21	-0.74	2.94	3.96

Source: Productivity Commission (2005a).

[41] Natural resource constraints are also evident in the fishing industry where production has stagnated since the early 1990s (Kearney et al 2003).

Table 4.7 Share of mining in GDP and the share of capital income in mining value-added

	%
Share of mining in GDP in 2003–04	4.63
Share of mining in GDP in 1983–84	6.54
Share of capital income in value-added 2002–03	79
Share of capital income in value-added 1982–83	64

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.8 The composition of mining value-added in 2001–02

	%
Coal mining	21.9
Oil extraction	29.2
Gas extraction	11.4
Other mining	31.0
Services to mining	6.5
Total mining	100.00

Source: ABS Cat. No. 8415.0 and DCITA's estimate of the allocation between oil and gas.

4.2.2 Forecasts for mining

Table 4.9 Forecasts for mining from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	3.0
Employment growth	0.6
Capital growth	1.2
LP growth (= production – employment)	2.4

Table 4.10 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	2.2	-0.4	2.6	3.1
Upper prediction	3.0	0.3	2.7	3.3
Lower prediction	0.8	-0.6	1.4	1.8

4.3.3 Comments on mining

Labour productivity in mining increased at an annual rate of 3.78 per cent per annum over the 20 years to 2003–04, but at a lower annual rate of 2.21 per cent in the 10 years ending at the same time (table 4.6). Capital deepening was responsible for most of productivity gains in mining.

Apparently, the two main factors that were driving labour productivity growth in mining were increasing mechanisation and successful exploration and development of new oil and gas fields.

With the possible exception of oil extraction, there are good prospects for further productivity gains in mining. The increasing mechanisation of mining is likely to continue with mining machinery becoming even larger and more sophisticated. Computerised controllers, sensors and MEMS incorporated into mining equipment will facilitate this progress. Robotic or semi-robotic excavators could be used in some areas. ICT equipment and electronic sensors will further improve automatic monitoring of the safety of mining operations. Advances in geophysical seismic and electro-magnetic instruments and computerised geological explorations will continue. Further improvements are expected in mineral concentration and extraction methods. Biomining (mentioned in section 3.3.3) might become important in some metal mining operations.

On the other hand, future prospects in regard to crude oil extraction costs are highly uncertain. Consequently, the share of oil production is an important factor in gauging uncertainties about expected productivity changes in mining. The information on the composition of mining value-added in table 4.8 indicates that over 40 per cent of mining output is related to oil and gas extraction. Assuming that over half of the item called 'services to mining' represents oil exploration costs leads to the conclusion that crude oil extraction accounts for around a third of Australian mining output.[42]

Current forecasts suggest that crude oil production in Australia will decline within the next 20 years as a result of the depletion of proven reserves. According to ABARE's projections, presented in Akmal et al (2004), Australian crude oil production is expected to fall by 5.5 per cent between 2001–02 and 2019–20. According to simulations conducted by the Australian Geological Survey Organisation in 1999 and reported in Foran and Poldy (2002), crude oil production by 2024 is likely to be over 30 per cent lower than in 2004. The large difference in the end period projections arise because Akmal et al (2004) assume that there will be some new discoveries through time, whereas the Australian Geological Survey Organisation projections cover only known reserves. It is very difficult to predict the rate of discovery of new reserves.

The forecasts about declining oil production imply that due to diminishing reserves the cost of oil per barrel will rise. It is possible that lower quality crude oil will be extracted, deeper oil wells will be sunk and more funds will be channelled into expensive off-shore developments. In productivity terms this could lead to the reduction in MFP and LP because more inputs will be needed to produce a given amount of output.

In summary, there are some promising technological opportunities for productivity improvements in mining. However, the uncertain outlook in the important field of oil

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42 As noted in section 2.6, due to confidentiality reasons the ABS does not present separate statistics on the value of crude oil output but lumps it together with gas production.

extraction calls for caution in aggregate forecasts. The LP growth rate prediction in this study for the next 20 years is well below the LP growth rate in mining recorded in the last 20 years (see tables 4.6 and 4.10). The mean prediction for MFP growth is slightly negative, reflecting the possible adverse effect of declining productivity in oil extraction. The upper prediction is between the average rates recorded in the previous 10 and 20 years. The lower prediction represents a case of marked deterioration in the productivity of oil extraction combined with a slowdown in capital deepening across the entire mining sector.

4.4 Manufacturing

4.4.1 Historical data

Table 4.11 Average annual productivity changes in manufacturing

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	3.15	1.37	1.78	4.57
10 years from 93–94 to 2003–04	3.22	0.89	2.33	5.82

Source: Productivity Commission (2005a)

Table 4.12 Share of manufacturing in GDP and the share of capital income in manufacturing value-added

	%
Share of manufacturing in GDP in 2003–04	11.54
Share of manufacturing in GDP in 1983–84	17.38
Share of capital income in value-added 2002–03	40
Share of capital income in value-added 1982–83	28

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.13 The composition of manufacturing value-added and labour productivity growth rates[a]

	Share in manufacturing value-added 2000–01	*Avarage annual LP growth rate 1984-85 to 2000–01*
	%	%
Food, beverage and tobacco	20.4	2.63
Textile, clothing, footwear and leather	3.6	1.49
Textiles and leather	*2.0*	1.39
Clothing and footwear	*1.6*	1.54
Wood and paper products	6.9	0.77
Printing and publishing	9.2	0.83
Chemical and petroleum products	13.8	1.93
Simply transformed chemicals	*5.0*	1.94
Elaborately transfd chemicals	*6.5*	1.20
Pharmaceuticals	*2.3*	5.20
Non-metallic mineral products	5.0	0.41
Metal products	19.0	2.48
Iron and steel	*3.6*	4.15
Non-ferrous metals	*7.9*	4.64
Simple metal fabrications	*7.5*	0.71
Machinery and equipment	18.7	3.45
Motor vehicles	*6.5*	4.99
Other transport equipment	*2.0*	1.47
Medical and scientific instrumts	*1.4*	4.76
Electronic equipment	*2.2*	11.67
Electrical equipment	*2.5*	1.97
Industrial Machinery	*4.2*	1.66
Furniture and other manufacturing	3.4	0.28
Total manufacturing	**100.0**	**2.30**

[a] The sub-industries of major industries are indented.

Source: NOIE (2004)

4.4.2 Forecasts for manufacturing

Table 4.14 Forecasts for manufacturing from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	2.5
Employment growth	0.6
Capital growth	-0.2
LP growth (= production – employment)	1.9

Table 4.15 This study's forecasts of average annual percentage changes: 2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	2.6	1.5	1.1	2.4
Upper prediction	3.5	1.9	1.6	3.3
Lower prediction	1.7	1.0	0.7	1.5

4.4.3 Comments on manufacturing

Labour productivity growth in manufacturing averaged 3.15 per cent in the 20 years to 2003–04. In the last 10 years capital deepening was the main driver of productivity growth.

Despite the fact that nowadays manufacturing accounts for only around 11.5 per cent of GDP, there is much more extensive ABS data on value-added and employment in individual manufacturing industries than what is available for the constituents of other sectors analysed in this paper. Given the abundance of historical data, it would be possible to make detailed predictions about productivity growth rates in individual manufacturing industries.

While a disaggregated approach is not followed in this report, table 4.13 presents information on the share of 18 manufacturing industries in the sector's value added in 2000–01 and average annual LP growth rates between 1984–85 and 2000–01. The figures are taken from NOIE (2004), which analysed manufacturing productivity growth in some detail. This table provides more information about manufacturing industries than is presented elsewhere in this report in regard to the sub-sectors of other major sectors.

The wide dispersion of LP growth rates between industries is the most striking feature of the numbers presented. While industries such as electronics, scientific instruments, iron and steel, non-ferrous metals and pharmaceuticals more than doubled their LP over 16 years, other industries such as wood and paper, non-metallic mineral products (cement, bricks and glass), simple metal fabrications and 'other' manufacturing (mainly furniture) recorded very little LP growth.

LP growth in electronics was particularly high, but examination of the data reveals that this productivity growth was driven mainly by quality-adjusted volume indexation applied to electronic products, reflecting tumbling international ICT prices, rather than a result of large new investment or greater intensity of effort (NOIE 2004). In Australia electronics is a fairly minor industry, but in overseas countries where it is much more important (such as the USA and Japan) it accounts for a large portion of manufacturing productivity growth.

In Australia the influence of the ICT revolution on manufacturing productivity was mainly through user rather than producer industries. Major ICT innovations that affected manufacturing include computerised controllers and electronic sensors incorporated into production equipment, computer aided design (CAD) and local area (LAN) communication and control networks in factories.

Computer controlled automation in manufacturing started in the 1960s. In the last 20 years it was adopted in Australia mainly in capital intensive facilities, including petroleum refineries, steel and aluminium smelters and rolling mills, cement plants and car assembly lines. Computer controlled equipment also assumed greater importance in high precision operations, including metal cutting and welding. To some extent, new technologies reliant on computer-controlled equipment (referred to as AMT, for advanced manufacturing technologies) have been introduced into virtually every manufacturing industry.

Despite the many possible applications of AMT in manufacturing, an innovation survey by the ABS conducted in 1997 on the application of AMT revealed that most small manufacturing firms (employing less than 100 persons) have neither used such technologies nor did they intend to acquire one in the following two years (NOIE 2004). Major impediments to the takeup of AMT include novelty, cost, lack of sufficient scale in production and the need for highly skilled operators. Moreover, like other dedicated (product specific) equipment, many specialised AMTs are not sold on the open market. A large portion of dedicated AMT equipment used in industry has been transferred by transnational corporations to their Australian subsidiaries or affiliates. Given that small firms, employing less than 100 persons, represent the bulk of Australian manufacturing, there may be considerable scope for further takeup of AMT in Australia. Bearing in mind that the AMT survey is fairly dated the current situation is not clear.

A new wave of computer-controlled automation in manufacturing is referred to in the technological futures literature as 'agile manufacturing'. This concept refers to computer controlled factory operations that proceed directly from new designs (technical drawings) on the computer into actual production, by providing appropriate digital instructions to machines and equipment controlled by a network of computerised controllers. In theory, agile manufacturing could enable highly customised low volume production runs. In view of the discussion about advanced automation in section 3.2.8, there are many impediments to the practical implementation of fully automated agile manufacturing beyond simple designs requiring only a few machine operations. Nonetheless, in a less than fully automated form, agile manufacturing is expected to play a greater role in the coming years.

The takeup of AMT in Australia will likely to expand, partly because of the strong international competition faced by local producers and partly because of the greater availability of AMT equipment on the open market. Additional productivity gains will arise from wider application of ICT equipment for controlling material movements and warehouse operations in factories by relying on RFIDs and other short distance wireless technologies.

In addition to ICT related innovations, manufacturing productivity will likely to benefit from innovations in other dynamic technological fields. Industrial biotechnology is expected to have a strong impact on productivity growth in pharmaceuticals, paper, plastics and in engineering industries involved in the production of biosensors and equipment for treating solid waste and wastewater (see section 3.3.3). Nanotechnology will likely to have a strong impact on electronics, scientific and medical instruments, pharmaceuticals and specialty chemicals (see section 3.5). Advances in material science could improve productivity in various metal and engineering industries. All told, manufacturing stands to benefit from rapid technological progress in several fields of research.

Given the substantial scope for further technological improvements in manufacturing, the mean MFP predictions of this study are in line with historical MFP growth rates recorded over the last 20 years. The greater part of productivity growth is expected to come from MFP growth. Under the mean prediction, the contribution of capital deepening is below the historical 20-year average, but approaches it under the optimistic prediction.

High-tech (that is, R&D intensive) industries such as electronics, medical and scientific instruments and pharmaceuticals are expected to continue to record higher productivity growth than the rest (see table 4.13). Low-tech industries including wood, paper, simple metal fabrications, building materials and furniture are likely to record higher productivity growth rates than in the past. Major technical difficulties with computerised automation will likely to persist in industries using discrete pieces of non-rigid materials, such as clothing and footwear and many lines of food processing.

4.5 Electricity, Gas and Water (EGW)

4.5.1 Historical data

Table 4.16 Average annual productivity changes in EGW

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	4.96	1.95	3.01	4.63
10 years from 93–94 to 2003–04	2.28	-0.42	2.70	3.82

Source: Productivity Commission (2005a)

Table 4.17 Share of EGW in GDP and the share of capital income in EGW value-added

	%
Share of EGW in GDP in 2003–04	2.40
Share of EGW in GDP in 1983–84	3.70
Share of capital income in value-added 2002–03	72
Share of capital income in value-added 1982–83	49

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.18 The composition of EGW value-added in 2003–04

	%
Electricity supply	66.1
Gas distribution	9.1
Water supply	24.8
Total EGW	100.0

Source: ABS Cat. No. 5204.0 unpublished data.

4.5.2 Forecasts for electricity, gas and water

Table 4.19 Forecasts for EGW from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	1.9
Employment growth	0.1
Capital growth	-0.1
LP growth (= production – employment)	1.8

Table 4.20 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	1.5	-0.5	2.1	2.7
Upper prediction	2.8	0.4	2.4	3.1
Lower prediction	0.2	-1.3	1.5	2.0

4.5.3 Comments on electricity, gas and water

Over the last 20 years LP growth in the EGW sector averaged an impressive 4.96 per cent per annum, but has declined to 2.28 per cent over the last 10 years. Around 60 per cent of this growth was the result of capital deepening. DCITA (2005a) suggests that productivity in EGW has substantially benefited from micro-economic reforms, which brought about increased commercialisation of public utilities, greater reliance on private sub-contractors and the privatisation of some facilities. It seems likely that microeconomic reforms will continue to inject more competition into this market.

On the technological side, increased computerisation was the main driver of productivity gains in the electricity sector. Much of the electricity grid has been computerised, with the distribution of power in regional transformer yards being remotely controlled through a centralised computer network. In addition, the thermodynamic efficiency of power generation has improved modestly with the introduction of boilers and turbines that can withstand higher temperatures.

Computerised remote control of pumps and valves to regulate the flow of water and gases and monitor the operation of the system has also helped to raise labour productivity in the water and gas distribution industries.

In electricity generation there appears to be scope for further improvements in energy efficiencies. According to Akmal et al (2004), the thermal efficiency of natural gas plants is expected to improve by an average 1.3 per cent a year between 2000–01 and 2009–10 and by 0.6 per cent from then to 2019–20. In contrast, thermal efficiency improvements in coal fired plants are expected to be small. The average thermal efficiency of all coal fired plants is projected to increase from around 37 per cent in 2001–02 to 39 per cent by 2019–20.

Additional technological improvements in electricity may be realised from the replacement of copper conductors by ceramic superconductors in transformers and underground transmission lines. These superconductors can operate at liquid nitrogen rather than liquid helium temperatures. The application of superconductors could reduce energy losses in the transmission-distribution system. Increasing usage of gas turbines and less expensive energy storage units may reduce the pressure on the system during times of peak demand.

In water supply there have been significant breakthroughs in recent years in sea water desalination and brackish water purification. NDSP (2002) reported that desalinated sea water of drinkable quality is obtainable for less than three dollars per tonne and further cost reductions are expected. There have been plans to construct a large desalination plant in Sydney, which according to media reports could produce drinkable water at a cost of less than $1.50 per tonne. It appears that within the next 20 years, sea water and brackish water desalination projects will make some contribution to alleviating drought problems in Australia. However, desalinated water will be more expensive than water from traditional sources, putting downward pressure on MFP.

Despite some promising prospects for technological improvements, this study's mean prediction for EGW LP growth in the next 20 years, at 1.5 per cent a year, is less than a third of the LP growth rate recorded in the previous 20 years, although it is not much below the LP growth rate recorded in the last 10 years. The main reason for this conservative prediction is the uncertain outlook about greenhouse gas abatement in electricity generation. As indicated in table 4.18, electricity accounts for around two-thirds of value-added in the EGW sector. Greenhouse gas abatement measures may lead to increases in the cost of electricity. This is the reason for predicting much lower MFP growth rates than in the past and negative MFP growth under the mean and pessimistic outlook.

But most likely, major changes in the electricity sector will not occur within the next 20 years. According to ABARE's projections for the Australian energy market to 2019–20 (Akmal et al 2004), the principal measures that will be taken to reducing greenhouse gas emissions will be through the replacement of some coal by natural gas in electricity generation and some small improvements in thermodynamic efficiencies. According to ABARE's predictions renewable energy sources (hydro, wind, solar, biomass) are expected to increase their share in electricity supply from 7.7 per cent in 2001–02 to 8.0 per cent by 2019–20, mainly as a result of increasing reliance on wind power and bagasse (a residual from sugar refining) as a source of fuel. These changes are unlikely to add much to the average unit cost of electricity.

Given that the average life span of power stations is between 40 and 50 years, the fact that there are currently no plans for a major transformation suggests that it is unlikely that fundamental changes in the system will occur within the next 20 years.[43] Yet some important changes cannot be ruled out within that period. Existing power stations could be retrofitted with more expensive pollution control apparatus, including equipment for CO_2 geo-sequestration. Moreover, wind power generators can be installed much quicker than conventional power plants.

In summary, it is possible that due to further decisions about emission standards and/or carbon taxes, more radical measures might be taken over the forecast period in changing energy sources and pollution control (including CO_2 reduction). However, major transformation of the electricity system is likely to post date the forecast period. Developments in this area on the international and domestic scene are difficult to predict. It is essential to recognise the large uncertainties surrounding electricity generation and greenhouse gas abatement and these are reflected in the wide dispersion of productivity growth predictions for the EGW sectors.

4.6 Construction

4.6.1 Historical data

Table 4.21 Average annual productivity changes in construction

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	0.84	0.61	0.23	1.26
10 years from 93–94 to 2003–04	1.55	1.78	-0.23	-0.62

Source: Productivity Commission (2005a).

Table 4.22 Share of construction in GDP and the share of capital income in construction value-added

	%
Share of construction in GDP in 2003–04	6.76
Share of construction in GDP in 1983–84	6.48
Share of capital income in value-added 2002–03	33
Share of capital income in value-added 1982–83	19

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

[43] Nuclear power is already in the political arena, but is unlikely to be introduced in Australia in the next 20 years.

Table 4.23 The composition of construction work done in 2003–04

	%
New residential construction	34.8
Alterations and additions to residential	6.6
Non-residential construction	20.8
Engineering	37.7
Total construction	100.0

Source: ABS Cat. No. 8755.0 (Construction Work Done) and Cat. No. 8752.0 (Building Activity).

4.6.2 Forecasts for construction

Table 4.24 Forecasts for construction from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	2.6
Employment growth	1.3
Capital growth	1.2
LP growth (= production – employment)	1.3

Table 4.25 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	1.9	1.1	0.8	2.0
Upper prediction	2.5	1.6	0.9	2.4
Lower prediction	1.3	0.8	0.5	1.4

4.6.3 Comments on construction

Annual LP growth in construction in the 20 years to 2003–04 averaged 0.84 per cent. This was well below the average rate of LP growth in the market sector of 2.66 per cent a year over the same period. Productivity growth in construction picked up slightly in the 10 years to 2003–04.

The comparatively low productivity growth in construction was apparently related to fairly slow technological progress in this sector in recent years. That might change markedly in the coming years. New computer controlled equipment is appearing on the market that is well suited for applications in construction and civil engineering. These include robotic equipment for excavation, cleaning, demolition, concrete laying and highway construction. Also, computerised controllers, electronic sensors and MEMS are being incorporated into other construction equipment, such as cranes and cement mixers. Advances in computer-aided design (CAD) could also raise productivity in construction.

In view of the difficulties in performing through computer controlled machinery eye-hand coordination (see section 3.2.8), the prospects for automating traditional construction work such as bricklaying, carpentry, roofing or tiling does not look promising. However, it is possible to replace much of this work by using prefabricated walls, beams, roof segments, steel frames and other building components. These components can be produced off-site in factories in a highly automated environment.

With the growing importance of 'agile' manufacturing, which can be used to produce customised panels and structural components in relatively small production runs, it is possible that the importance of off-site manufacture will increase in both residential and non-residential construction in the coming years (Hampson and Brandon 2004). Much will depend on new investment in the production of construction components and the establishment of closer ties between builders and manufacturers. Currently, the main impediments to the application of off-site manufacturing include the shortage of production facilities, shortage of skills and experience in on-site positioning and jointing, cultural inertia, the craft mentality in the industry and individualised consumer demand. According to survey results reported by Hampson and Brandon (2004) most construction managers do not believe that off-site manufacture will become the dominant method in the industry within the next 15 years.

Computers are expected to be more widely used in construction to assist design, management and coordination. Computerised 'virtual prototyping' is a particularly promising application. This is an advanced form of computer-aided design (CAD) that can provide vivid three-dimensional visualisation of building plans. Virtual prototyping can offer detailed visual displays of the plan to clients and suppliers before the work has started. It can help to meet the client's needs, improve quality, supply chain management and the procurement of prefabricated components. Other ICT innovations that are expected to gain popularity in the coming years are hand-held ICT devices that can be used to access instantaneously plans, schedules, material orders and other information to facilitate management and coordination on the site.

Given a number of technological opportunities for productivity improvements in construction, this study's mean prediction for annual LP growth in construction (1.9 per cent) is significantly higher than the historical rate over the last 20 years and to a lesser extent over the last decade. Even the pessimistic prediction puts productivity growth well above what was recorded in the last 20 years. Yet even so, construction is predicted to record lower LP growth than the average in other market sectors (2.2 per cent).

4.7 Wholesale trade

4.7.1 Historical data

Table 4.26 Average annual productivity changes in wholesale trade

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	2.47	1.75	0.72	2.51
10 years from 93–94 to 2003–04	5.37	4.34	1.03	3.65

Source: Productivity Commission (2005a).

Table 4.27 Share of wholesale trade in GDP and the share of capital income in wholesale trade value-added

	%
Share of wholesale trade in GDP in 2003–04	5.88
Share of wholesale trade in GDP in 1983–84	8.70
Share of capital income in value-added 2002–03	27
Share of capital income in value-added 1982–83	27

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.28 The composition of wholesale trade value-added 2002–03

	%
Basic material wholesaling	15.9
Machinery and motor vehicles	47.7
Personal and household goods	36.4
Total wholesale	100.0

Source: ABS Cat. No. 5204.0 unpublished data.

4.7.2 Forecasts for wholesale trade

Table 4.29 Forecasts for wholesale trade from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	2.9
Employment growth	1.0
Capital growth	0.5
LP growth (= production – employment)	1.9

Table 4.30 This study's forecasts of average annual percentage changes: 2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	2.0	1.2	0.8	2.6
Upper prediction	2.4	1.5	0.9	2.8
Lower prediction	1.4	0.9	0.6	1.8

4.5.3 Comments on wholesale trade

Wholesale trade recorded an average LP growth rate of 2.47 per cent per annum in the 20 years to 2003–04. However, in the 10 years from 1993–94 to 2003–04 LP growth averaged an impressive 5.37 per cent a year.

The acceleration in productivity growth during the second 10 year period was related to more pervasive application of computers and broadband for conducting wholesale transactions and more effective utilisation of computers in organising logistics, supply chain management and stock control.[44] A high percentage of business-to-business wholesale transactions are now based on e–commerce rather than personal contacts.

The trend toward greater computerisation of wholesale trade is expected to continue although it may taper off. The introduction of RFID tags (see section 3.2.5) will lead to further automation in warehouse operations, through increasing usage of robotic palletizers and trolleys and improved capabilities in locating quickly the stock items required. It will also reduce the need for stock counting that can be carried out automatically using RFID readers. Stock asset lives could be constantly monitored.

This study's prediction for annual LP growth in wholesale trade in the next 20 years is 1.9 per cent, which is below the average rate recorded in the previous 20 years. Some deceleration in productivity growth is to be expected given the already high level of computerisation in this sector. The upper prediction is in line with the historical trend in the previous 20 years. As in the past, the larger share of LP growth is expected to come from MFP growth rather than capital deepening.

[44] Johnston et al (2000) present a detailed analysis of productivity growth in the wholesale and retail trade sectors.

4.8 Retail trade and repairs

4.8.1 Historical data

Table 4.31 Average annual productivity changes in retail trade

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	1.24	0.51	0.73	3.90
10 years from 93–94 to 2003–04	2.37	1.57	0.79	4.35

Source: Productivity Commission (2005a).

Table 4.32 Share of retail trade in GDP and the share of capital income in retail trade value-added

	%
Share of retail trade in GDP in 2003–04	5.90
Share of retail trade in GDP in 1983–84	6.65
Share of capital income in value-added 2002–03	17
Share of capital income in value-added 1982–83	16

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.33 The composition of retail trade value-added in 2002–03

	%
Food retailing	33.3
Personal and household retailing	47.9
Motor vehicle retailing and services	18.8
Total retail	100.0

Source: ABS Cat. No. 5204.0 unpublished data.

4.8.2 Forecasts for retail trade

Table 4.34 Forecasts for retail trade from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	2.8
Employment growth	1.0
Capital growth	0.5
LP growth (= production – employment)	1.8

Table 4.35 This study's forecasts of average annual percentage changes: 2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	1.7	1.1	0.6	2.8
Upper prediction	2.0	1.4	0.6	3.0
Lower prediction	1.1	0.7	0.4	1.8

4.8.3 Comments on retail trade and repairs

Average productivity growth in retail trade over the 20 years to 2003–04 was 1.24 per cent per annum.[45] The corresponding figure in wholesale trade was twice as high at 2.47 per cent (table 4.26). While both wholesale and retail trade benefited from increased automation as a result of barcode scanners and computer aided stock control, wholesale trade was able to gain more out of computerisation for several reasons.

One is the greater usage of e-commerce in wholesale than in retail trade. Making orders through the computer is common practice in business-to-business transactions. It is much less common in consumer purchasing. The consumer usually wants to see and touch what he/she buys and may enjoy the experience of shopping. Also, there are no significant cost savings involved in ordering goods through e-mail, if the delivery is carried out through mail or courier service. By contrast, wholesale trade transactions involved deliveries through company trucks and other transport services well before e-mail ordering was introduced.

Some studies (for example, TIME 2000) predict that a high proportion of retail trade in the next decade or two will be carried out through e-commerce. It is hard to see that happening on a large scale unless major changes are made in the delivery and/or collection of goods purchased through e-mail.

Another impediment to productivity growth in retailing is related to small family shops, which still represent a significant portion of the sector. Some of these shops sell niche products, others provide services to a local community. Some provide employment to people who find it difficult to obtain alternative employment or prefer to be involved in retailing due to life-style considerations. Retail trade, being a labour intensive industry, is one of the few sectors providing employment opportunities to this population group.[46] Small independent shops are likely to lag in labour productivity even if they employ computer equipment.

Large retail chains will likely to benefit in the coming years from the introduction of RFIDs, which could replace barcode scanners in some shops and make shopping almost as

[45] But note a significant pickup in the last decade.

[46] The others are: cafes, restaurants, taxis and light road transport, small buildings and renovations, some recreational and entertainment services and personal services. In retail trade and these other activities, capital requirements and barriers to entry are relatively low. All sectors associated with these activities recorded below average productivity growth over the last 20 years.

automatic as using a vending machine.[47] In addition, wider use of e-money (besides credit cards) for small transactions will also likely to contribute to productivity growth.

According to a Treasury working paper by Rahman (2005), the productivity level in Australian retailing amounted in 2002 to less than 50 per cent of the level in the USA. This estimate suggests that there is considerable scope for further productivity gains.

The median prediction for LP growth in retail trade in the next 20 years is above the LP growth rate recorded in the past. In view of the disappointing LP growth performance in the last 20 years (given the introduction of barcode scanners), one would expect that the higher rate of productivity growth witnessed in the last 10 years will continue in the near future.[48] Also, there are some technological opportunities through RFIDs and e-commerce for further productivity gains in supply chain management. As in the past, most of the productivity gains are expected to arise from MFP growth rather than capital deepening.

4.9 Accommodation, cafes and restaurants (ACR)

4.9.1 Historical data

Table 4.36 Average annual productivity changes in ACR

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	0.06	-0.58	0.64	2.74
10 years from 93–94 to 2003–04	1.54	0.89	0.64	2.54

Source: Productivity Commission (2005a).

Table 4.37 Share of ACR in GDP and the share of capital income in ACR value-added

	%
Share of ACR in GDP in 2003–04	2.24
Share of ACR in GDP in 1983–84	1.56
Share of capital income in value-added 2002–03	25
Share of capital income in value-added 1982–83	21

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

[47] RFIDs can enable automatic stock taking and quick information on stock asset lives as well as more effective protection against pilfering in shops.

[48] The disappointing productivity growth shown in the ABS-Productivity Commission statistics might be partly related to measurement problems.

4.9.2 Forecasts for accommodation, cafes and restaurants

Table 4.38 Forecasts for ACR from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	2.9
Employment growth	1.9
Capital growth	2.0
LP growth (= production – employment)	1.0

Table 4.39 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	0.8	0.4	0.4	1.3
Upper prediction	1.0	0.5	0.5	1.6
Lower prediction	0.5	0.2	0.2	0.9

4.9.3 Comments on accommodation, cafes and restaurants

Labour productivity growth in the ACR sector in the 20 years to 2003–04 was close to zero. One possible explanation for the absence of LP growth may be the influx of low wage workers and self-employed persons into pubs, cafes and restaurants (where capital requirements and entry barriers are relatively low). On the technological front, there were relatively few opportunities for productivity improvements in clubs, pubs, cafes and restaurants, but some productivity gains were made in hotels as a result of computerised bookings and reservations. Also lower cost buildings have been developed that are easier to maintain and run.

There are some new technological opportunities opening up in this sector. In some cafes and restaurants waiters record orders on small ICT devices (palm pilots), which are relayed through radio signals to the food preparation area. With current technologies many of the waiter's functions could be computerised. Customers could place orders through a computer located on the table directly to the kitchen. The same computer can inform the customers when the meals are ready to be collected from the counter. This kind of arrangement might be used in the future in cheaper cafes and restaurants.

There are a number of new innovations that can be used in hotels and accommodation including robotic cleaners, advanced electronic security systems and improved e-commerce transactions in bookings and payments.[49] Wider use of web pages and Internet bookings can

[49] There is no published information from the ABS on the split-up between clubs, pubs, cafes and restaurants on the one hand and hotels and accommodation on the other.

enable hotels more forward planning and the attainment through differential pricing of higher occupancy rates all year round.

This study's mean prediction for LP growth in the next 20 years is 0.7 per cent per annum compared with near zero growth recorded in the previous 20 years. Hotels and accommodation are likely to be the main sources of productivity gains. The ACR sector is expected to record the lowest LP growth rate among all the broad market sectors examined.

4.10 Transport and storage

4.10.1 Historical data

Table 4.40 Average annual productivity changes in transport

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	2.60	2.16	0.45	1.25
10 years from 93–94 to 2003–04	2.84	2.44	0.39	1.07

Source: Productivity Commission (2005a).

Table 4.41 Share of transport in GDP and the share of capital income in transport value-added

	%
Share of transport in GDP in 2003–04	5.41
Share of transport in GDP in 1983–84	5.57
Share of capital income in value-added 2002–03	36
Share of capital income in value-added 1982–83	29

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.42 The composition of transport value-added in 2003–04

	%
Road transport	34.6
Rail, pipeline and other transport	8.7
Water transport	3.3
Air transport	15.5
Services to transport (including seaports, airports); storage	37.9
Total transport	100.0

Source: ABS Cat. No. 5204.0 unpublished data.

4.10.2 Forecasts for transport and storage

Table 4.43 Forecasts for transport from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	3.0
Employment growth	1.4
Capital growth	1.5
LP growth (= production – employment)	1.6

Table 4.44 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	1.5	0.5	1.0	2.4
Upper prediction	2.1	0.7	1.4	3.2
Lower prediction	0.3	-0.3	0.5	1.4

4.10.3 Comments on transport

Transport recorded an annual LP growth rate of 2.6 per cent in the 20 years to 2003–04. As in other sectors (apart from manufacturing) little information is available on productivity improvements in constituent industries. From information presented in DCITA (2005a, section 3.4), it appears that productivity growth was particularly strong in air and sea transport. In addition, microeconomic reforms have helped to lift productivity in rail transport as well as in seaports and airports.[50]

Judging from technological futures studies, significant improvements in air transport are likely to continue. In the next 20 years commercial aircraft are expected to become larger, more fuel efficient and more automated. To a lesser extent, the same applies to sea and rail transport as well. Various types of high speed and ultra-high speed trains are under development for inter-urban transport. Fully automated navigation of ships and planes using global positioning system (GPS) is technically feasible, but is unlikely to be implemented in the near future outside military applications.

Alternative forms of road transport

There are more uncertainties concerning road transport than for other transport sectors. To start with, it should be noted that at the national accounts sectoral level road transport covers only transport for business use but not for personal use. This means that private cars, which account for the bulk of road transport, are excluded from the value-added generating

50 These microeconomic reform measures included corporatisation, privatisation and the out-sourcing of many activities.

transport sector. The items included are trucks, vans, buses, taxis and cars used by private or public trading enterprises. Given that part of 'services to transport' in table 4.42 relates to road transport, it appears that road transport represents over 40 per cent of the transport sector in the national accounts.

As noted earlier, uncertainties in energy markets introduce wider uncertainties into the forecasts. Similar considerations apply in regard to road transport and to a lesser extent other transport. While energy sources for air, sea and rail transport are unlikely to change much during the forecast period, the same is less certain in regard to motor vehicles.[51].

Despite the recent sharp rise in oil prices and significant public interest in alternative forms of fuel, it does not appear very likely that a major switch from petroleum run vehicles to alternative forms of road transport will occur within the next 20 years. Alternative fuels/vehicle technologies have not yet established themselves as cost-effective or commercially viable. Yet, if high oil prices are sustained that will provide an incentive to innovation. According to Bureau of Transport and Regional Economics (2003) projections for metropolitan fuel use (around 70 per cent of total), less than 10 per cent of this fuel will be sourced from ethanol, natural gas and liquid petroleum gas by 2020. Over 90 per cent is predicted to be unleaded petrol and diesel.

On the electric car front the only commercial alternative to petrol cars currently on the market is a hybrid petrol-electric car that converts the energy released during braking and slowing down into electric power rather than allowing it to dissipate as heat. It is possible that within the next 20 years commercially competitive electric cars will be developed, but this is far from certain.[52] Even if this were to happen it would take many years until the existing stock of vehicles is replaced.

What is fairly certain is that some further gains will be made in the fuel efficiency of petroleum-run motor vehicles by making cars lighter and reducing air drag and friction losses. According to Bureau of Transport and Regional Economics (2003) projections, the average fuel efficiency of new cars (in terms of litres per 100km) will improve by 20 per cent between 2000 and 2020. Increasing market penetration of hybrid petrol-electric cars will also contribute to improved fuel efficiency.

Even without substitution into more expensive alternative fuel vehicles, possible higher petroleum prices, instability in oil markets and stricter emission standards will likely to reduce the rate of MFP growth in transport.[53]

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[51] In rail transport it is possible to substitute electricity for diesel fuel, but that substitution depends mainly on whether traffic density can justify electrification of the line and not on broader environmental or energy concerns.

[52] The history of electric cars is a remarkable case study of unexpectedly slow technological progress. Despite intensive R&D efforts in the last 30 years, electric cars are still not commercially competitive with petrol cars. This is surprising in view of the fact that battery run cars were competitive with petrol cars in the early years of the 20th century and were widely used in urban transport (Encyclopaedia Britannica 2004).

[53] Greater adoption of telecommuting might reduce somewhat the demand for car travel.

Electronic traffic control

Turning to a different subject, computer controlled collision prevention systems have been developed that can measure distance to the car in front using small radars or optical triangulation and automatically activate the brakes to prevent collision. More sophisticated systems can monitor lateral traffic and prevent crossing a lane if that could lead to a collision. These collision prevention systems might be widely installed in motor vehicles within the next 20 years.

Considerable attention is being paid on how to reduce traffic congestion problems (European Commission 1999). Plans are under way to install a large number of electronic surveillance devices along busy roads to monitor traffic density. The information collected through this monitoring system could then be relayed through electronic signals on the roads or through radio messages to the drivers of trucks, taxis and commercial vehicles to advise them on how to avoid traffic jams.[54] Information on alternative routes can be provided through GPS navigation devices. This type of congestion minimising system could improve productivity in road transport.

The predictions for transport

In view of the many uncertainties surrounding road transport, this study's mean prediction for LP growth in the transport sector (1.5 per cent per annum) is below the historical trend. The lower prediction (0.3 per cent LP growth and -0.3 per cent MFP growth) is based on the assumption that higher petroleum prices will induce some substitution toward more expensive energy efficient or alternative fuel vehicles, thereby reducing MFP in transport in the next 20 years.[55]

4.11 Communications

4.11.1 Historical data

Table 4.45 Average annual productivity changes in communications

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	6.32	3.62	2.70	5.67
10 years from 93–94 to 2003–04	4.71	2.06	2.65	5.16

Source: Productivity Commission (2005a).

54 A more ambitious scheme envisages centralised computer systems controlling and driving motor vehicles on busy highways, in order to enable high-speed high-density traffic with minimal risk of collision (TIME 2000). Such complex system, which requires installing automatic driver mechanism in motor vehicles, is unlikely to be implemented within the next 30 years.

55 As noted in section 2.6, to a large extent changes in oil prices are reflected in the terms of foreign trade rather than GDP or sectoral productivity data (with the exception of oil extraction in mining). By virtue of national accounts definitions, changes in the terms of trade affect real national disposable income (RNNDI) but not GDP.

Table 4.46 Share of communications in GDP and the share of capital income in communications value-added

	%
Share of communications in GDP in 2003–04	2.87
Share of communications in GDP in 1983–84	2.22
Share of capital income in value-added 2002–03	50
Share of capital income in value-added 1982–83	27

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

4.11.2 Forecasts for communications

Table 4.47 Forecasts for communications from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	4.4
Employment growth	2.2
Capital growth	1.9
LP growth (= production – employment)	2.2

Table 4.48 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	6.1	2.7	3.3	5.3
Upper prediction	7.3	3.1	4.1	6.5
Lower prediction	5.2	2.0	3.1	5.1

4.11.3 Comments on communications

Communications recorded 6.32 per cent per annual LP growth in the 20 years to 2003–04. This was the highest productivity growth rate among all the sectors examined. A large portion of LP growth was driven by technological progress, which is partly reflected in the greater importance of MFP growth compared with capital deepening.

The communications industry is made up of two major sub-sectors; one is mail and courier services the other is telecommunications. The ABS does not provide separate information on these sub-sectors. The following discussion starts with telecommunications.

In a similar manner to computer equipment, quality-adjusted prices of telecommunications equipment were falling in the last couple of decades. Major innovations in the field during that period included extensive application of optical fibre cables, the replacement of analogue by digital signals, digital communication switches and mobile cellular networks. Opening up large sections of the industry to competition also helped to raise productivity and reduce prices. The fall in the price of telecommunications spurred rapid expansion in the consumption of telecommunication services, including cable and satellite TV, faxes, mobile phones and the Internet.

As indicated in sections 3.2.3 and 3.2.4, rapid technological progress in telecommunications is expected to continue in the next 20 years. Broadband communications will expand with much greater signal densities passing through optical fibre cables and there will be much quicker and cheaper line connections through 'next generation' electronic and optical switches. In addition, many more satellites and drones in the sky will expand radio communication capabilities. Intelligent multiplexing and focussed directional radio signals will enable better utilisation of the radio wave spectrum.

The main expansion of telecommunication services will be in highly signal intensive applications, such as video telephones and high definition digital cable TV. The user will be able to choose from a large menu of movies and other programs. New telecommunications dependent games, including 'virtual reality' sport matches, requiring physical effort from participants located in distant places, might enter into the market (TIME 2000).[56] Video conferencing and other video communications in business and professional contacts will intensify.[57] Electronic newspapers, bulletins and advertising will gradually replace some of the printed media. Internet-based communications will also replace some broadcasting and live entertainment services.

Ubiquitous communications will become the norm and there will be increasing reliance on Internet-based integrated connectivity at the expense of traditional services such as dial-up-phones and TV/radio broadcasts. Phone and fax numbers will be gradually replaced by Internet-type addresses. Most telecommunications will be converted from analogue to digital signals. This transformation will require extensive standard setting and regulatory changes to ensure interoperability, network integrity, security and the protection of privacy (Australian Communications Authority 2005).

With many times more signals passing through the system without the need to employ more workers, labour productivity will continue to rise as fast as in recent times. 'Hedonic' valuation of changes in the output of this sector raises many difficult issues that will not be examined here. Suffice to say that given the expected exponential increase in the volume of signals passing through the system, it is reasonable to assume that historical output and productivity growth rates according to the ABS quality-adjusted volume estimates will continue in the medium-term. Increased competition among telecommunication carriers will probably also contribute to higher productivity.

From the limited information available on postal services, it appears that further technical progress will be made in electronic mail sorting equipment. Competition from private

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[56] The Australian Communications Authority (2005) reports that in some Asian countries online gamers already outnumber online shoppers by a ratio of two to one.

[57] This could lead to a greater acceptance of tele-commuting from home in office jobs.

service providers will likely to intensify in the parcel delivery market. Because of much slower rate of technological progress, productivity gains in postal services will be considerably lower than in telecommunications.

This study's mean LP growth prediction for the sector for the next 20 years is in line with the average recorded between 1983–84 and 2003–04. Due to continuing rapid technological progress in telecommunications, communications is expected to remain the strongest productivity growth sector in the economy in the next 20 years.

The MONASH general-equilibrium model projects a much smaller rate of growth in LP and capital deepening in communications than what is indicated from the in-house study. These differences arise because the MONASH projections are based on nominal quantities discounted by the general level of inflation and not on 'hedonic' volume indexation used by the in-house study, Productivity Commission (2005a) and the ABS—an approach that indicates very large quality-adjusted volume increases for ICT goods and services.

4.12 Finance and insurance

4.12.1 Historical data

Table 4.49 Average annual productivity changes in finance

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	3.30	0.86	2.44	5.71
10 years from 93–94 to 2003–04	3.60	1.05	2.55	5.44

Source: Productivity Commission (2005a).

Table 4.50 Share of finance in GDP and the share of capital income in finance value-added

	%
Share of finance in GDP in 2003–04	8.09
Share of finance in GDP in 1983–84	4.67
Share of capital income in value-added 2002–03	55
Share of capital income in value-added 1982–83	32

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.51 The composition of finance value-added in 2002–03

	%
Banking and other finance	53.1
Insurance	18.0
Services to finance	28.9
Total finance	100.0

Source: ABS Cat. No.5204.0 unpublished data.

4.12.2 Forecasts for finance and insurance

Table 4.52 Forecasts for finance from the MONASH model
Average annual percentage changes 2003 to 2024

	%
Production growth	3.0
Employment growth	0.3
Capital growth	1.8
LP growth (= production – employment)	2.7

Table 4.53 This study's forecasts of average annual percentage changes:
2004 to 2024

	LP growth	*MFP growth*	*Growth due to capital deepn'g*	*Capital deepening*
	%	%	%	%
Mean prediction	2.2	0.8	1.4	2.4
Upper prediction	2.7	0.6	2.0	3.3
Lower prediction	1.7	0.4	1.3	2.1

4.12.3 Comments on finance and insurance

The finance and insurance sector recorded 3.3 per cent annual LP growth from 1983–84 to 2003–04. Most of this came from capital deepening, reflecting heavy investment in ICT equipment and software and the effect of tumbling ICT prices. This sector is now the most computerised among white-collar industries.

There are opportunities for further productivity improvements through more advanced ICT systems. The replacement of cheques by alternative payment systems through the Internet will likely to continue. This could eliminate much clerical work still required for processing cheques. Security issues pose a threat to the adoption of this approach. Provided that these security problems are rectified, it is possible that most cheque transactions will be replaced by Internet based payments during the forecast period.[58] Apart from the minimisation of actual security problems there is also a need to build up public trust in Internet transactions in order to attain a greater utilisation of the web for financial transactions.

Various forms of micro-payment systems (e-money) are expected to be more widely used in face-to-face transactions. These are better suited for small transactions than credit cards. The open stored-value system allows the value of a 'smart' card to be used in the same manner as any other payment method currently in place (Good 2003). Smart cards can be used for purse-to-purse transactions without having to inform the card company about each

[58] Internet-based replacement to the current paper cheque system is a particular application related to the broader issue of how to establish legally binding, verifiable and protected electronic signatures on the web and other communication channels.

transaction. Wider use of e-money depends on its acceptance by retailers and small service providers. Micro-payment systems may contribute to improved productivity not only in the finance sector but also in service industries where small payments are commonly used, such as retailing, restaurants, public transport and entertainment.

Cybermoney is a micro-payment system based on a generally recognised personal financial account that can be used up to its limit for any purchase on the worldwide web.[59] Appropriate security and authentication of this kind of financial instrument also requires strong safeguards against hacking and viruses as well as widespread public trust in the system. In addition, more insurance transactions could be conducted through the Internet under more favourable public trust and security conditions.

In summary, there are still major technological opportunities for productivity improvements in finance and insurance, but in many cases their implementation depends on improving the security environment and public trust in the Internet. An increasingly computer literate population will facilitate greater acceptance of on-line financial transactions.

Given the already high level of computerisation in this sector, future productivity gains are unlikely to match those of the past. This study's mean LP growth rate prediction for finance and insurance over the next 20 years is 2.3 per cent per annum, which is substantially less than the historical rate. The optimistic prediction, at 2.7 per cent a year, is closer to the historical trend. As in the past, most of productivity growth is expected to arise from capital deepening of ICT equipment and software.

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[59] The collection of indirect taxes in the buyer's country of residence on small purchases made through the Internet from supplier in another country, is another issue that is yet to be fully resolved.

4.13 Cultural and recreational services (CRS)

4.13.1 Historical data

Table 4.54 Average annual productivity changes in CRS

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
20 years from 83–84 to 2003–04	-0.54	-2.00	1.46	3.65
10 years from 93–94 to 2003–04	0.44	-1.69	2.13	5.39

Source: Productivity Commission (2005a).

Table 4.55 Share of CRS in GDP and the share of capital income in CRS value-added

	%
Share of CRS in GDP in 2003–04	1.89
Share of CRS in GDP in 1983–84	1.84
Share of capital income in value-added 2002–03	41
Share of capital income in value-added 1982–83	39

Source: ABS National Accounts Cat.No. 5204.0 published and unpublished data.

Table 4.56 The composition of CRS value-added in 1998–99

	%
Motion picture, radio and television services	35.9
Libraries, museums and the arts	21.2
Sport, gambling and recreational services	42.9
Total CRS	100.0

Source: ABS (2004a).

4.13.2 Forecasts for cultural and recreational services

Table 4.57 Forecasts for CRS from the MONASH model

average annual percentage changes 2003 to 2024

	%
Production growth	3.7
Employment growth	2.9
Capital growth	1.9
LP growth (= production – employment)	0.8

Table 4.58 This study's forecasts of average annual percentage changes: 2004 to 2024

	LP growth	MFP growth	Growth due to capital deepn'g	Capital deepening
	%	%	%	%
Mean prediction	0.8	0.2	0.6	1.3
Upper prediction	1.6	0.3	1.3	2.7
Lower prediction	0.4	0.0	0.4	0.9

4.13.3 Comments on cultural and recreational services (CRS)

Cultural and recreational services recorded slightly negative LP growth and highly negative MFP growth (-2.0 per cent a year) in the 20 years to 2003–04. It is not clear why the Productivity Commission estimates, which are based on ABS data, show such a large negative MFP change in this sector.

It appears that major sub-sectors of CRS, including sport clubs, gambling services, museums and recreational parks did not enjoy much MFP growth in recent years. However, the sub-sector called 'motion picture, radio and television services' in table 4.56 did benefit from various electronic innovations, and negative MFP growth in this field does not appear very plausible.

There is no sufficient information to judge to what extent the historical data in table 4.54 represents some unusual productivity development or is a reflection of 'hedonic' output valuation problems. Whatever the case may be, it seems likely that LP and MFP growth in this sector in the next 20 years will be positive. The MONASH model predicts positive productivity growth in the CRS sector.

The TV industry is expected to record strong technology-driven productivity gains, due to the expansion of broadband to households and wider takeup of high-resolution TV services by consumers. In addition, some areas in the sport and entertainment industries are likely to record modest 'hedonic' productivity gains as a result of advances in on-line bookings, registrations and e-money micro-payments.

Consequently, this study predicts positive but not particularly high productivity growth in the sector, in contrast to what is shown from the historical estimates. Given the uncertainty about the historical data, the mean predicted LP growth rate is based on the MONASH projection. Much of productivity growth will be driven by the expansion of pay-TV and other entertainment services. Given that these services require heavy capital investment, LP growth will be probably driven mainly by capital deepening.

After accommodation and restaurants, CRS is expected to record the lowest productivity growth rate among all the major market sectors examined.

4.14 Property, business and professional services (PBPS)

4.14.1 Historical data

Table 4.59 Average annual productivity changes in PBPS

	LP growth
	%
8 years from 1995–96 to 2003–04	1.07

Source: ABS National Accounts Cat.No. 5204.0 and Cat. No. 6203.0.

Table 4.60 Share of PBPS in GDP

	%
Share in GDP in 2003–04	11.49
Share in GDP in 1983–84	6.01

Source: ABS National Accounts Cat.No. 5204.0.

Table 4.61 The composition of PBPS value-added in 1998–99

	%
Property services	37.7
Scientific research, technical and computer services	27.3
Legal, accounting, marketing and business management services	35.0
Other business services	18.5
Total property and business services	100.0

Source: ABS (2004a).

4.14.2 Forecasts for property, business and professional services

Table 4.62 Forecasts for PBPS from the MONASH model
average annual percentage changes 2003 to 2024

	%
Production growth	3.7
Employment growth	3.0
Capital growth	2.4
LP growth (= production – employment)	0.7

Table 4.63 This study's forecasts of average annual percentage changes: 2004 to 2024

	LP growth
	%
Mean prediction	0.9
Upper prediction	1.3
Lower prediction	0.6

4.14.3 Comments on property, business and professional services

Value-added volume indexation of PBPS consistent with other market sectors only started in 1995–96. A double-deflated value-added volume index for the PBPS industry is available only from that time. Consequently, the ABS has not yet incorporated PBPS into market sector measures of productivity, which currently commence in 1964–65.

This study derived an estimate for LP growth between 1995–96 and 2003–04 using ABS national accounts and labour force data. During this eight year period, the value-added volume estimates for PBPS in the national accounts were consistent with other 'market sector' estimates. Over these eight years, LP growth averaged 1.07 per cent per annum. Apart from this isolated LP growth estimate, there is no other published productivity information in this sector. Even the information on the composition of this large sector (table 4.61) is based on fairly dated data from the ABS 1998–99 input-output tables.

The lack of more statistical information on the PBPS sector is a cause for concern. In 2003–04 the share of PBPS in GDP was very close to that of the largest first digit ANZSIC sector – manufacturing (see tables 4.12 and 4.60). Since the trend is for the share of manufacturing to decline and for PBPS to rise, by now PBPS is probably the largest major sector in the economy. It is a very heterogeneous sector, ranging from property services (including housing rent) and equipment hire to labour hire, business and professional services. Quality-adjusted volume indexation in this diverse sector obviously poses major difficulties.

PBPS recorded the largest increase of share in GDP between 1983–84 and 2003–04 among all the sectors examined. Due to lack of detailed information, the reasons and sub-sectoral decomposition of this increase are unclear.

It appears that the long running property boom was an important contributing factor. The tendency by many enterprises to outsource non-core business, computer and professional services to outside suppliers and the increasing importance of labour hire firms, might have been even more influential. This implies that the rising share of PBPS was partly due to accounting reclassification of value-added in the national accounts. It appears that some value-added has been transferred from sectors such as manufacturing, mining, construction and government into PBPS without substantial change in the work performed.[60]

In the absence of historical information on MFP and capital deepening, the predictions for PBPS are restricted only to labour productivity growth. The predictions presented in table

[60] Other sectors that may have increased their share in the national accounts as a result of increased outsourcing are road transport and construction.

4.63 are based on the LP growth forecast from the MONASH model and on the average LP growth rate according to ABS data over the eight years from 1995–1996 to 2003–04. It is reasonable to surmise that some of the LP growth will come from capital deepening (particularly in property services and equipment hire) and some from the growing knowledge base in engineering, computer and other professional services, which shows up as MFP growth. Wider use of computerised transactions, particularly in real estate and legal services, will also contribute to MFP growth.

4.15 Other non-market sectors

Apart from PBPS, there are another five major sectors that are not included in 'market sector' industries and for which detailed historical productivity estimates are not available from Productivity Commission (2005a). These sectors are education, health, government services and defence and imputed rent on dwellings. In the absence of adequate historical information no attempt has been made in this study to make detailed productivity forecasts for these sectors. Instead, the LP growth projections from the ORANI model are used to establish sectoral predictions that are used later for predicting aggregate LP growth. The exception is government services and defence, where national accounting volume indexation puts the volume of output in direct proportion to labour inputs, hence LP growth is by definition zero (ABS 2000). Table 4.64 shows the projections from the MONASH model for non-market sectors with the exception of government services and defence.

Table 4.64 Forecasts for non-market sectors from the MONASH model
average annual percentage changes 2003 to 2024

	Ouput growth	*Labour growth*	*LP growth*
	%	%	%
Education	3.0	1.4	1.6
Health and community services	3.0	1.6	1.4
Personal and other services	2.9	2.1	0.8
Imputed rent on dwellings	2.8	1.2[a]	1.6

[a] For imputed rent on dwellings the labour growth prediction is the overall population growth projection in the MONASH model.

Source: Table C.2 in the appendix.

For imputed rent on dwellings the labour growth prediction in table 4.64 is the aggregate employment growth projection from the MONASH model, which is identical to population growth in the forecasting version of the model. The annual growth figure for imputed rent on dwellings represents the expected rate of increase in imputed rent per capita rather than LP growth measured by the change in output per working hour. In other words, the increase in imputed rent reflects more residential assets per person (that is, capital deepening).

The MONASH LP growth projections from table 4.64 were taken as the mean predictions for LP growth rates in non-market sectors. Using the confidence interval estimates discussed in section 2.4, the upper LP growth estimate were put at around 25 per cent above the mean and the lower LP growth estimate at around 35 per cent below the mean. Based on the outlier numbers in table 2.1, there is at least 80 per cent chance that the actual outcome will be located between these upper and lower bounds. The resultant predictions are shown in table 4.65.

In the absence of sufficient information no attempt has been made to predict MFP growth rates for these sectors. The main purpose of the predictions in table 4.65 is to enable aggregate predictions of LP growth for the entire economy, a subject taken up in section 6.1.

Table 4.65 This study's forecasts of LP growth for 'non market' sectors
average annual percentage changes: 2004 to 2024

	Mean prediction	*Upper prediction*	*Lower prediction*
	%	%	%
Education	1.6	2.0	1.2
Health and community services	1.4	1.7	1.0
Personal and other services	0.8	1.1	0.5
Imputed rent on dwellings[a]	1.6	2.0	1.2
Government services and defence	0.0	0.0	0.0

[a] The predictions for imputed rent on dwellings represent the rate of change in residential assets per person rather than LP growth.

5. Productivity growth in education and health

In both education and health care there are many applications where labour productivity could be improved by substituting ICT capital for labour.

As noted in section 1.3, health care and education are not part of the 'market sector', hence no detailed historical productivity growth figures are available from Productivity Commission (2005a) or the ABS. The LP growth predictions for these sectors in table 4.65 are based on projections from the MONASH model and not the in-house study.

Despite the difficulties in deriving quantitative predictions, one should not ignore the fact that ICT-related innovations could open the way for substantial productivity improvements in these sectors. This subject will be examined in this chapter, which highlights technological opportunities for productivity improvements without trying to quantify expected productivity gains.

5.1 Possible productivity improvements in health care

5.1.1 Some introductory comments

As indicated in the discussion in chapter 3, a large number of innovations in biotechnology, ICT, new materials and nanotechnology will contribute to further improvements in health care. In fact, health care is one of the technologically most dynamic fields nowadays. Innovations in diagnostics, pharmaceuticals, drug delivery and less invasive surgery will continue to raise life expectancy, which may be regarded as the ultimate performance indicator of the health care system.[61] Increasing life expectancy combined with declining birth rates are the reasons for population ageing.

Indications are that new labour saving technologies (particularly ICT technologies) can lead to substantial productivity improvements, in the sense that the same quantity of labour inputs can deliver higher quality health care results. The purpose of this section is to review briefly some of these productivity-enhancing innovations, particularly in health monitoring and nursing care. Given an ageing population and escalating health care costs, the economic importance of these productivity enhancing technologies cannot be underestimated.

For the purpose of the following discussion these innovations are grouped as follows:

- Computerised monitoring of patients through local area network (LAN).
- Remote monitoring through broadband communications.
- Electronic management of health records.
- New approaches to self-care and preventative medicine.

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[61] However, biological constraints related to the process of ageing might curtail the rate of increase in life expectancy despite rapid progress in medical technologies (Productivity Commission 2005b).

All the potential productivity improvements reviewed in this chapter are related to ICT. However, not all ICT-related innovations in medical care are covered. ICT plays an important role in modern diagnostic technologies (such as ultrasound, endoscopy and magnetic resonance imaging). ICT also plays a key role in precision surgery through electronic sensors and computerised remotely controlled surgical apparatus that can be used for probing, cutting and stitching. These innovations are not reviewed here. The discussion concentrates only on ICT innovations that facilitate patient monitoring and nursing care.

5.1.2 Monitoring patients through local area networks

As mentioned in section 3.2.4, RFIDs and other mobile ICT devices can be used to send signals about the condition and location of patients to LAN computer terminals in hospitals, nursing homes or retirement villages. Such a local area network can be based on a dense network of RFID readers, more widely spaced Wi-Fi transponders or other short-distance wireless ICT system.

Smart clothes and sensory devices have been developed that are worn by the patient and transmit to the computer information about vital signs such as heart rate, blood pressure, electrocardiogram (ECG) waves, temperature and mobility. Special vests, inlaid with electrical and photonic conductors, can relay even more information about the patient's condition, including respiration and blood oxygen level (CSC 2002). These technologies are already being used in some hospitals and their application is likely to become more pervasive in the coming years.

The computer can be used to screen information automatically and alert the medical/nursing staff only when serious abnormal signs are detected. Also a computer file can record automatically the readings of monitoring devices over time. In addition, barcode labels or RFIDs attached to medicine packages can be used to ensure that usage accords with prescription. This arrangement can reduce mistakes in the administration of injections and drugs.

Evidently, wireless local area network (LAN) based computer monitoring has the potential to improve the productivity of nursing and other staff in medical institutions. Some improvements have been already achieved and more are likely to follow.

5.1.3 Remote monitoring through broadband connections

Broadband technologies can enhance diagnostic outcomes for a range of clinical applications, including ultrasound, radiology and psychiatry (DCITA 2004). This is particularly important in Australia with its widely dispersed non-urban population. Through high-speed connectivity a patient's diagnostic signs can be transmitted through broadband from a remote clinic to a hospital. The speed of a broadband connection enables a clinician to respond quickly to a change in a patient's condition.

Diagnostic tests through remote clinics combined with routine monitoring of vital signs communicated from home, could allow some chronically ill patients to remain in their homes, possibly reducing the costs associated with prolonged stays in the public hospital system.

But there are some serious impediments to this approach. The collection, analysis and reporting back of data on patients, as well as physician initiated communication to help patients manage disease, is known as remote disease management (RDM). While RDM appears promising at first sight, practical application encounters social difficulties as well as constraints on the physician time in going through extensive computer records. A USA survey conducted in 2003 reported that a mere 7 per cent of doctors who were already online used RDM technology (mainly for monitoring patient blood glucose levels), an insignificant increase from 5 per cent two years earlier (Katz et al 2004). It appears that more widespread application of RDM requires specialist nursing staff in clinics to process and screen the incoming information. In addition, suitable information screening software is needed to prevent information overload on medical staff.

A broadband network can facilitate video conferencing between medical staff scattered over a wide area, allowing them to talk to their peers about particular cases or participate in professional development seminars. This can be particularly important in remote areas that suffer from a shortage of specialists.

The Centre for Networking Technologies for the Information Economy (CeNTIE) is currently supporting the development of a haptic-acoustic-visual virtual reality device, which enables doctors wearing special headsets to work within a three-dimensional context and interact with remote colleagues through high-speed networks. It is envisaged that one day these devices will enable medical students in remote locations to train on virtual patients.

It is also technically feasible to use semi-robotic surgical apparatus connected to broadband to perform operation on a patient through remote control by a surgeon sitting before a video screen a large distance away. However, tele-surgery might be considered too risky by many people.

A report prepared by Access Economics (2003) estimated a potential net economic benefit of $190 million over 10 years from the deployment of broadband in major hospitals lacking broadband capability.

5.1.4 Electronic management of health records

The Australian Government and state/territory governments are working collaboratively to establish a national electronic health information network—HealthConnect. The HealthConnect project is designed to improve information flows across the health sector by allowing patient information to be collected, stored and exchanged electronically between authorised health care providers.

HealthConnect will improve health outcomes by assisting coordination of healthcare services, reducing duplication of services and creating a comprehensive, lifetime record for the consumer. For example, one of the case studies conducted as part of the HealthConnect trial in South Australia has demonstrated a noticeable reduction in the number of pathology and radiology tests ordered as a result of providers having ready access to earlier test results and therefore not needing to duplicate tests unnecessarily.

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There are still many unresolved issues in relation to patient privacy. Also many general practitioners and specialist clinics do not have the technical expertise or the ICT infrastructure to take full advantage of the HealthConnect initiative.

Despite these impediments computerised management of health records will likely to expand in the coming years, with the possibility that at a later stage the information base will expand from medical history and pathology tests to include also information on the individual's genome. In addition, such database could contain self-monitoring results on weight, blood pressure, glucose, cholesterol level and the like.

5.1.5 New approaches to self-care and preventative medicine

Currently, the most widely used application of ICT in self-care is in seeking medical information through the Internet. According to a recent USA survey, reported in Katz et al (2004), around two-third of Internet users sought medical advice on the Internet concerning their health problems or somebody else's. Around 5 per cent of respondents visited an Internet health site the day before the survey.

Medical information obtained through the Internet can sometimes empower a patient and provide more detailed information about his/her medical condition and method of treatment than the advice received from the physician. The main problem in this area is the proliferation of medical sites, which sometimes provide misleading information in order to promote certain products or services. The difficulty in understanding more professional sites by a layman is another major handicap.

The application of ICT in self-care extends well beyond medical information on the Internet. The ICT monitoring devices used in hospitals and nursing homes could be also used at home to send information to a computer. This can be a personal computer containing a health-monitoring program or alternatively the information can be sent through the personal computer to a computer in a medical centre. There are already a number of personal health testing devices that can send through RFIDs information to a medical condition recording computer file on pulse rate, blood pressure, temperature and glucose level.[62]

More effective monitoring of medical condition at home and the transmission of regular information to a health condition recording computer file that can alert the physician to signs of danger might reduce the need for medical consultations, pathology tests and the transfer of feeble persons to nursing homes. However, the earlier mentioned difficulties encountered with remote disease management (RDM) should be borne in mind (see section 5.1.3).

The development of versatile computer controlled wheelchairs and other computerised aid equipment that can respond to pushbuttons, voices or gestures, could reduce the nursing care costs of people with severe disabilities. Experiments are under way with artificial limbs that

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[62] Some promising new home medical testing devices include microlaser to scan the back of the eye to check ocular pressure, blood pressure and carbon dioxide level. Biological sensors embedded into the toilet seat can automatically complete urinalysis and stool test. Toothbrushes with embedded sensors can check for gum disease and measure bone density.

can respond to brain signals. In some cases eyesight and hearing can be partially restored by means of implanted digital devices.

5.2 Possible productivity improvements in education

5.2.1 Computers in education

Computers are already widely used in education and their application is expected to intensify in the coming years. Further productivity gains are likely to follow, in the sense that more knowledge can be conveyed with a given amount of teaching resources.

Like books, computers enable autodidactic learning. But computers have some great advantages over books. First, the material can be presented in a more interesting manner involving games, puzzles, multi-media and virtual reality. And unlike books, the material can be presented in an interactive manner, requiring active participation by the student and feedback about the correctness of answers to prompts.[63]

The fact that effective learning usually requires feedback is a psychological principle that has been recognised for a long time. The ability of computers to provide feedback was the main reason for early interest in computerised teaching more than three decades ago. Since then considerable progress has been made in developing software programs to teach subjects ranging from mathematics to languages.[64]

As with any autodidactic approach, computers are not suitable for the socialisation of students. Yet, developing the social skills of children through interactions with peers and teachers is often a more important objective of education than the provision of general knowledge and skills. The greater motivating power of teachers compared with computers should also not be ignored. Therefore, computers cannot replace teachers and classrooms, however, they can supplement them in an effective manner. The optimal balance between traditional classroom education and computer-based education inside or outside the classroom is a subject that still requires much research and will not be examined here.

Suffice to note that in an age of ubiquitous computing and pervasive virtual reality games, the application of computers for teaching purposes could further diminish the sense of reality and responsibility of young persons surrounded by artificial sensory inputs. The European Commission (2004) study warns about possible negative social consequences from certain new technologies. The application of computers in education could have some potentially damaging social consequences. How to strike the right balance and establish an optimal mix of teaching methods is a subject outside the scope of this report.

The following two sections review possible applications of computers as a tutoring device and as an aid to life-long adult education.

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[63] On the other hand, many people find it easier to read printed matter than computer screens.

[64] Computers can also administer tests and score them automatically. Multiple choice tests are particularly well suited for that purpose. Some success has been reported in computerised scoring of literature tests using programs that incorporate some elements of 'artificial intelligence' (CSC 2002).

5.2.2 Tutoring through computers

As noted earlier, one of the great advantages of computers in education is that they can provide feedback to the student. They can also present educational material in a more interesting style than books. These two advantages open the way for the application of computers as a tutoring device from kindergartens to universities.

For younger age groups the potential for computer-aided tutoring is particularly promising through various teaching toys. Many such toys are already on the market. At the kindergarten level these toys include teaching robots displaying computer controlled movements, voices and flickering lights. Less expensive teaching aids are based on desktop computers that can show educational games on a screen.[65] These teaching aids have to use strong casings in order to reduce the risk of damage. Computerised teaching toys can be used to teach children language skills (by broadening vocabulary and presenting pronunciations), rhymes, object recognition, spatial understanding, basic reasoning as well as literacy and numeracy skills.

Older age groups may not require teaching toys, but could still benefit from teaching games. RAND (2000) predicts that many techniques for educational uses of computers will likely to be derived from the entertainment industry. Because the entertainment industry is largely unregulated, faces few resource constraints and enjoys an innovative culture, many more new ideas and techniques will likely to spring up in the entertainment context than in the education context. For better or for worse, many of these techniques will be transferred to educational applications.

The main objective of computerised teaching for older students is to provide interesting and entertaining presentation and, perhaps more importantly, to provide effective feedback. The feedback need not be restricted to indicating right or wrong answers. Depending on the complexity of the software, the feedback may involve step-by-step instructions on how to solve problems, with the student being constantly guided to the right path.

An important objective of computer-aided education is to familiarise students with computer skills. ICT proficiency is already becoming an essential prerequisite in the modern working environment. ICT skills are becoming the third skill for life alongside literacy and numeracy. With the increasing pervasiveness of computers and portable personal digital assistant (PDA) devices, memory based knowledge might become less valuable than nowadays. On the other hand, more importance will be given to reasoning skills that enable the user to store information and linkages on the computer and search effectively through a computer (or the Internet) for specific information. Knowledge workers will need to be

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65 Another notable ICT related innovation in pre-school education might be the installation of video cameras in kindergartens. These tele-monitoring devices can enable the parent to observe the child in the care centre through broadband communications from work or home. This kind of video monitoring is already used in some places in the USA and Japan.

aware on how and when to use computers to supplement their own knowledge base.[66] No doubt, the education system will have an important role to play in developing these skills.

RAND (2000) is fairly pessimistic about the diffusion of ICT applications in the USA education system in the near future. Reasons include inertia, entrenched unions, political interference, unfamiliarity with and inability to use new technologies and the cost of new equipment, software and infrastructure. Examination of the impediments in Australia is outside the scope of this report.

In a ministerial press release, the Minister for Education, Science and Training, Dr Nelson (2005), outlines recent initiatives by the Australian Government in cooperation with State/Territory governments to support ICT applications in education. These initiatives include broadband connections between Australian universities as well as with universities abroad. Wireless broadband is already being used to extend the reach of education services to isolated areas through the school-of-the-air initiative. Nelson (2005) also mentions that since 1998 Australian Government departments and the private sector donated 106 000 pieces of computer equipment to schools.

Another major initiative is funding for ICT-related professional development programmes for teachers. The training of teachers and administrators in the use of the new technology will be a critical factor in determining the speed of diffusion of computer-aided education in Australia.

5.2.3 ICT and adult education

Adult education is becoming increasingly important in a knowledge intensive world with a constant need for training and retraining. Research on adult education shows that it has to be flexible and well attuned to the needs of the student. These requirements are usually more easily met through computer rather than classroom education. Also, socialisation is a less important objective in adult education than for younger cohorts.

One of the major benefits of ICT, and broadband in particular, in education is the opportunity that it provides for remote content delivery. With a greater number of accredited and award courses available via web-based education, there is considerable scope for upskilling. Web-based education offers flexibility and variation in the mode of delivery (for example, print, video-links, immediate or delayed feedback through telecommunications) and in the constraints of place, time and distance. Flexibility in content delivery allows for courses to be moulded to the needs of the students in a more cost-effective manner (DCITA 2004).

A much wider variety of courses and programs can be accessed as place-based limitations are removed. Individuals can access courses anywhere within Australia or overseas, which is of particular value in specialised fields where local training opportunities are limited. By

[66] Even in the information age not all important information is freely available on the web or in libraries. Much technological and commercial information is kept secret by private enterprises. In addition, some information is available on the web for a price and the prospective buyer has to decide whether to pay for it before seeing its content.

removing restrictions on time, place and distance, web-based education can be of particular benefit to people in rural and remote areas, people with disabilities and those with family/caring and/or work commitments.

There is scope for employers to support further education through computers due to improved flexibility in relation to work arrangements, educational access and travel time. Promoting a culture and practice of computer-aided learning in the workplace can enable individuals to progress through their careers without major education/training related disruption to their style of living.

Nelson (2005) notes that the Australian Government funded Basic IT Enabling Skills Programme will help each year 11 500 mature-age job seekers to undergo training to enable them to operate competently personal computers in the workplace.

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6. GDP and structural change

This chapter aggregates the forecasts presented in chapter 4 to derive predictions for the growth in GDP per capita. Some predictions are also made about changes in the sectoral composition of GDP and the distribution of employment between different sectors, in other words, about structural change.

6.1 Real GDP per capita

Table 6.1 shows aggregate predictions, based on the sectoral forecasts presented in chapter 4. Tables D.1, D.2 and D.3 in the appendix show the underlying sectoral predictions.

Table 6.1 Aggregate predictions of average annual changes

	Predictions	*LP growth*	*MFP growth*	*Due to cap deepn'g*	*Capital deepn'g*
		%	%	%	%
Market sector	Mean	2.18	0.97	1.21	2.55
	Upper	2.82	1.23	1.47	3.10
	Lower	1.34	0.49	0.85	1.76
All-sectors (GDP level)	Mean	1.78			
	Upper	2.30			
	Lower	1.15			

Source: Chapter 4 and tables D.1, D.2 and D.3 in the appendix.

The upper part of table 6.1 presents summary for the 12 'market sectors' listed in section 1.3. The bottom part, which covers predictions at the GDP level, is limited to LP growth. It also includes (from tables 4.63 and 4.65) predictions for non-market sectors. The all-sectors LP growth predictions in the lower part do not yet represent predicted annual changes in real GDP per capita. To obtain estimates for changes in real GDP per capita some further adjustments are needed.

The LP predictions in table 6.1 refer to productivity changes per working hour. But almost certainly average working hours per capita will not remain fixed over next 20 years. The Productivity Commission (2005b) report analyses in some depth likely changes in labour force participation rates and working hours as a result of expected demographic changes, particularly population ageing. This subject is not analysed in the present report, which relies in this area on the forecasts of Productivity Commission (2005b).

According to the predictions presented in Productivity Commission (2005b) figure 3.22, effective labour supply per capita in 2024 will be around four per cent lower than in 2004. The main reasons for this decrease are reduction in workforce participation rate and average weekly working hours as a result of population ageing.[67]

[67] Workforce participation rate refers to the proportion of the population who are in the workforce by virtue of working or looking for work.

Probably, the Productivity Commission's projections are a bit on the conservative side, because, they were deliberately based on current policy settings and the continuation of past trends, so as to illustrate what would happen in the absence of new policies. It is likely that emerging government policies will result in better participation outcomes. Gruen and Garbutt (2003) suggest that if the Australian participation rate was to approach the OECD's average then Australia might experience a rising participation rate in the next 20 years. Moreover, some advances in medical technology (discussed in section 3.3.1), including better treatment for arthritis, memory impairment, depression and schizophrenia, might help some people to move into the workforce.

The Productivity Commission's effective labour supply per capita estimate does not include a reduction in productivity per hour due to rise in the average age of the workforce.[68] Productivity Commission (2005b) was unable to determine whether ageing has an effect on productivity besides workforce participation. In many occupations the higher knowledge base and experience associated with age can lead to improved productivity. On the other hand, in some occupations, particularly those requiring heavy muscular effort or sharp senses, productivity usually decreases after certain age. The overall effect across all occupations is unclear.[69]

Table 6.2 Real GDP per capita calculations

Predictions	*All sectors LP growth rate from table 6.1*	*Adjustment for 4% less working hours*	*Final predicted annual growth rates*	*Increase in real GDP per capita 2004 to 2024*
	%	%	%	%
Mean	1.78	1.57	1.57	36.6
Upper	2.30	2.09	1.83	43.7
Lower	1.15	0.95	1.26	28.4

Source: Table 6.1 and Productivity Commission (2005b figure 3.22).

Table 6.2 shows predictions based on the all-sectors LP growth rates in table 6.1 after adjusting them in such a manner that the cumulative LP figures by 2024 are reduced by 4 per cent to account for expected decrease in effective working hours per capita. The third column in table 6.2 shows the modified annual LP growth estimates after this adjustment.

The fourth column shows yet another adjustment. In calculating aggregate LP growth rates under optimistic or pessimistic scenarios, all the optimistic and pessimistic sectoral predictions were added up separately in order to obtain the respective aggregate estimates. But, arguably negative and positive sectoral outcomes will usually not occur together. Above and below average results for individual sectors will partially cancel out in random

[68] According to Productivity Commission (2005b) figure 3.24, the average age of male employees is expected to rise from 40 to 41.5 years between 2004 and 2024. The corresponding increase for female employees is from 38 to 40 years.

[69] Earning data indicate that wages tends to increase with age, which supports the hypothesis of increasing productivity with age, assuming that under competitive labour market conditions wages tend to be in line with productivity. But it should be noted that above the age of 55 earnings per hour starts to drop (Productivity Commission 2005b).

variations at the aggregate level. In order to obtain more realistic aggregate predictions, which take into account probabilistic reversion to the mean, the study takes the average between the upper and lower predictions and the mean in column (3), to obtain the final annual growth predictions in column (4).

Using the figures in column (4), column (5) shows the total predicted increase in real GDP per capita between 2004 and 2024. These figures suggest that there is 80 per cent probability that real GDP per capita will increase by between 28 and 44 per cent over the next 20 years.[70]

The change in real GDP per capita may be a fairly good indicator of change in net income per person. Starting from 1985–86, the ABS has published estimates for real net national disposable income (RNNDI), based on constant-price GDP adjusted by changes in the terms of trade, cross-border income flows and the depreciation of capital assets. In some respects RNNDI seems to be a better indicator of 'real' national income than GDP. Between 1985–86 and 2003–04, RNNDI per capita increased by 47.8 per cent while real GDP per capita increased by 45.6 per cent (ABS Cat. No. 5204.0), indicating that the two indicators tend to move in tandem. Given that sectoral value-added data add up to GDP, this report uses real GDP per capita rather than RNNDI per capita as the basic income indicator.

Finally, a few words about expected changes in unemployment. This report does not present forecasts on this item because it is not a direct driver of productivity growth. Suffice to say that there will be a number of opposing influences on unemployment. On the one hand, population ageing is expected to reduce labour supply thereby putting a downward pressure on unemployment. Moreover, the falling share in the labour force of the youngest cohort will tend to reduce unemployment, because of the high frictional unemployment rates among recently started or first-time job seekers. On the other hand, the continuing automation of many activities may lead to more structural unemployment. However, the widely held view among labour market economists is that technological change and unemployment rates are not related in the long-run (see Layard et al 1991).

On the balance, it seems likely that unemployment will fall in the next 20 years. The new industrial relation reforms promoted by the Australian Government, as well as reforms of the welfare system could increase labour market flexibility and provide added incentives for some welfare recipients to work or study. If successful, the net effect of these measures would be to reduce unemployment (Lewis 2005). The influx of low skilled workers might put some downward pressure on productivity (and wages) in labour intensive sectors, a possibility that has been factored into the pessimistic predictions.

Even if unemployment remains fairly steady over the next 20 years, major changes are likely to occur in labour markets. In the light of recent trends, it seems likely that there will be increasing demand for many categories of skilled labour (professionals and tradespersons) and decreasing demand for unskilled labour (including some semi-skilled white collar workers). Programs aimed at improving the computer skills of job seekers could help in reducing unemployment.

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[70] Section 2.4 explains how the 80 per cent probability estimate was derived.

6.2 Comparisons with other Australian forecasts

Two recent Australian studies made predictions about the expected growth in real GDP per capita in the coming decades—one is Treasury (2002), the other is Productivity Commission (2005b). Table 6.3 shows relevant predictions from these two studies.

Table 6.3 Actual and predicted annual real GDP per capita growth rates[a]

Decade	*Treasury (2002)*	*Productivity Commission (2005b)*
	%	%
1980s	1.8	
1990s	2.2	2.14
2000s	2.1	1.95
2010s	1.5	1.46
2020s	1.4	1.27
2030s	1.5	1.50
Geometric average 2004–2024	**1.66**	**1.57**

a Assuming an underlying long-term growth rate of 1.75 per cent a year.

Source: Treasury (2002), Productivity Commission (2005b, table 5.1).

Both sets of predictions in table 6.3 are based on similar assumptions. Both studies assume a long-term underlying real GDP per capita growth rate of 1.75 per cent a year, based on the average rate from the early 1980s to the early years of this decade.[71] Taking into account expected changes in labour force participation and average working hours as a result of changes in the demographic profile, these studies derive the estimated growth rates shown in table 6.3.[72]

In order to compare these predictions with the single period prediction of the present study (from 2004 to 2024), a geometric average was taken of the decade-by-decade predictions, based on 6 years in the 2000s decade, 10 years in the 2010s and 4 years in the 2020s. This yields the average single period estimates shown in the bottom line of table 6.3.

The mean real GDP per capita growth prediction of 1.57 per cent of this study (table 6.2) is slightly lower than Treasury (2002) but is equal to the prediction in Productivity Commission (2005b). The similarity of forecasts is due to the fact that all three studies use similar base period results for extrapolation. Moreover, the present study's calculation of real GDP growth per capita is based on Productivity Commission's prediction of four per cent fall in effective labour supply per person between 2004 and 2024. Treasury (2002) used similar calculations in respect to the effect of demographic changes on labour supply.

The reason that this study obtained slightly lower mean predictions than Treasury (2002) appears to be partly connected with anticipated problems in energy markets that are

[71] In fact, both studies examined predictions based on different underlying long-term rates of growth, but their preferred choice is 1.75 per cent per annum. Table 6.3 shows only predictions corresponding to that choice.

[72] Treasury (2002) assumes slightly increasing labour force participation in the 2000s decade, which leads to 2.1 per cent predicted growth in GDP per capita.

explicitly factored into the present forecasts but do not feature in Treasury (2002).[73] Small differences in assumptions about workforce participation rates between Treasury (2002) and Productivity Commission (2005b) (the source for labour supply projections in this report) could be another reason for the difference observed.

The MONASH projections presented in this report yield an estimated real GDP growth rate of 2.6 per cent per annum between 2003 and 2024 and increase in aggregate employment at the rate of 1.2 per cent a year. Given that the MONASH projections assume that employment grows at the same rate as population, these two estimates imply a real GDP per capita growth rate of 1.4 per cent a year, which is lower than the 1.57 per cent mean estimate of the present study. The main reason for the difference appears to be related to lower capital deepening projections in MONASH.

6.3 Predicting structural changes in the economy

The national accounts information used for extrapolating productivity trends can be also used to make predictions by extrapolation about the likely future sectoral composition of the economy. These predictions are based on much less detailed investigation than was carried out in respect to productivity growth. Given the less detailed nature of these structural change forecasts, only mean predictions are presented without confidence intervals.

Table 6.4 shows the calculations used to derive the predicted shares of sectors in total employment in 2023–24. The starting point for the calculation is the sectoral employment shares (in terms of working hours) recorded in 2003–04. The data is obtained from the ABS labour force statistics (Cat. 6203.0). The 2003–04 sectoral shares are shown in column (2) of table 6.4.

The next step involves calculating the expected increases in output between 2003–04 and 2023–24. These calculations are summarised in table E.1 in the appendix. The calculations are based largely on the trend growth in sectoral real value-added between 1983–84 and 2003–04 according to the national accounts. At the next stage, the historical figures in some sectors were adjusted in anticipation of possible future departures from the past trends. These adjustments involved reducing expected output in 2023–24 in the PBPS sector while increasing expected output in manufacturing, mining and agriculture, on the assumption that the trend to outsource activities to PBPS will slow down. In addition, the predicted real value-added of construction in 2023–24 has been reduced by 10 per cent and transferred to manufacturing in recognition of expected increase in the importance of off-site manufacture in construction. The predicted ratios from table E.1 of real output in 2023–24 over the output in 2003–04 are shown in column (3) of table 6.4.

While increased real output will increase the demand for labour, this will be partly offset by improvements in labour productivity. The labour productivity growth rates outlined in chapter 4 (summarised in table D.1 in the appendix) were used to calculate the expected

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[73] Neither are energy issues analysed in Productivity Commission (2005b), but in this case there is no difference in the forecasts to explain.

ratio of LP in 2023–24 compared with 2003–04. These expected ratios are shown in column (4) of table 6.4.

Table 6.4 Calculation of predicted employment shares in 2023–24

	Actual employ ment shares 2003–04	*Predictd output 2024 over 2004*	*LP ratio 2024 over 2004*	*Labour volume 2023–24*	*Predictd employ ment share 2023–24*
	%	ratio	ratio	%	%
Agriculture	4.3	1.96	1.58	5.3	3.5
Mining	1.3	2.61	1.55	2.2	1.4
Manufacturing	12.8	2.01	1.67	15.4	10.1
Electricity, gas, water	0.8	1.63	1.36	1.0	0.6
Construction	9.3	2.06	1.45	13.3	8.7
Wholesale trade	5.1	2.03	1.47	7.0	4.6
Retail trade	12.7	1.92	1.41	17.4	11.4
Accommodation, restaurants	4.5	2.02	1.16	7.8	5.1
Total transport	5.2	2.25	1.35	8.7	5.7
Communication services	1.9	4.54	3.27	2.6	1.7
Finance and insurance	3.7	2.61	1.57	6.2	4.0
Property and business services	11.8	2.33	1.20	22.9	15.0
Government and defence	4.3	1.52	1.00	6.5	4.3
Education	7.2	1.88	1.37	9.9	6.5
Health and community services	9.0	2.36	1.32	16.1	10.6
Cultural and recreational	2.1	1.82	1.17	3.3	2.1
Personal and other services	4.0	2.06	1.17	7.0	4.6
Total employment	100.0			152.5	100.0

Source: ABS Cat. No. 5204.0, 6203.0 and tables D.1 and E.1 in the appendix.

Taking the 2003–04 shares, and multiplying them by the output ratios in column (3) and dividing by the LP ratios in column (4) yields predicted labour volumes in 2023–24. These are shown in column (5). Normalising predicted labour volumes to 100 per cent, yields the predicted employment shares in 2023–24 presented in the last column of table 6.4.

Table 6.5 shows side by side historical employment shares, the predictions from table 6.4 and predicted shares based on sectoral employment growth rates from the MONASH model. Notable differences between the in-house and MONASH predictions include agriculture, finance, property and business services, cultural and recreational services and health care.

These intuitive predictions indicate that in the next 20 years employment shares will increase mainly in PBPS, health care, personal services and accommodation/restaurants. The largest falls in employment shares are expected in manufacturing, agriculture, construction and wholesale/retail trade. The expected rise in the share of PBPS reflects expected continuation of the trend to outsource business activities to outside professional or labour hire firms.

Table 6.5 Distribution of employment between sectors
In terms of total working hours

	Actual	*Actual*	*Predicted*	*Change*	*MONASH*
	1983–84	*2003–04*	*2023–24*	*04–24*	*2023–24*
	%	%	%	%	%
Agriculture	7.3	4.3	3.5	-0.8	4.3
Mining	1.7	1.3	1.4	0.1	1.1
Manufacturing	18.5	12.8	10.1	-2.7	10.8
Electricity, gas, water	2.2	0.8	0.6	-0.2	0.6
Construction	7.1	9.3	8.7	-0.6	9.0
Wholesale trade	6.8	5.1	4.6	-0.5	4.6
Retail trade	12.8	12.7	11.4	-1.3	11.3
Accommodation, restaurants	3.0	4.5	5.1	0.6	4.9
Total transport	5.6	5.2	5.7	0.5	5.1
Communication services	2.2	1.9	1.7	-0.2	2.2
Finance and insurance	3.9	3.7	4.0	0.3	2.9
Property and business	6.3	11.8	15.0	3.2	15.9
Government and defence	4.7	4.3	4.3	0.0	3.5
Education	6.2	7.2	6.5	-0.7	7.1
Health and community	7.2	9.0	10.6	1.6	9.4
Cultural and recreational	1.5	2.1	2.1	0.0	2.8
Personal and other services	3.0	4.0	4.6	0.6	4.5
Total economy	100.0	100.0	100.0	0.0	100.0

Source: Tables 6.4 and C.2 in this report.

The expected strong growth of the health care sector according to the in-house predictions is partly driven by population ageing. More effective treatment of cancer and cardiovascular diseases (see section 3.3.1) may result in a steeper shift of resources to the health care in order to look after an older population. This issue has been discussed at considerable length in Treasury (2002) and Productivity Commission (2005b).

The same type of calculation can be used to derive from 2003–04 value-added figures the predicted sectoral composition of GDP in 2023–24 in current prices. These predictions provide a different perspective on anticipated structural changes in the economy.

In this case it is more appropriate to deflate the forecasted increase in real output by the expected increase in MFP rather than LP, based on the assumption that changes in MFP will be reflected in changes in relative prices (see Jorgenson et al 2002, Bassanini and Scarpetti 2002). The relevant calculations are presented in table E.2 in the appendix.

The results from these calculations are presented in table 6.6. The sectoral gains and losses in shares tend to follow a similar pattern to employment, though usually with smaller changes.

A notable difference occurs in mining whose current price value-added share in GDP is expected to increase much more than its share in national employment. This is a reflection of expected further large investment in mining and higher oil prices than in 2003–04. Notice that there is significant difference between the predicted share of mining between the in-house study and the MONASH model.

Table 6.6 Sectoral value-added composition of nominal GDP
in current prices

	actual 1983–84	actual 2003–04	predicted 2023–24	change 04 to 24	MONASH[a] 2023–24
	%	%	%	%	%
Agriculture	4.8	3.7	2.9	-0.8	3.7
Mining	6.5	4.6	6.9	2.3	4.6
Manufacturing	17.4	11.5	9.1	-2.4	10.5
Electricity, gas and water	3.7	2.4	2.3	-0.1	1.9
Construction	6.5	6.8	5.9	-0.8	6.3
Wholesale trade	8.7	5.9	5.0	-0.9	5.8
Retail trade	6.6	5.9	4.8	-1.1	5.7
Accommodation, restaurants	1.6	2.2	2.2	0.0	2.2
Transport and storage	5.6	5.4	5.8	0.4	5.4
Communication services	2.2	2.9	4.0	1.1	3.8
Finance and insurance	4.7	8.1	9.5	1.4	8.1
Property and business services	6.0	11.5	12.9	1.4	13.2
Government and defence	4.2	4.2	3.4	-0.8	3.8
Education	4.8	4.7	4.0	-0.7	4.7
Health and community services	5.1	6.4	6.9	0.6	6.5
Cultural and recreational service	1.8	1.9	1.7	-0.1	2.2
Personal and other services	1.7	2.5	2.5	0.0	2.4
Ownership of dwellings	8.2	9.5	10.2	0.7	9.2
Total GDP	100.0	100.0	100.0	0.0	100.0

[a] The MONASH shares are calculated using the predicted 'real' output growth rates from the MONASH model.
Source: ABS National Accounts Cat.No. 5204.0 and tables D.1, E.1 and E.2 in the appendix.

Sectors that are expected to record substantial increase in their share in GDP include mining, communications, finance, health and PBPS. Sectors that are predicted to record falling shares include agriculture, manufacturing, construction, trade, government services and education.

6.4 Major conclusions

Section 1.1 raised a number of issues for investigation. It is now possible to provide some brief answers.

The main sources of productivity growth

The report suggests that the main sources will be capital deepening (that is, more capital per worker) combined with technological progress in ICT and to a lesser extent in biotechnology and nanotechnology. Productivity growth will be also strongly influenced by changes in workplace relations, competitive conditions and the social environment.

The effect of population ageing on income per capita

According to Productivity Commission predictions, population ageing will reduce effective labour supply per capita by four percent over the next 20 years. Based on this estimate, the mean prediction of this study suggests that as a result of ageing the annual rate of growth in

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real GDP per capita will be reduced from 1.79 per cent to 1.58 per cent during the forecast period.[74]

The effect of energy related problems on real GDP growth

The value-added of all energy sectors combined (oil, gas, coal and electricity) accounts for around 5.3 per cent of GDP. It is possible that under conditions of tightening oil supplies and the adoption of more stringent greenhouse gas abatement measures, GDP per capita might be reduced by up to 3 per cent by 2024 compared with the level that would prevail in the absence of these problems. Any such fall would be relatively small compared with predicted increase in GDP per capita of between 28 and 44 per cent between 2004 and 2024.

Expected changes in the sectoral composition of the economy

The structural change analysis suggests that over the next 20 years the share in GDP and/or employment of health services, professional and business services, communications and mining will rise. On the other hand, the GDP and employment shares of manufacturing, agriculture, construction, wholesale and retail trade are expected to fall.

6.5 Some policy issues

All told, the predictions in this report suggest that given the current strong momentum of technological progress in ICT, as well as biotechnology, nanotechnology and material science, real GDP per capita will likely to maintain a healthy growth in the next 20 years, despite population ageing and energy related issues. Further micro-economic reform will likely to stimulate economic growth. However, the average rate of growth over the next 20 years will be probably lower than the over two per cent annual growth rates in GDP per capita recorded in the last decade.

While policy issues are outside the scope of this report, it should be noted that in order to realise the predicted productivity benefits it will be necessary to support an appropriate level of investment in skill formation and in ICT related R&D. Tumbling international ICT prices are not sufficient by themselves to ensure strong economic growth. The introduction of new ICT technologies involves an extensive learning process that creates significant knowledge and innovation related externalities, which are reflected mainly in MFP growth[75]. More information on this subject can be found in section 3.2.11 and in section B.5 in the appendix.

[74] In a similar vein, McDonald (2004) concludes that an ageing population is not a threat to living standards given expected large increases in productivity. The main economic problem is expected to be increasing burden on the public purse due to escalating demand for expensive new medical technologies. McDonald (2004) notes that the resolution of that problem rests with government.

[75] Network externalities are also important in the ICT area. The addition of a new user to a digital telecommunications network may benefit some existing users who do not have to pay for that benefit.

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A Time-series of real GDP per capita

Table A.1 Real GDP per capita 1949–50 to 2003–04

In constant 2002–03 prices

Year ended June	*Population at 30th June*	*GDP per capita in 2002–03 prices*	*Annual growth in real GDP per capita*
	in 000s	$ 000s	%
1950	8179	13.05	
1951	8422	13.44	3.03
1952	8637	13.47	0.17
1953	8815	13.08	-2.87
1954	8987	13.64	4.24
1955	9200	14.10	3.41
1956	9426	14.43	2.31
1957	9640	14.38	-0.29
1958	9842	14.38	-0.01
1959	10056	15.11	5.05
1960	10275	15.61	3.31
1961	10508	15.67	0.38
1962	10701	15.60	-0.46
1963	10907	16.26	4.22
1964	11122	17.09	5.10
1965	11341	17.77	4.01
1966	11599	17.78	0.03
1967	11799	18.61	4.71
1968	12009	19.21	3.22
1969	12263	20.12	4.75
1970	12507	21.15	5.10
1971	13067	21.02	-0.60
1972	13304	21.46	2.08
1973	13505	21.77	1.44
1974	13723	22.35	2.68
1975	13893	22.30	-0.24
1976	14033	22.70	1.80
1977	14192	23.22	2.29
1978	14359	23.18	-0.19
1979	14516	23.90	3.14
1980	14695	24.37	1.97
1981	14923	24.78	1.69
1982	15184	25.11	1.33
1983	15393	24.19	-3.68
1984	15579	25.04	3.52
1985	15788	26.02	3.90
1986	16018	26.75	2.80
1987	16264	26.96	0.81
1988	16532	27.95	3.65
1989	16814	28.58	2.28

Year ended June	*Population at 30th June*	*GDP per capita in 2002-03 prices*	*Annual growth in real GDP per capita*
1990	17065	29.22	2.22
1991	17284	28.82	-1.37
1993	17656	29.32	2.67
1994	17838	30.15	2.84
1995	18054	31.04	2.97
1996	18311	31.89	2.72
1997	18518	32.73	2.64
1998	18711	33.85	3.42
1999	18926	35.24	4.11
2000	19153	36.14	2.57
2001	19413	36.37	0.63
2002	19641	37.35	2.70
2003	19881	38.03	1.82
2004	20130	38.93	2.35

Source: Foster (1996), ABS Cat. No. 5204.0.

Table A.2 Comparison of average real GDP per capita growth rates in prior 10 years and posterior 20 years

Year ended June	*Average annual growth rate prior 10 years*	*Average annual growth rate posterior 20 years*	*Ratio of growth rates in posterior over prior years*
	%	%	
1960	1.81	2.25	1.25
1961	1.54	2.32	1.50
1962	1.48	2.41	1.63
1963	2.20	2.01	0.91
1964	2.28	1.93	0.85
1965	2.34	1.92	0.82
1966	2.11	2.06	0.98
1967	2.61	1.87	0.72
1968	2.94	1.89	0.64
1969	2.91	1.77	0.61
1970	3.08	1.63	0.53
1971	2.98	1.59	0.53
1972	3.24	1.44	0.44
1973	2.96	1.50	0.51
1974	2.72	1.51	0.55
1975	2.30	1.67	0.73
1976	2.48	1.71	0.69
1977	2.24	1.73	0.77
1978	1.89	1.91	1.01
1979	1.74	1.96	1.13
1980	1.43	1.99	1.39
1981	1.66	1.94	1.17
1982	1.58	2.00	1.27
1983	1.06	2.29	2.16
1984	1.14	2.23	1.95

Source: Table A.1.

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B The theory and measurement of productivity growth

B.1 Key concepts

The following discussion briefly explains some key concepts to readers who are not familiar with economic growth models. To understand the discussion a basic knowledge of calculus is required. The interested reader can find more detailed methodological discussion on the measurement of labour and multifactor productivity in Productivity Commission (1999), Parham et al (2001) and Carlaw and Lipsey (2003).

The widely used economic growth equation (Solow 1957) has the form:

$$Y(t) = A(t)*f(K(t), L(t)) \tag{B.1}$$

where

Y(t) is the level of real output (of the economy or an industry) in year t,

K is net capital stock,

L is the level of employment,

f represents a constant return to scale aggregate production function, where the factors of production are K and L.

A(t) is the multifactor productivity (MFP) term, representing the combined effect of technological progress, capacity utilisation and various economic-institutional factors on output. Note, all the arguments in eq. (B.1) are time dependent.

L is measured in terms of the number of persons employed (or working hours). In this paper working hours are used.

K is valued in terms of constant prices. It is calculated by using the ‘perpetual inventory’ method, which involves accumulating new purchases of capital goods over time and taking away depreciation, using estimated aggregate asset lives. Some methodological problems related to quality-adjusted constant price indexation of capital stocks are discussed in section 2.3 in the text and in section B.4 in this appendix.

Y is measured at the national level by GDP. At the sectoral level it is measured by the value-added volume indices discussed in section 2.2.

B.2 The mathematical framework

Given a first degree homogeneous (constant return to scale) production function and competitive market clearing conditions, the following equation can be derived from eq. (B.1) (Solow 1957, Carlaw and Lipsey 2003):

$$\frac{d\log(A)}{dt} = \frac{d\log(Y)}{dt} - \left[s_k \frac{d\log(K)}{dt} + s_L \frac{d\log(L)}{dt} \right] \tag{B.2}$$

where dlog/dt represent logarithmic differentials, which for small changes are approximately equal to percentage changes. In ‘growth accounting’ studies, S_k and S_L represent the share of capital and labour income from total income (the same as total output or value-added). The assumptions of constant return to scale and competitive market clearing conditions ensure that S_k and S_L add up to one. In econometric production function models, S_k and S_L represent output elasticities estimated from regression results and do not necessarily add up to one.

It is evident from eq. (B.2) that change in multifactor productivity defines the portion of output growth that cannot be explained by changes in labour and capital.[76] This residual term is determined mainly by technological progress and changes in economic-institutional factors.[77]

After some algebraic rearrangements, eq. (B.2) can be put as:

$$\frac{d\log(A)}{dt} = \left[\frac{d\log(Y)}{dt} - \frac{d\log(L)}{dt}\right] - \left[S_k\frac{d\log(K)}{dt} - S_k\frac{d\log(L)}{dt}\right]$$
$$= \frac{d\log}{dt}\left(\frac{Y}{L}\right) - S_k\frac{d\log}{dt}\left(\frac{K}{L}\right) \qquad \text{(B.3)}$$

where $\frac{d\log}{dt}\left(\frac{Y}{L}\right)$ is the logarithmic change in LP and $\frac{d\log}{dt}\left(\frac{K}{L}\right)$ is the logarithmic change in the capital-labour ratio (capital deepening). Given that small logarithmic differentials are almost identical to percentage changes, eq. (B.3) indicates that change in MFP is the change in LP minus the contribution to growth of change in the capital-labour ratio. This definition is used in eq. (1.1) in section 1.2.

B.3 Possible generalisations

On a more general level than the two-factor production framework, output can be defined as:

$Y(t) = A(x_1 \ldots x_n, t) * f(K_1 \ldots K_h, L_1 \ldots L_m, t)$ (B.4)

where f is a first degree homogeneous function.

$x_1 \ldots x_n$ represent n variables determining MFP growth, such as domestic and overseas R&D, learning-by-doing, capacity utilisation and the like. $K_1 \ldots K_h$ represent h different forms of capital (machinery and equipment, structures, land, transport equipment, ICT equipment, software, etc.). $L_1 \ldots L_m$ represent m different forms of labour (skilled, unskilled, tradesmen, farmers, clerks, etc.).

In theory, more disaggregation can enable more detailed analysis of the factors driving productivity growth. In practice, there are serious methodological and measurement

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76 According to the underlying algebraic definition, MFP is output divided by total inputs.

77 In the short-run, changes in capacity utilisation could also have a significant effect on MFP growth. Other potentially influential factors include changes in economies of scale or in the terms of foreign trade.

difficulties involved in attributing economic growth to various factors (see NOIE 2004 and DCITA 2005a and 2005b).

B.4 Measuring capital deepening

The change in the capital-labour ratio (represented by $\frac{d\log}{dt}\left(\frac{K}{L}\right)$ in eq B.3) is referred to in the literature as capital deepening. In the Australian national accounts (as well as those of other OECD countries) the valuation of capital stocks is based on detailed quality-adjusted (hedonic) volume indexation rather then on the depreciated monetary value of capital discounted by a general price deflator. The 'hedonic' indexation approach to the valuation of constant price capital stocks raises some difficult conceptual problems when labour productivity growth is allocated between MFP growth and capital deepening, using eq. (B.3).

The prices of capital goods that benefited from significant technological progress will tend to fall relative to the prices of other goods (that is, the general GDP price deflator). Consequently, higher capital-labour ratios of some capital categories will reflect, apart from increased investment, also the effect of falling relative prices. The falling relative price effect is particularly marked for ICT equipment, which benefited from phenomenal price reductions in recent decades.

DCITA (2005a) estimates that tumbling ICT prices accounted for 31 per cent of capital deepening in service industries between 1984–85 and 2001–02 and for 27 per cent in manufacturing between 1984–85 and 2000–01. These estimates are based on figures from Parham et al (2001), Collecchia and Schreyer (2001) and Bassanini and Scarpetta (2002).

The fact that a portion of what is defined in this paper as 'capital deepening' represents the effect of technological progress rather than investment per se, has some important implications that should be borne in mind when examining the MFP and capital deepening forecasts in chapters 4 and 6. First, higher capital-labour ratio is not driven exclusively by increased investment. Second, the impact of technological progress is not confined entirely to MFP growth but some of it is reflected in capital deepening. Under conditions of factor-neutral technological change, the MFP term in eq. (B.1) (that is, the A(t) term) is supposed to measure the full effect of technological progress on productivity growth. But given the way MFP and capital deepening are calculated in the national accounts this is not the case.

B.5 A few notes on growth theories

A number of theoretical explanations have been put forward about what is driving MFP growth. Generally, most explanations attribute changes in MFP in the long-run to the adoption of more advanced technologies and associated changes in work practices and organisations. In the short-run, cyclical factor and changes in the institutional-economic environment may have an important role to play.

Endogenous growth theories draw attention to the fact that technological progress depends on economic incentives and that only part of technological knowledge used by a country (or industry) is available to all through open publications and free trade in capital goods. Some other technological knowledge is not freely accessible but can be acquired through internal R&D or production experience.[78] Moreover, the utilisation of all technological knowledge (both public and tacit) depends on the level of human capital in the economy. R&D expenditure and investment in human capital are specified as decision variables in some growth model.

Another strand of growth models emphasise the importance of learning-by-doing in industrial development, given that much of the tacit technological knowledge used by industry is acquired inside the firm rather than from open information. The interested reader can find good surveys on endogenous growth models and the learning-by-doing aspects of industrial development in Aghion and Howitt (1998), Bureau of Industry Economics (1992), DeLong and Summers (1991 and 1992), Industry Commission (1995) and Nelson (1990).

[78] Internal R&D often involves the development of state-of-the-art product-specific machinery and software that is not sold on the open market. The limited transfer of such machinery and software to non-affiliated enterprises is usually carried out through licensing agreements (see Nelson 1990 and Caves 1996).

C Detailed sectoral forecasts from the MONASH model

C.1 Assumptions for changes in technology and tastes

The MONASH forecasts rest on modelling assumptions based on the observation of recent trends. The numbers in columns (3) to (5) of Table C.1 summarise the assumptions concerning changes in technologies and consumer tastes in the 114 product groups covered in the model. These are extrapolations of trends calculated from a MONASH simulation for a recent historical period.

The numbers in column (3) are CoPS assumptions for the average annual rates of change in the absorption of commodities as intermediate inputs per unit of production in industries. For example, in each year of the forecast period industries increase their intermediate inputs of electronic equipment (commodity 75) by 2.3 per cent more than their outputs. This represents the increasing penetration of ICT into all production activities.

The numbers in column (4) are CoPS assumptions for household tastes (or preferences). Changes in preferences are changes in household usages of commodities and services not explained by changes in prices or incomes. For example, it is assumed that consumption of Insurance (104) will increase at a rate 4.0 per cent a year faster than can be explained on the basis of changes in prices and changes in the average budget of households.

The numbers in column (5) are CoPS assumptions about the annual rate of change in the usage of primary factors (labour, capital and agricultural land) per unit of output in each sector. For example, the number for Communications (100) means that in each year the communications industry is expected to use 4.0 per cent less primary factors per unit of output. Change in the usage of primary factors per unit output represents MFP growth in the MONASH model.

C.2 Forecasts of industry output, employment and capital

The core results of a MONASH simulation include detailed forecasts of output and employment by industry. Table C.2 shows the forecasts for 112 industries covered in the model. More aggregated sectoral forecasts from MONASH are discussed in chapter 4.

In order to facilitate the study of tables C.1 and C.2 the industries are grouped in line with the broader sectoral classification followed in chapter 4. The sectoral groups are marked with bold letters.

Notice that MONASH presents output and employment rate of growth predictions (which by subtraction yield LP growth) also for non-market sectors, including health, education and government services.

In the MONASH forecasts reported in this paper there is no distinction between the number of people employed and working hours. Consequently, no predictions are made in respect to changes in average weekly working hours or the ratio of part-time to full-time employees.

Table C.1 Assumptions for Tariffs, Technology and Tastes

Average annual percentage changes, 2003 to 2024

Code	Commodity	Inputs to: production(a)	Inputs to: consumption(b)	Primary factors in production(c)
		%	%	%
	Agriculture, Forestry and Fishing			
1	Wool	-0.1	-0.4	-1.0
2	Sheep	-1.1	1.2	-1.0
3	Wheat	-0.5	-0.3	-1.4
4	Barley	2.7	12.2	-1.4
5	Other coarse grains	0.7	1.4	-0.9
6	Meat cattle	-0.9	0.7	-0.6
7	Milk Cattle and Pigs	-0.1	0.2	-1.6
8	Other Farming Export	-1.1	-1.0	-1.1
9	Other Farming Import	-0.2	0.6	-1.5
10	Poultry	0.8	0.7	-3.4
11	Services to Agriculture	-0.4	-1.3	-0.1
12	Forestry and Logging	0.6	-0.6	-0.1
13	Fishing and Hunting	-0.9	0.7	-2.9
	Mining			
14	Ferrous Metal Ores	-1.3	-0.9	-5.2
15	Non-Ferrous Metal Ores	-3.7	-0.7	-4.0
16	Black Coal	-1.8	-2.6	-0.1
17	Crude oil, gas and brown coal	-0.2	-0.9	-0.1
18	Other Minerals	0.1	1.3	-0.3
19	Services to Mining nec	-3.5	-2.9	-0.1
	Processed food and beverages			
20	Meat Products	0.8	1.2	-1.0
21	Milk Products	0.2	0.7	-2.8
22	Fruit and Vegetable Prods	-0.4	2.7	-4.8
23	Margarine, Oils, Fats nec	-3.2	-1.9	-0.1
24	Flour and Cereal Products	0.0	0.7	-0.1
25	Bread Cakes and Biscuits	-0.7	-1.6	-0.1
26	Confectionery and Cocoa	-0.5	-1.4	-0.3
27	Other Food Products	-1.5	0.9	-0.9
28	Soft Drinks, Cordials	-0.8	1.0	-0.1
29	Beer and Malt	-1.1	-1.5	-0.1
30	Other Alcoholic Drinks	-0.6	-1.1	-0.1
31	Tobacco Products	-0.9	-2.9	-0.1

Table C.1 continued

Code	Commodity	Inputs to: production(a)	Inputs to: consumption(b)	Primary factors in production(c)
		%	%	%
	Textiles, Clothing and Footwear			
32	Cotton Ginning, etc.	-0.4	11.4	-1.5
33	Man-Made Fibre, Yarns	0.6	2.1	-0.9
34	Cotton Yarns, Fabrics	-1.3	-0.5	-1.0
35	Wool, Worsted Fabrics	-2.9	-2.3	-0.1
36	Textile Finishing	-0.6	0.0	-0.5
37	Textile Floor Coverings	-1.7	-4.8	-2.4
38	Other Textile Products	-1.0	0.1	-1.6
39	Knitting Mills	-2.4	-2.1	-0.9
40	Clothing	-0.5	-1.9	-2.1
41	Footwear	-0.6	-2.1	-0.9
	Wood and Paper			
42	Sawmill Products	-3.0	-4.4	-0.1
43	Veneers and Wood Boards	0.6	3.8	-0.1
44	Joinery and Wood Products	-1.5	-2.2	-0.1
45	Furniture and Mattresses	2.3	-0.5	-0.1
46	Pulp, Paper, Paperboard	-0.4	1.3	-0.3
47	Bags and Containers	-0.6	13.1	-1.2
48	Paper Products nec	-4.1	5.5	-0.8
	Printing and Publishing			
49	Newspapers and Books	-3.1	-1.7	-0.1
50	Commercial Printing	0.7	3.1	-0.1
	Petroleum Refining and Chemicals			
51	Chemical Fertilisers	0.1	2.7	-0.1
52	Other Basic Chemicals	1.4	5.5	-0.1
53	Paints and Varnishes	-0.1	2.3	-0.2
54	Pharmaceutical Goods	2.3	3.3	-0.1
55	Soap and Detergents	-4.2	-1.3	-0.1
56	Cosmetics and Toiletries	-4.2	0.6	-0.8
57	Other Chemical Goods	2.1	7.1	-0.5
58	Petrol and Coal Products	-0.5	-1.9	-0.1
	Non-metallic Mineral Processing			
59	Glass and Glass Products	-0.6	-2.4	-0.2
60	Clay Products, Refractories	-0.7	-3.0	-0.1
61	Cement	-1.5	0.1	-0.4
62	Ready Mixed Concrete	-0.6	-0.7	-1.3
63	Concrete Products	-0.3	-2.1	-1.1
64	Non-Metallic Mineral Prods	1.4	4.5	-1.9
	Metal Smelting			
65	Basic Iron and Steel	0.6	3.7	-1.1
66	Non-Ferrous Metals	1.3	4.7	-1.9

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Table C.1 continued

Code	Commodity	Inputs to: production(a)	Inputs to: consumption(b)	Primary factors in production(c)
		%	%	%
	Simple Metal Fabrications			
67	Structural Metal Products	1.0	-0.5	-0.1
68	Sheet Metal Products	-2.7	-5.4	-0.4
69	Other Metal Products	1.2	-0.1	-0.1
	Transport Equipment			
70	Motor Vehicles and Parts	1.6	0.7	-0.4
71	Ships and Boats	-0.1	-1.6	-3.0
72	Railway Rolling-stock	-4.0	-4.3	-2.8
73	Aircraft	-1.3	0.3	-3.8
	Electrical and Electronics			
74	Scientific Equipment	2.5	4.0	-2.7
75	Electronic Equipment	2.3	4.3	-1.8
76	Household Appliances	2.5	-2.5	-2.2
77	Other Electrical Goods	0.7	-4.1	-2.1
	Production Equipment			
78	Agricultural Machinery	1.8	3.6	-0.1
79	Construction Machinery	1.9	1.3	-0.1
80	Other Machinery	1.2	1.0	-0.1
	Other Manufacturing			
81	Leather Products	-1.2	-2.6	-0.1
82	Rubber Products	0.4	2.4	-0.4
83	Plastic Products	-0.8	0.6	-0.1
84	Signs, Writing Equipment	-3.5	-1.2	-0.1
85	Other Manufacturing	-2.9	-2.3	-0.1
	Electricity, Gas and Water			
86	Electricity	-0.5	0.0	-3.0
87	Gas	-0.6	0.0	-2.1
88	Water, Sewerage, Drainage	-0.5	0.0	-1.9
	Construction			
89	Residential Building	0.0	4.4	-0.1
90	Other Construction	-0.4	4.4	-0.1
91	**Wholesale Trade**	-1.4	-3.0	-0.1
	Retail Trade and Repairs			
92	Retail Trade	-0.3	-2.3	-0.2
93	Mechanical Repairs	-2.6	-2.0	-0.1
94	Other Repairs	-2.2	-2.7	-0.1
	Transport and Storage			
95	Road Transport	0.2	-1.2	-0.7
96	Rail and Other Transport	0.0	-2.0	-4.8
97	Water Transport	-3.8	-4.4	-1.0
98	Air Transport	-2.1	1.2	-3.5
99	Services to Transport	0.1	-0.2	-0.1
100	**Communication**	1.7	0.0	-4.0

Table C.1 continued

Code	Commodity	Inputs to: production(a)	Inputs to: consumption(b)	Primary factors in production(c)
		%	%	%
	Finance and Insurance			
101	Banking	0.1	0.1	-3.1
102	Non-Bank Finance	0.1	2.3	-4.5
103	Investment and Services	0.0	1.7	-3.1
104	Insurance	-0.3	4.0	-2.7
105	**Other Business Services**	1.9	0.2	-0.1
106	**Ownership of Dwellings**	-0.9	0.1	0.0
	Government Services			
107	Public Administration	-0.8	-1.3	-0.2
108	Defence	-0.9	-0.8	-1.2
109	Health	-0.8	0.2	-0.4
110	Education, Libraries	-0.7	0.7	-0.4
111	Welfare Services	-0.7	-1.0	-0.1
112	**Entertainment, Leisure**	0.6	1.2	-0.1
113	**Restaurants, Hotels**	-1.1	-1.1	-0.1
114	**Personal Services**	-0.8	0.0	-0.1

(a) Annual rate of change of use per unit of output of industries using the commodity.

(b) Annual rate of shift of consumption function.

(c) Exogenously imposed annual rate of change of use of primary factors per unit of production of industry. Subject to change in sign, this is closely related to the concept of MFP growth used elsewhere in this report.

Table C.2 Forecasts for Industry Ouput, Employment and Capital

Average annual percentage changes, 2003 to 2024

	Industry	*Production*	*Employment*	*Capital*
		%	%	%
	Agriculture, Forestry, Fishing			
1	Pastoral zone	2.9	1.5	-1.7
2	Wheat-sheep zone	3.0	1.3	-1.7
3	High rainfall zone	2.9	1.5	-1.0
4	Northern beef	3.4	2.3	-1.1
5	Milk Cattle and Pigs	3.7	1.9	-1.8
6	Other Farming Export	3.1	1.6	-1.9
7	Other Farming Import	3.7	2.0	-1.7
8	Poultry	2.6	0.5	-2.3
9	Services to Agriculture	3.3	2.2	-1.2
10	Forestry and Logging	2.5	0.6	0.5
11	Fishing and Hunting	1.2	-0.9	-3.1
	Mining			
12	Ferrous Metal Ores	2.6	0.0	-2.0
13	Non-Ferrous Metal Ores	3.5	1.2	0.8
14	Black Coal	2.3	0.4	0.6
15	Crude oil, gas and brown coal	2.9	-0.9	2.5
16	Other Minerals	4.9	2.6	3.3
17	Services to Mining nec	-0.9	-3.2	-1.5
	Processed Food and Beverages			
18	Meat Products	2.6	0.9	-0.4
19	Milk Products	2.8	0.9	-0.9
20	Fruit and Vegetable Prods	2.4	0.5	-1.8
21	Margarine, Oils, Fats nec	2.6	1.2	-2.3
22	Flour and Cereal Products	4.2	2.5	1.7
23	Bread Cakes and Biscuits	0.2	-1.6	-2.2
24	Confectionery and Cocoa	1.9	0.0	-2.1
25	Other Food Products	1.9	0.0	-1.4
26	Soft Drinks, Cordials	2.4	0.8	0.8
27	Beer and Malt	1.2	-0.5	-1.3
28	Other Alcoholic Drinks	4.4	2.9	2.0
29	Tobacco Products	-0.6	-2.6	-3.4
	Textiles, Clothing and Footwear			
30	Cotton Ginning, etc.	2.7	0.2	-2.9
31	Man-Made Fibre, Yarns	1.3	-0.9	-1.3
32	Cotton Yarns, Fabrics	2.4	0.3	-0.4
33	Wool, Worsted Fabrics	-0.4	-2.8	-3.5
34	Textile Finishing	0.6	-2.0	-2.2
35	Textile Floor Coverings	-1.0	-3.5	-3.2
36	Other Textile Products	1.6	-0.6	-0.5
37	Knitting Mills	-0.3	-2.8	-3.4
38	Clothing	-0.2	-2.9	-2.3
39	Footwear	-2.4	-5.0	-4.1

Table C.2 continued

	Industry	*Production*	*Employment*	*Capital*
		%	%	%
	Wood and Paper			
40	Sawmill Products	0.5	-0.6	-1.8
41	Veneers and Wood Boards	2.6	1.4	0.2
42	Joinery and Wood Products	0.9	-0.2	-0.8
43	Furniture and Mattresses	1.4	0.7	-0.8
44	Pulp, Paper, Paperboard	1.0	1.2	0.5
45	Bags and Containers	2.1	1.5	1.5
46	Paper Products nec	2.0	1.5	1.7
	Printing and Publishing			
47	Newspapers and Books	1.1	-0.5	0.7
48	Commercial Printing	2.4	0.7	2.3
	Petroleum Refining and Chemicals			
49	Chemical Fertilisers	-1.0	-2.8	-3.3
50	Other Basic Chemicals	3.3	2.1	0.4
51	Paints and Varnishes	2.6	0.9	0.6
52	Pharmaceutical Goods	2.9	1.2	0.7
53	Soap and Detergents	1.3	-0.3	-1.1
54	Cosmetics and Toiletries	1.3	-0.6	-1.4
55	Other Chemical Goods	3.1	1.5	1.0
56	Petrol and Coal Products	1.9	0.3	0.7
	Non-metallic Mineral Products			
57	Glass and Glass Products	1.8	-0.4	-1.0
58	Clay Products, Refractories	1.0	-1.3	-1.1
59	Cement	1.1	-1.2	-0.9
60	Ready Mixed Concrete	2.2	0.0	-0.8
61	Concrete Products	2.5	0.3	-0.7
62	Non-Metallic Mineral Prods	2.4	0.1	-0.4
	Metal Smelting			
63	Basic Iron and Steel	2.6	0.1	-1.1
64	Non-Ferrous Metals	3.9	1.6	-0.9
	Simply Fabricated Metal Products			
65	Structural Metal Products	3.5	1.1	-0.1
66	Sheet Metal Products	4.5	2.0	-1.3
67	Other Metal Products	2.4	-0.1	-1.2
	Transport Equipment			
68	Motor Vehicles and Parts	1.7	-0.2	0.8
69	Ships and Boats	3.2	1.2	0.4
70	Railway Rolling-stock	0.0	-1.9	-1.5
71	Aircraft	2.8	0.7	0.4
	Electrical and Electronics			
72	Scientific Equipment	3.1	1.0	-1.1
73	Electronic Equipment	6.2	4.1	1.5
74	Household Appliances	2.2	0.1	-1.7
75	Other Electrical Goods	3.1	1.0	-1.6

Table C.2 continued

	Industry	*Production*	*Employment*	*Capital*
		%	%	%
	Production Equipment			
76	Agricultural Machinery	2.5	0.5	-1.7
77	Construction Machinery	4.0	2.0	-2.1
78	Other Machinery	2.8	0.8	-1.3
	Other Manufacturing			
79	Leather Products	4.6	2.3	-0.2
80	Rubber Products	1.6	-1.0	-1.8
81	Plastic Products	2.0	-0.6	-1.0
82	Signs, Writing Equipment	1.0	-1.1	-1.2
83	Other Manufacturing	2.5	0.4	-0.8
	Electricity, Gas and Water (EGW)			
84	Electricity	1.7	0.0	-0.5
85	Gas	1.7	-0.2	0.0
86	Water, Sewerage, Drainage	2.3	0.2	0.6
	Construction			
87	Residential Building	1.8	0.5	0.9
88	Other Construction	3.0	1.7	1.4
89	**Wholesale Trade**	2.9	1.0	0.5
	Retail Trade and Repairs			
90	Retail Trade	3.1	1.2	0.7
91	Mechanical Repairs	1.3	-0.5	-0.7
92	Other Repairs	1.2	-0.7	-0.8
	Transport and Storage			
93	Road Transport	2.9	1.3	1.9
94	Rail and Other Transport	2.3	-0.4	-1.2
95	Water Transport	2.0	1.1	0.7
96	Air Transport	3.1	1.6	0.9
97	Services to Transport	3.2	1.8	1.8
98	**Communication**	4.4	2.2	1.9
	Finance and Insurance			
99	Banking	2.9	0.6	1.8
100	Non-Bank Finance	3.1	-0.8	1.3
101	Investment and Services	3.1	1.1	2.5
102	Insurance	3.1	-0.7	1.8
103	**Other Business Services**	3.7	3.0	2.4
104	**Ownership of Dwellings**	2.8	-0.8	2.8
	Government Services			
105	Public Administration	2.5	0.5	0.7
106	Defence	1.9	-0.2	2.7
107	Health	3.0	1.6	1.9
108	Education, Libraries	3.0	1.4	0.7
109	Welfare Services	3.3	1.9	1.9
110	**Entertainment, Leisure**	3.7	2.9	1.9
111	**Restaurants, Hotels**	2.9	1.9	2.0
112	**Personal Services**	2.9	2.1	3.8

D Summaries of predictions used in this report

D.1 Mean predictions: annual growth rates 2004 to 2024

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
Agriculture	2.3	1.4	0.9	1.3
Mining	2.2	-0.4	2.6	3.1
Manufacturing	2.6	1.5	1.1	2.4
Electricity, gas, water	1.5	-0.5	2.1	2.7
Construction	1.9	1.1	0.8	2.0
Wholesale trade	1.9	1.2	0.7	2.3
Retail trade	1.7	1.1	0.6	2.8
Accommodation and restaurants	0.7	0.4	0.4	1.3
Transport and storage	1.5	0.5	1.0	2.4
Communication services	6.1	2.7	3.3	5.3
Finance and insurance	2.3	0.8	1.4	2.4
Cultural and recreational	0.8	0.2	0.6	1.4
Market sector mean	**2.2**	**1.0**	**1.2**	**2.5**
Property and business services	0.9			
Government services	0.0[a]			
Education	1.6			
Health and community services	1.4			
Personal and other services	0.8			
Imputed rent on dwellings	1.6			
Overall mean	**1.78**			

[a] LP growth is set to zero in government services because according to national accounts conventions real output in this sector is proportional to labour inputs, hence by definition LP growth is zero.

D.2 Optimistic predictions: annual growth rates 2004 to 2024

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
Agriculture	3.1	1.7	1.3	1.9
Mining	3.0	0.3	2.7	3.3
Manufacturing	3.5	1.9	1.6	3.3
Electricity, gas, water	2.8	0.4	2.4	3.1
Construction	2.2	1.3	0.9	2.4
Wholesale trade	2.4	1.5	0.9	2.8
Retail trade	2.0	1.4	0.6	3.0
Accommodation and restaurants	1.0	0.5	0.5	1.6
Transport and storage	2.1	0.7	1.4	3.2
Communication services	7.4	3.1	4.1	6.5
Finance and insurance	2.7	0.6	2.0	3.3
Cultural and recreational	1.6	0.3	1.3	2.7
Market sector mean	**2.8**	**1.2**	**1.5**	**3.1**
Property and business services	1.3			
Government services	0.0			
Education	2.0			
Health and community services	1.7			
Personal and other services	1.1			
Imputed rent on dwellings	2.0			
Overall mean	**2.30**			

D.3 Pessimistic predictions: annual growth rates 2004 to 2024

	LP growth	*MFP growth*	*Due to capital deepn'g*	*Capital deepn'g*
	%	%	%	%
Agriculture	1.1	0.6	0.4	0.6
Mining	0.8	-0.6	1.4	1.8
Manufacturing	1.7	1.0	0.7	1.5
Electricity, gas, water	0.2	-1.3	1.5	2.0
Construction	1.3	0.8	0.5	1.4
Wholesale trade	1.3	0.7	0.6	1.8
Retail trade	1.1	0.7	0.4	1.9
Accommodation and restaurants	0.5	0.2	0.2	0.9
Transport and storage	0.3	-0.3	0.5	1.4
Communication services	5.2	2.0	3.1	5.1
Finance and insurance	1.7	0.4	1.3	2.1
Cultural and recreational	0.4	0.0	0.4	0.9
Market sector mean	**1.3**	**0.5**	**0.8**	**1.8**
Property and business services	0.6			
Government services	0.0			
Education	1.2			
Health and community services	1.0			
Personal and other services	0.5			
Imputed rent on dwellings	1.3			
Overall mean	**1.15**			

E Predictions of structural change

Table E.1 Predicted output in 2023–24 over the base level in 2003–04

	Actual output 2003–04 over 1983–84	*Predicted output 2023–24 over 2003–04*
	%	%
Agriculture	1.50	1.96
Mining	2.46	2.61
Manufacturing	1.53	2.01
Electricity, gas, water	1.63	1.63
Construction	2.16	2.06
Wholesale trade	2.03	2.03
Retail trade	1.92	1.92
Accommodation, restaurants	2.02	2.02
Total transport	2.25	2.25
Communication services	4.54	4.54
Finance and insurance	2.74	2.61
Property and business services	3.00	2.33
Government and defence	1.69	1.52
Education	1.66	1.88
Health and community services	2.25	2.36
Cultural and recreational	1.82	1.82
Personal and other services	1.89	2.06
Imputed rent on dwellings	2.04	2.04
Total (GDP)	2.07	2.07

Table E.2 Calculation of predicted sectoral shares in GDP in 2023–24

In current prices

	Actual value-added shares 2003–04	*Output ratio 2024 Over 2004*	*MFP ratio 2024 over 2004*	*Output volume 2023–24*	*Predictd value-added shares 2023–24*
	%			%	%
Agriculture	3.7	1.96	1.32	5.4	2.9
Mining	4.6	2.61	0.93	13.1	6.9
Manufacturing	11.5	2.01	1.35	17.2	9.1
Electricity, gas, water	2.4	1.63	0.90	4.3	2.3
Construction	6.8	2.06	1.24	11.2	5.9
Wholesale trade	5.9	2.03	1.27	9.4	5.0
Retail trade	5.9	1.92	1.25	9.1	4.8
Accommodation, restaurants	2.2	2.02	1.08	4.2	2.2
Total transport	5.4	2.25	1.11	10.9	5.8
Communication services	2.9	4.54	1.72	7.6	4.0
Finance and insurance	8.1	2.61	1.18	17.9	9.5
Property and business services	11.5	2.33	1.10[a]	24.4	12.9
Government and defence	4.2	1.52	1.00	6.4	3.4
Education	4.7	1.88	1.17[a]	7.6	4.0
Health and community services	6.4	2.36	1.15[a]	13.1	6.9
Cultural and recreational	1.9	1.82	1.04	3.3	1.7
Personal and other services	2.5	2.06	1.08[a]	4.7	2.5
Imputed rent on dwellings	9.5	2.04	1.00	19.4	10.2
Total (GDP)	100.0			189.1	100.0

[a] MFP ratios in non-market sectors are calculated on the assumption that MFP growth amounts to half the MONASH predicted LP growth rates. The exception is imputed rent on dwellings where only capital deepening occurs, therefore MFP growth is zero.

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References

Abt, C. C. 2003, 'The future of energy from the perspective of the social sciences' in Cooper, R. N and Layard, R. (Eds) 2003, *What the Future Holds: Insights from Social Science,* MIT Press, pp. 77–122.

Access Economics 2003, *The Economic Impact of an Accelerated Rollout of Broadband in Hospitals*, *http://www2.dcita.gov.au/__data/assets/file/11821/Broadband_in_Hospitals.pdf*

Aghion, P. and Howitt, P. 1998, *Endogenous Growth Theory,* The MIT Press, Cambridge, Massachusetts.

Akmal, M., Thorpe, S., Dickson, A., Burg, G., and Klijn, N. 2004, *Australian Energy: National and State Projections to 2019–20,* Australian Bureau of Agricultural and Resource Economics (ABARE) eReport 04.11, Prepared for the Australian Government Department of Industry, Tourism and Resources, Canberra.

AMP.NATSEM 2004, *Income and Wealth Report Issue 8,* September 2004, National Centre for Social and Economic Modelling Pty. Ltd., Canberra.

Australian Bureau of Statistics (ABS) 2000, *Australian System of National Accounts, Concepts, Sources and Methods,* Cat. No. 5216.0.

—— 2003, *Population Projections Australia*, Cat. No. 3222.0,

—— 2004a, *Australian National Accounts: Input–Output Tables 1998–99*, Cat. No. 5209.0.55.001, Electronic Publication.

—— 2004b *Year Book Australia*, Cat. No. 1301.0.

—— yearly, *Australian System of National Accounts*, Cat. No. 5204.0.

—— yearly, *Labour Force Australia,* Cat. No. 6203.0, time series from ABS SuperTable.

—— yearly, *Research and Experimental Development: Business Australia*, Cat. No. 8104.0.

—— yearly, *Mining Operations,* Cat. No. 8415.0.

Australian Communications Authority 2005, *Vision 20/20: Future Scenarios for the Communications Industry – Implications for Regulations,* Final Report, Canberra.

Australian National Security Review (2004), 'ICT security obsolete in next five years, say experts', in *Australian National Security Review,* Vol. 2, No. 11, November 2004, Canberra.

Ayres, R. U., Ayres, L. W. and Warr, B. 2003, 'Energy, power and work in the US economy, 1900–1998', *Energy,* vol. 28, pp. 219–273, Elsevier Science Ltd.

Bassanini, A. and Scarpetti, S. 2002, 'Growth, technological change and ICT diffusion: recent evidence from OECD countries', *Oxford Review of Economic Policy*, Vo. 1, No. 3, Oxford University Press, pp. 324–344.

Bean, C. 2000, 'The Australian economic "miracle": a view from the north', in Gruen, D. and Shresta, S. (eds), *The Australian Economy in the 1990s*, Economic Group, Reserve Bank of Australia.

British Petroleum 2004, 'BP: World oil and gas reserves still growing at healthy pace', *Oil and Gas Journal*, 21 June 2004, www.energybulletin.net/761.html

Brynjolfsson, E. and Hitt, L. 1996, 'Paradox lost? firm-level evidence on the returns to information systems spending', *Management Science*, vol. 42, No. 4, pp. 541–558.

Bureau of Industry Economics 1992, *Recent Developments in the Theory of Economic Growth: Policy Implications,* Occasional Paper 11, AGPS, Canberra.

Bureau of Transport and Regional Economics 2003, *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020*, Final draft report to Environment Australia, www.btre.gov.au/docs/joint_reports/urbanpollutants_draft.aspx

Business Council of Australia 2004, *Aspire Australia 2025: Change is Inevitable, Progress is Not,* www.bca.com.au/content.asp?newsID=94443

Carlaw, K. I. And Lipsey, R. G. 2003, 'Productivity, technology and economic growth: what is the relationship?', *Journal of Economic Surveys*, Vol. 17, No. 3, pp. 457–95.

Caves, R. E, 1996, *Multinational Enterprise and Economic Analysis,* Cambridge University Press.

Colecchia, A. and Schreyer, P. 2001, *ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries,* OECD Science, Technology and Industry Directorate, Paris.

Computer Science Corporation (CSC) 2002*, On the Edge: Exploring Next-Generation Digital Disruptions, www.csc.com,* USA.

—— 2003, *The Architecture rEvolution: Exploring the Network Effect on Infrastructure, Applications and Business Process, www.csc.com*, USA.

Commonwealth Scientific and Industrial Research Organisation (CSIRO) *2004, Biomining: the next mineral revolution, www.csiro.au/index.asp?type=featureArticle&id=BioMining*.

Cooper, R. N and Layard, R. (Eds) 2003, *What the Future Holds: Insights from Social Science,* MIT Press, USA

David, P. 1990, 'The Dynamo and the Computer: A Historical Perspective on the Modern Productivity Paradox', *American Economic Review*, Vol. 80 (2), pp. 355–361.

DeLong, J. B. 2000, 'What went right in the 1990s? Sources for American and prospects for world economic growth', in Gruen, D. and Shresta, S. (eds), *The Australian Economy in the 1990s*, Economic Group, Reserve Bank of Australia.

PREVIOUS PAGE PRINT CLOSE NEXT PAGE

DeLong, J. B. and Summers, L. 1991, ‘Equipment investment and economic growth’, *Quarterly Journal of Economics*, vol. CVI, issue 2.

—— 1992, ‘Equipment investment and economic growth: how strong is the nexus?’, *Brookings Papers on Economic Activity,* No. 2, Washington, D.C.

Department of Communications, Information Technology and the Arts (DCITA) 2004, Submission by the Information Economy Division in response to a discussion paper released by the Treasurer on Australia’s Demographic Challenges, Canberra.

—— 2005a, *Productivity Growth in Service Industries*, Occasional Economic Paper, Canberra.

—— 2005b, *ICT and Australian Productivity: Methodologies and Measurement*, Occasional Economic Paper, Canberra.

Dewan, S. and Min, C. 1997, ‘The substitution of information technology for other factors of production: a firm level analysis’, *Management Science*, vol. 43, No. 12, pp. 1660–1675.

Diewert, E. 2004, Productivity Perspectives in Australia: Conclusions and Future Directions, paper presented at the Productivity Perspectives 2004 conference sponsored by the ABS and the Productivity Commission, December 2004, Canberra.

Diewert, E. and Lawrence, D. 2004a, Measurement Problems in Regulation, Seminar paper presented to Australian Competition and Consumer Commission, Melbourne, 22 July.

—— 2005a, ‘The Role of ICT in Australia’s economic performance: an investigation of assumptions influencing the productivity estimates’, in *ICT and Australian Productivity: Methodologies and Measurement,* DCITA Occasional Economic Paper, Canberra, pp. 55–94.

—— 2005b, *Estimating Aggregate Productivity Growth for Australia: The Role of Information and Communications Technology,* DCITA Occasional Economic Paper, prepared by Meyrick and Associates for the Dept. of Communications, Information Technology and the Arts, Canberra.

Dixon, P. and Rimmer, M. 2002, *Dynamic General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH*, North-Holland Publishing.

Dunlop, M., Turner, G. M. and Howden, S. M. 2004, *Future Sustainability of the Australian Grains Industry*, Report prepared for the Grains Council of Australia and Grains research and Development Corporation, CSIRO Sustainable Ecosystems, Canberra, www.cse.csiro.au/research/futures/grainsfutures/index.htm

Eckersley, R. 1998, *Measuring Progress*, CSIRO Publishing, Melbourne.

Encyclopaedia Britannica 2004, *Encyclopaedia Britannica,* CD Deluxe Edition, Australia.

Energy Information Administration 2001, *Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur Dioxide, Nitrogen Oxides, Carbon Dioxide and Mercury and a Renewable Portfolio Standard*, USA Dept. of Energy, www.eia.doe.gov/oiaf/servicept/epp/pdf/sroiaf(2001)03.pdf

European Commission 1999, *The Futures Project: Technology Map*, edited by Cahill, E. and Scapolo, F., European Commission Directorate-General Joint Research Centre, Institute for Prospective Technological Studies, Seville.

—— 2000, *The IPTS Futures Project: Synthesis Report,* European Commission Directorate-General Joint Research Centre, Institute for Prospective Technological Studies, Seville.

—— 2004, *Converging Technologies – Shaping the Future of European Societies,* www.ntnu.no/2020/final_report_en.pdf

European Science Foundation (ESF) 2005, *ESF Scientific Forward Look on Nanomedicine*, European Science Foundation Policy Briefing, *http://www.esf.org/newsrelease/83/SPB23Nanomedicine.pdf*

Foran B. and Poldy, F. 2002, *Future Dilemmas: Options to 2050 for Australia's Population, Technology, Resources and Environment*, CSIRO Sustainable Ecosystems, Report to the Department of Immigration and Multicultural and Indigenous Affairs, Canberra.

Foster, R. A. 1996, *Australian Economic Statistics 1949–50 to 1994–95,* Reserve Bank of Australia, Occasional Paper No. 8,

Gartner 2004, *Gartner Outlines Most Significant Technology Driven Shifts in the Next Decade,* Gartner Press Release 1/6/2004, www3.gartner.com/5_about/press_release/asset_62507_11.jsp

Good, B. A. 2003, 'E-money and the Payment System', chapter 19 in Jones D. C. (editor), *New Economy Handbook*, Elsevier Academic Press

Gordon, R. 2003, 'Exploding Productivity Growth: Context, Cause and Implications', *Brookings Papers on Economic Activity,* Vol. 2, 2003, pp. 207–297.

Gregor, S., Fernandez, W., Holtham, D., Martin, M., Stern, S. Vitale, M., Pratt, G. 2005, *Achieving Value from ICT: Key Management Strategies,* Department of Communications, Information Technology and the Arts, Research Study, Canberra.

Grubler, A. 1997, 'On the pattern of diffusion of innovation', in *Technological Trajectories and the Human Environment*, eds. Ausubel, J. and Langford, D., National Academy of Engineering, Washington, D.C. pp. 14–32.

Gruen, D. and Garbutt, M. 2003, *The Output Implications of Higher Labour Force Participation,* Treasury Working Paper 2003 – 02, Canberra.

Halal, W. E. 2000, 'The top emerging technologies', *The Futurist*, July/August issue, George Washington University.

Hampson, K. and Brandon, P. 2004, *Construction 2020 – A Vision for Australia's Property and Construction Industry,* CRC Construction Innovation, Brisbane, http://www.construction2020.construction-innovation.info/files/C2020-Vision-Report.pdf

Inklaar, R., O'Mahony, M. and Timmer, M. 2003, *ICT and Europe's Productivity Performance; Industry-level Growth Account Comparisons with the United States,* Research Memorandum GD-68, Groningen Growth and Development Centre, University of Groningen, The Netherlands.

Industry Commission (IC) 1995, *Research and Development*, Inquiry Report, AGPS, Canberra.

—— 1997, *Assessing Australia's Productivity Performance*, AGPS, Canberra.

Johnston, A., Porter, D., Cobbold, T., Dolamore, R. (2000), *Productivity in Australia's Wholesale and Retail Trade,* Staff Research Paper, Productivity Commission, Canberra.

Jorgenson, D. W., Mun Ho and Stiroh, K. J. 2002, *Information Technology, Education and the Sources of Economic Growth across US Industries,* Harvard University, USA. *http://post.economics.harvard.edu/faculty/jorgensen/papers/jhscriw.pdf.*

Katz, J. E., Rice, R. E., Acord, S. K. 2004, 'e-health networks and social transformations: expectations of centralization, experiences of decentralization' in Casells, M (editor) *The Network Society: a Cross-cultural Perspective*, Edward Elgar, Cheltenham, England, pp. 293–318.

Kearney, B., Foran, B., Poldy, F. and Lowe, D. 2003, *Modelling Australia's Fisheries to 2050: Policy and Management Implications*, CSIRO Resource Futures, Canberra, www.cse.csiro.au/research/futures/fishfutures/index.htm

Kurzweil, R. 2005, 'Human 2.0', *Sydney Morning Herald*, 24th October 2005.

Kümmel, L., Henn, J. and Linberger, D. 2002, 'Capital, labor, energy and creativity: modeling innovation diffusion', *Structural Change and Economic Dynamics*, vol. 13 pp. 415–433, Elsevier Science Ireland Ltd.

Layard, R., Nickell, S. and Jackman, R. 1991, *Unemployment: Macroeconomic Performance and the Labour Market*, Oxford University Press, Oxford.

Lewis, P. 2005, 'Low pay or no pay? Economics of the minimum wage', *Policy*, vol. 21, no. 3, pp. 14–20.

McDonald, I. 2004, *Ageing no burden to future rich,* The University of Melbourne media release 27th April 2004, www.uninews.unimelb.edu.au/articleid_1383.html

McNeill, J. 1999, 'GDP growth and human wellbeing: a brief look at why we need a better measure of progress', *New England Perspectives,* Vol. 3, 1999, pp. 135–144.

National Dryland Salinity Program (NDSP) 2002, *Desalination technologies too costly for thirsty cities*, Media Release 19th September 2002, *www.nspd.gov.au/45_media_centre/15_media_releases/desal.htm*

National Office for the Information Economy (NOIE) 2004, *Productivity Growth in Australian Manufacturing,* NOIE Occasional Economic Paper, Canberra.

Nonatechwriter.com 2004, *Sizing Nanotechnology Value Chain—New Report from Lux Research*, www.nanotechwire.com/news.asp?mid_1248.

Nelson, B. 2005, *Ministers united on education and training in the information age,* Media release by Dr Brendan Nelson, Australian Government Minister for Education, Science and Training, 11 February 2005, *www.dest.gov.au/Ministers/Media/Nelson/2005/02/n1046110205.asp*

Nelson, R. R. 1990, 'Capitalism as an engine of progress', *Research Policy*, vol. 19.

Oliner, S. and Sichel, D. 2002, 'Information Technology: Where are we now and where are we going?' *Federal Reserve Bank of Atlanta Economic Review*, 87(3), pp. 15–44.

Organisation for Economic Cooperation and Development (OECD) 2001, *The Application of Biotechnology for Industrial Sustainability,* OECD Publication Service, Paris.

——2002, *Looking Back at Looking Forward: Foresight through the Centuries*, OECD International Futures Programme, Directorat for Science, Technology and Industry, Paris.

—— 2004a, *The Economic Impact of ICT: Measurement, Evidence and Implications,* Economic Analysis and Statistics Division, Directorat for Science, Technology and Industry, Paris.

—— 2004b, 'Emerging Technology Applications' in *Information Technology Outlook 2004*, DSTI/ICCP/IE(2003)12/chap7/rev1, Directorat for Science, Technology and Industry, Paris.

—— 2005, *Building Partnerships for Progress,* OECD Science, Technology and Industry Directorat, Paris, www.oecd.org/sti/scoreboard.

Ovum Report 2003, *Productivity and Organisational Transformation: Optimising Investment in ICT,* The National Office for the Information Economy (NOIE), *www.noie.gov.au/publications/NOIE/Ovum_report*.

Parham, D. 2004a, 'Sources of Australia's Productivity Revival", *The Economic Record,* Vol. 80, No. 249, pp. 239–257.

Parham, D. 2004b, ICT: An engine or enabler of Australia's productivity growth? Paper presented in the Asia Pacific Productivity Conference 2004, Queensland University, Brisbane.

Parham, D., Roberts, P. and Sun. H. 2001, *Information Technology and Australia's Productivity Surge,* Staff Research Paper, Canberra.

Poole, W. 1999, *A St. Louis Perspective on Long-Term Economic Growth,* Speech by the President of the Federal Reserve Bank of St. Louis, *www.stlouisfed.org/news/speeches/1999/04_16_99.html*

PREVIOUS PAGE PRINT CLOSE NEXT PAGE

Productivity Commission 1999, *Microeconomic Reforms and Australian Productivity: Exploring the Links,* Commission Research Paper, Volume 1: Report, AusInfo, Canberra.

—— 2004a, *ICT Use and Productivity: A Synthesis from Studies of Australian Firms*, Commission Research Paper, Canberra.

—— 2005a, *Industry Productivity Estimates*, *www.pc.gov.au/work/productivity/industry/html*

—— 2005b, *Economic Implications of an Ageing Australia,* Draft Research Report, Productivity Commission, Canberra.

Rahman, J. 2005, *Comparing Australian and United States Productivity*, Treasury Working Paper, www.treasury.gov.au/document/987/HTML/docshell.asp?url=o4_comparing_productivity.asp

RAND 2000, *The Global Course of the Information Revolution: Technological Trends*, Proceeding of an International Conference, RAND's National Security Research Division, USA

—— 2001, *The Global Technology Revolution: Bio/Nano/Materials Trends and their Synergies with Information Technology,* RAND National Defence Research Institute, USA.

Schreyer, P. 2000, *The contribution of Information and Communication Technology to Output Growth: A Study of the G7 Countries,* OECD Directorate for Science, Technology and Industry, Paris.

Solow, R. 1957, 'Technical change and the aggregate production function', *Review of Economics and Statistics*, vol. 31, pp. 312–320.

Stiroh, K. 2001, *Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?,* Federal Reserve Bank of New York.

TIME 2000, *Visions of the 21th Century*, *wwww.time.com/time/reports/v21/home.html.*

Tegart, G. 2002, *Future Perspectives on Information and Communication Technologies in Europe*, Report for the National Office for the Information Economy, Canberra

Treasury 2002, *Intergenerational Report,* 2002–03 Budget Paper No. 5, Canberra.

UK Industrial Biotechnology Task Force 2004, *Industrial Biotechnology: Delivering Sustainability and Competitiveness,* www.biowise.org.uk/core_files/IBTF%20Report%20draft%20for%20public%20consultation.pdf

vnunet 2005, *HP claims nano-electronic breakthrough*, www.vnunet.com/vnunet/news/2137704/hp-nano-circuit-crossbar

Watson, I., Buchanan, J., Campbell, I., Briggs, C. 2003, F*ragmented Futures: New Challenges in Working Life*, acirt University of Sydney, The Federation Press, Sydney.

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