January 2021
TTRP 21-02

2021 Intergenerational Report
Treasury Technical Research Paper Series

Projecting Long Run Productivity Growth Rates for the 2021 Intergenerational Report

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[1] The views in this paper are those of the authors and do not necessarily reflect those of NSW Treasury.
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NSW GOVERNMENT

Preface

Labour productivity growth is one of three cornerstones of potential long-term economic growth, together with *population* growth and labour force *participation*. Together, these factors comprise the so-called three-Ps. Labour productivity refers to the amount of output produced per hour worked.

Factors that can affect labour productivity include technological change, the quality of education, upskilling, organisational change and the amount of capital available to workers. Over time, productivity determines an economy's capacity to grow, create income and wealth and ultimately deliver an improved quality of life.

Despite the significance of labour productivity to the material living standards of New South Wales (NSW) residents, it is inherently difficult to measure, and even harder to predict future growth rates. The majority of academic literature on the subject therefore seeks to make sense of past growth, rather than predict future growth. State based productivity growth is additionally difficult to predict, given it is reliant on many global and national factors. It also depends on future rates of technological progress, much of which is outside of the primary control of local firms or government.

NSW Treasury's model for long-term economic and fiscal projections, the *Long-Term Fiscal Pressures Model (LTFPM)* has therefore, tended to apply a relatively simple methodology for projecting long-term labour productivity a 30-year historical annual average. The transition to a long-run equilibrium rate occurs over a five year period. This differs from Treasury's more granular modelling approaches applied to projecting long-term population growth and long-term labour force participation rates.

NSW Treasury last published long term labour productivity projections in the *2016 New South Wales Intergenerational Report (IGR)*. Since this time, there have been several developments likely to have affected productivity growth. These have the capacity to significantly impact productivity going forward, including the current COVID-19 economic shock.

This paper evaluates the appropriateness of the current long run labour productivity growth assumption ahead of the next NSW IGR, to be released in 2021. It examines methodologies used by other leading Treasuries and financial institutions for projecting productivity growth, and reviews trends and factors that may influence the future growth path. The proposed methodology and projections contained in this paper are preliminary and will be finalised for the 2021 IGR.

This paper also seeks to add to the consideration of long-run productivity growth from the viewpoint of a sub-national jurisdiction. Most of the publicly available literature on this subject being concentrated at a national level. This paper was also prepared during the COVID-19 pandemic. While 2019-20 Australian Bureau of Statistics (ABS) State Accounts productivity data has recently been published, this paper focuses the discussion and analysis on the long-run trends up to 2018-19. The potential long-run impact of COVID-19 will be further discussed in the 2021 NSW IGR.

This paper is part of a Treasury Technical Research Paper (TTRP) series that unpacks the key drivers of long-term economic growth and the fiscal outlook in the lead up to the 2021 NSW IGR. This is the second of these papers, following the publication of the long-term participation rate paper in August 2020.[2]

[2] https://www.treasury.nsw.gov.au/sites/default/files/2020-08/2021%20IGR%20TTRP%20-%20Preliminary%20Participation%20Rate%20Projections%20for%20the%202021%20IGR_0.pdf

Acknowledgement

NSW Treasury acknowledges the Traditional Owners of the land on which we live and work, the oldest continuing cultures in human history.

We pay respect to Elders past and present, and the emerging leaders of tomorrow.

We celebrate the continuing connection of Aboriginal and Torres Strait Islander peoples to Country, language and culture and acknowledge the important contributions Aboriginal and Torres Strait Islander peoples make to our communities and economies.

We reflect on the continuing impact of policies of the past, and recognise our responsibility to work with and for Aboriginal and Torres Strait Islander peoples, families and communities, towards better economic, social and cultural outcomes.

Note
The authors thanks Peter Horn, Brendan Elliot, Kevin Ge, Danielle Doherty and Simon Davis for their contributions to the paper and Michael Warlters, Michael Gadiel, Ian Beckett, John Janssen, John Salerian, Stephanie Parsons, Lachlan Dynan, Stephen Walters, Richard Cox, Aruna Sathanapally, Angelica Leviste, James Glenn and Joann Wilkie for their detailed comments on various drafts.

Contents

Abstract

The uncertainty and complexity of productivity growth, and its vulnerability to external shocks, has meant the most common approach for projecting economy-wide long-run labour productivity is to assume future growth will behave in a similar fashion to that of previous decades. This relatively simple methodological approach can appear crude given the importance of labour productivity growth projections to supporting public sector decision making.

This paper begins with a review of the methodologies used by national and international economic and fiscal institutions to project long-run productivity growth. This is complemented by an assessment of certain structural trends and influences on NSW productivity growth, considering how these may contribute to future growth. Together, this analysis supports NSW Treasury's understanding of long-run productivity growth in the State and provides the basis for appropriate projections of productivity into the future.

The existing methodology assumes NSW long-run productivity will grow in line with the average annual rate seen over the past 30-years, and that this rate will be achieved within five years of the latest actuals. The analysis in the paper supports the retention of the existing methodology for projecting the long-run equilibrium rate, while further consideration should be given to the speed of transition to this rate.

This approach, while relatively simple, is appropriate given the large amounts of uncertainty in projecting future productivity growth. The 30-year period represents the extent to which productivity data is available at a sub-national level. It also captures a long history of boom periods, recessions, industry transitions to a knowledge and service based economy, and large-scale technological change. The five-year transition period to equilibrium is viewed as relatively quick given a number of downside risks over the short, to medium, term.

JEL Classification Numbers: E24, J11, J21, J23

Keywords: productivity, structural change, technology, reforms, long-term projections

1. Introduction

Labour productivity growth has long been a fascination of governments, academia, and economic think-tanks, among others, given its importance to long-term economic growth and material living standards, as well as its inherent unpredictability. This has led to an ever growing compilation of global research into the underlying drivers of, and barriers to, labour productivity. This research sits alongside assessments of how these factors have shaped the past, and predictions as to how these could influence the future. Productivity growth, however, remains a challenge to measure, understand and predict. Within this context, this paper aims to provide greater context around the New South Wales specific productivity growth story and what this may indicate for future growth.

Intellectual framework for modelling long-run productivity growth

NSW Treasury's Long-Term Fiscal Pressures Model (LFPM) uses the 'three P's' (population, participation and productivity) framework to produce long-term economic projections. Population and participation projections determine the total hours worked in the economy. Labour productivity describes the effectiveness of these labour hours in generating state income and is calculated as the ratio of Gross State Product (GSP) to hours worked. Labour productivity has direct implications for government taxation revenues, as well as creating opportunities for public spending and saving. A robust long-term labour productivity growth rate projection is, therefore, critical to long-term fiscal modelling.

Unlike population and participation, which are econometrically modelled in the LTFPM, previous IGRs have assumed both State and national labour productivity will continue to grow in line with their 30-year historical annual averages. Softening productivity growth from the early 2000's has meant NSW and Australian long-run productivity growth rate projections have successively been revised down from 1.7 per cent (2006 IGR), to 1.6 per cent (2011 IGR) and 1.5 per cent (2016 IGR). This paper explores the appropriateness of continuing with this productivity methodology for the 2021 IGR through analysing some key underlying influences of productivity growth.

Improvements in labour productivity are driven by capital deepening and multi-factor productivity (MFP) growth. Appendix A explains the basic theory behind this neoclassical model. Capital deepening refers to the changing ratio of capital to labour or increasing capital intensity. A higher ratio means that each unit of labour has more capital to work with to produce output, generally making labour more productive. MFP reflects how well labour and capital work together in the production process, for example, a firm automating a previously labour-intensive factory production line.

Sources of MFP are numerous and are generally described as factors such as technical and organisational innovation and efficiencies, and includes the effects of technology, changes in government policy, education, health management practices, brand names, network effects, economies of scale, weather related effects, and capacity utilisation. The nature of productivity measurement, however, means the calculation also captures measurement errors[3].

The most accurate estimates of labour productivity are for market sector industries (for example, private goods producers), where output is tangible and prices are set by markets. Here, the ABS can more accurately measure output. While focusing analysis on the market sector exclusively would therefore be preferable from a statistical robustness perspective, it would still not perfectly capture productivity growth in these sectors, for example the productivity growth of private banks.

The LTFPM also requires a labour productivity growth projection across all sectors, including non-market sector industries. These include public administration and safety, healthcare and social assistance and education and training. In these growing industries, productivity measurement is more difficult as the labour inputs (wages) and value outputs are not determined by market mechanisms.

[3] Zeng, S. et al. (2018)

Measured productivity will therefore generally be lower in these industries to the extent output is partly measured by these non-market driven labour input costs. This likely undervalues the true importance of these industries as facilitators for productivity improvements in the broader economy, as well as their role in supporting higher living standards.

2. Comparing Long-Run Productivity Modelling Methodologies

Chapter highlights

The current NSW Treasury methodology for projecting long-run productivity growth applies a 30-year historical annual average growth rate as the baseline assumption for future growth. This equilibrium rate is assumed to be reached over a five-year period.

Updating the data to 2018-19 would suggest a revised NSW labour productivity growth assumption of 1.3 per cent per annum for the 2021 IGR, and a national growth rate of 1.5 per cent. This is a decline of 0.2 per cent from the 2016 IGR projections for NSW of 1.5 per cent, while the national growth rate remains the same. Examples of sub-national jurisdictions publishing research on long-run productivity are rare. This chapter, therefore discusses national jurisdictions and international non-government organisations.

The most common methodology used by international government and non-government economic and fiscal institutions for projecting long-run labour productivity is an assumption that productivity will grow in line with a historical average. The largest methodological differences between jurisdictions tend to be: the length of the historical periods, which can range from around 20 years to 50 years; the application of weights that place more importance on recent history; and, the removal of extra-ordinary period/s from the historical time series.

The OECD's long-term scenarios model is a notable exemption. It incorporates several independent variables into its long-run productivity growth projections for potential output.[4] It also allows for a more dynamic estimation of productivity growth in each country. However, this model also remains dependent on past outcomes to project future productivity growth. This is because its main determinant, technological growth, is based off average historical performance.

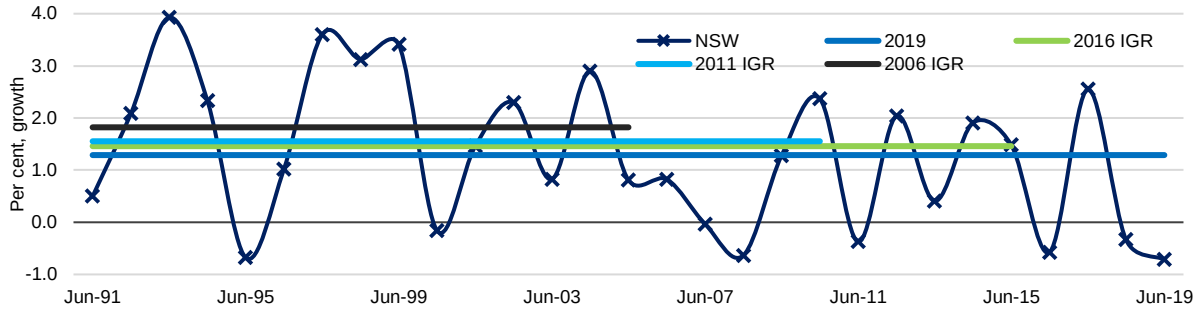
New South Wales Intergenerational Report Assumptions

Previous NSW IGRs have assumed State and national labour productivity will grow at a constant rate, in line with a 30-year historical average annual growth rate. The 2016 IGR adopted two years of budget projections before transitioning to the equilibrium rate a five-year period. Over time, this assumed long-run productivity growth rate has declined from 1.7 per cent per year in the 2006 IGR, to 1.6 per cent in the 2011 IGR and to 1.5 per cent in the 2016 IGR. These declines reflect lower average productivity growth over the 15 years period to 2016. Notably, the State and national annual growth rates have been identical in these IGRs.

As Chart 1 shows, over the past 29 years,[5] (1989-90 to 2018-19) the average growth of New South Wales labour productivity has declined further to 1.3 per cent per annum. Over a 30-year period, Australian labour productivity has averaged 1.5 per cent. If the methodology for projecting future productivity for growth were to remain unchanged, these would be the state and national growth rates for labour productivity adopted in the 2021 IGR.

[4] Guillemette Y., Turner, D. (2018).
[5] For the States, productivity records begin in 1989-90, providing 29 years of information for analysis. Nationally, over forty years of information is available.

Chart 1: NSW labour productivity growth history, with average lines for the previous Reports



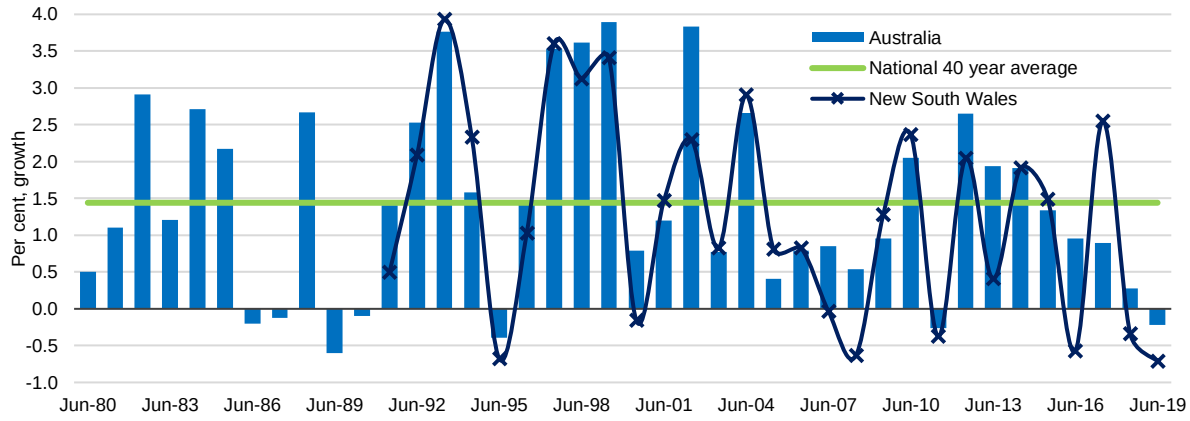
Source: ABS 5220.0, 6202.0 and NSW Treasury

Methodological Review of other jurisdictions

Australian Commonwealth Treasury

The Australian Commonwealth Treasury's previous Intergenerational Report's (2002, 2007, 2010 and 2015) have used a 30-year historical average as its baseline assumption for projecting long-run productivity growth. As national productivity growth rates have declined over this period (see Chart 2), so has this long-run productivity assumption, from 1.75 per cent per annum in 2002 to 1.5 per cent in 2015.

Chart 2: National productivity growth has slowed compared to the forty-year average



Source: ABS 5202.0, 6202.0, 5206.0 and NSW Treasury

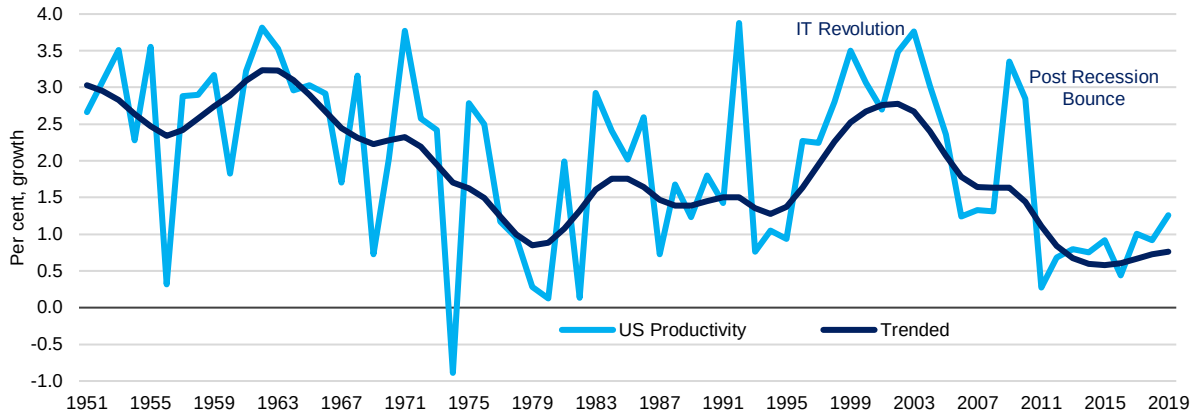
The United States Congressional Budget Office

The United States Congressional Budget Office (CBO) publishes a Long-Term Budget Outlook every year.[6] The CBO's approach to modelling long-term productivity uses history as a guide, whilst applying more weight to recent trends, rather than applying a strict historical average (see Chart 3). The CBO has been reducing this long-run growth rate relatively quickly over recent years, from 1.8 per cent per annum in its 2015 Report, to 1.5 per cent in its June 2019 Report. This Report notes that while the US 50-year productivity historical growth rate is 1.7 per cent per annum, economy-wide

[6] US Congressional Budget Office. (2020).

labour productivity is expected to grow more slowly than it has in the past. This reflects *"slower growth of total factor productivity and less private investment in capital goods.*[7]*"*

Chart 3: US productivity growth has slowed over time

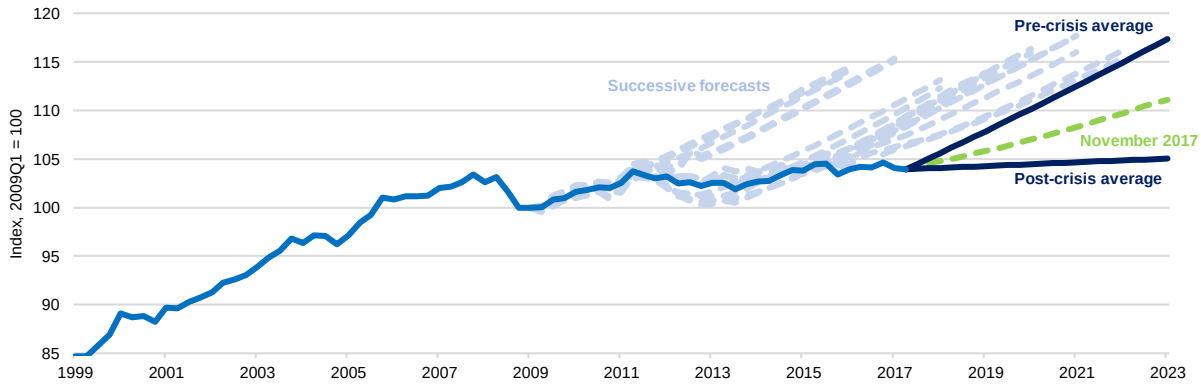


Trended with Hodrick-Prescott filter, lambda=100
Source: US Congressional Budget Office. (2020) and NSW Treasury

The UK Office for Budget Responsibility

The UK Office for Budget Responsibility (OBR) regularly produces a Fiscal Sustainability Report (FSR), last published in July 2020. The OBR's long-term productivity growth projections assume a gradual return towards a 50-year annual average growth of 2.0 per cent.[8] This longer history largely reflects the UK's annual productivity growth rate prior to the global financial crisis (GFC) of 2.1 per cent. Since the GFC, productivity growth has consistently undershot pre-crisis outcomes (Chart 4).

Chart 4: UK productivity growth has consistently undershot expectations since the GFC



Source: UK Office for Budget Responsibility (2017) and NSW Treasury

Following a 2017 review of the productivity assumption, the OBR decided to change the rate at which productivity growth returns to this steady state rate of 2.0 per cent. This change in methodology assumes the slower growth since the GFC is a long-run abnormality, which will be progressively unwound. Current constraints to growth are expected to fade, and the four sectors primarily responsible for the slowdown — finance, manufacturing, ICT and professional services — are projected to lift. In practice, the OBR optimistically assumes that potential productivity growth will rise by 0.1-percentage points a year until it reaches its steady state rate of 2.0 per cent.

[7] US Congressional Budget Office. (2020).
[8] UK Office for Budget Responsibility. (2018).

New Zealand Treasury

New Zealand Treasury releases an update on the long-term fiscal position in their Long-Term Fiscal Statement at least every four years, with the most recent report released in November 2016. [9] These Reports have used a mixed approach, with considerations including the historical average, the prospects for convergence towards high-income countries, and the lagged effect of policy reforms. This has resulted in an assumed long-run growth rate of 1.5 per cent per annum in their Reports.

The New Zealand Treasury conducted a comprehensive review of its long-run productivity growth rate as part of the Treasury's 2019 Half-Year Economic and Fiscal Update. The review found the mixed approach to be out of step with that of other national public finance departments. The review found the case for New Zealand to converge on higher-income countries has weakened and has adopted a 30-year historical rolling horizon approach. This has resulted in a reduced long-run productivity growth rate of 1.2 per cent.[10] This lower rate also suggests the current cycle of slower productivity growth is incomplete.

Other international finance agencies

Canada's Department of Finance and Switzerland's Federal Department of Finance are two other agencies that use historical averages as their assumption for future productivity growth. Canada's Department of Finance regularly publishes an Update of Long-Run Economic and Fiscal Projections, which includes long-run productivity growth rate projections. Their 2018 Report assumed future labour productivity growth would grow in line with a 48-year historical average of 1.2 per cent per annum. [11] Switzerland's Federal Department of Finance produces a report on the Long-Term Sustainability of Public Finances at least every four years. Their most recent Report in 2016 assumed future productivity growth in line with the average growth between 1992 and 2014, 1.2 per cent per annum. [12]

The Organisation for Economic Co-operation and Development (OECD)

The OECD's 2018 publication, 'The Long View: Scenarios for the World Economy to 2060' (Guillemette et al, 2018) presented an update to their 2014 long-term potential output projections across 51 countries and country groups, incorporating several methodology revisions. Potential output is measured using a Cobb-Douglas production function[13] (see Appendix A) featuring physical capital and trend employment as inputs plus a variable for labour efficiency (MFP).[14] This methodology places greater focus on the MFP (labour efficiency) measure of labour compared to the approaches listed above, and offers a more dynamic approach to modelling productivity growth through its inclusion of several exogenous (human capital) and endogenous (openness, adjusted for country size) variables.

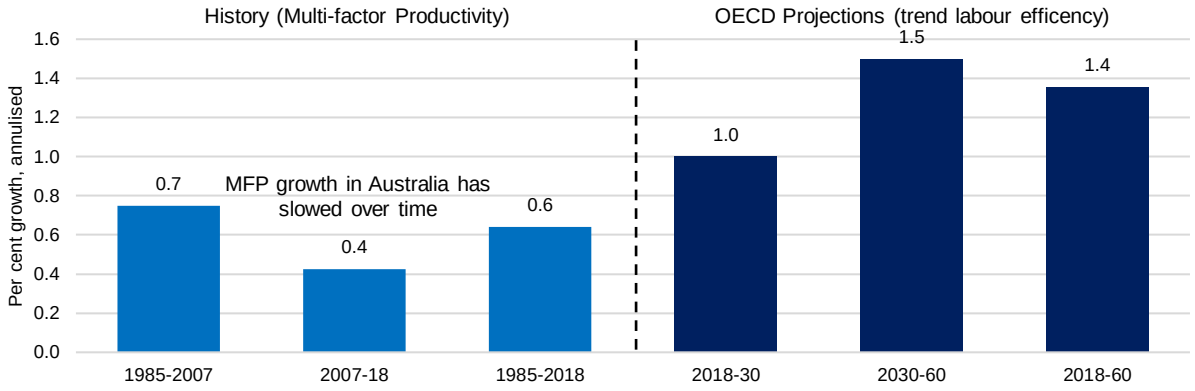
The OECD methodology for projecting a country's labour efficiency measure assumes conditional convergence based on factors including the quality of institutions,[15] human capital,[16] product market regulation, openness to trade, distance to markets, low and stable inflation, income inequality[17] and domestic and global research and development (R&D).[18,19] Long-run labour efficiency converges to an assumed exogenous annual rate of global technological progress of 1.5 per cent per annum. This

[9] New Zealand Treasury. (2018).
[10] The review highlights the challenges that the structural reforms of the 1980s and 90s place on a strict application of this long-run historical approach, although notes such an approach abstracts from the interpretation of business cycles and structural change.
[11] Department of Finance Canada. (2018).
[12] Federal Department of Finance Switzerland. (2016).
[13] With constant returns to scale
[14] Labour efficiency is closely related to multifactor productivity (MFP) or total factor productivity (TFP)–the part of output not explained by inputs.
[15] Based on the World's Bank rule of law indicator
[16] Based on average years of schooling attainment
[17] Based on GINI coefficients
[18] Uses accumulated stocks of R&D
[19] Guillemette. et al. (2017).

rate is the primary driver of long-run productivity growth and represents the mid-point between performance recorded pre and post the Global Financial Crisis (GFC). The OECD notes this methodology for assuming technological process highlights its inherent uncertainty.

The OECD projects Australia's labour efficiency will average 1.4 per cent annually between 2018 and 2060. [20] This rate of growth noticeably exceeds historical outcomes (see Chart 5). Combined with the OECD's projected rate of capital deepening,[21] labour productivity growth is expected to average around 2.0 per cent a year to 2060. This rate would require a significant improvement from Australia's recent rates of productivity growth and is heavily reliant on an assumption for technological progress, whilst also capturing Australia's proximity to growing markets (primarily in Asia) over time. This is projected to boost its labour efficiency by 0.07 per cent per annum.

Chart 5: OECD projections for labour efficiency noticeably exceed historical outcomes



Source: OECD, Guillemette et al, 2018 and NSW Treasury

[20] Guillemette, Y., Turner, D. (2018).
[21] Capital per worker

3. International and State Productivity Performance

Chapter Highlights

New South Wales is the second most productive Australian State, behind only the capital intensive, commodities-driven Western Australia, where a high output to capital ratio boosts labour productivity. NSW's good performance reflects the state's strengths in the highly productive business services industries (for example, finance and insurance services). NSW productivity growth rates over recent decades tell a different story, having been lower than the national average by around 0.3 percentage points each year since 1989-90. This is representative of relatively lower productivity growth within 14 of Australia's 19 industries since 1989-90. This is likely reflective of economic convergence across the states, where other states are catching up to more productive NSW businesses. It also suggests that that broad-based improvements due to changes in economic policy and technology across the country or specific to New South Wales will be the long-term determinate of productivity growth.

Relatively weaker productivity growth over recent decades supports theories of within industry and State-wide convergence. In the absence of significant policy reforms, state-wide convergence from other states towards New South Wales could lead to State productivity growth remaining below the national average by around 0.1 to 0.2 percentage points per annum over the next forty years. State-wide convergence is likely to be driven by the non-commodities driven states conditionally converging on NSW. Further, NSW cannot rely on significant economic convergence towards the United States for improvements in productivity growth, given Australian productivity levels have remained around 80 per cent of the United States since 1950.

The Role of Convergence in Productivity Growth

Economic convergence

Economic convergence is a theory that suggests, over time, economies with lower productivity levels will converge towards economies with higher productivity levels, given their capacity to adopt the technologies and practices of these more productive economies. Convergence theory partially explains high levels of productivity growth in the United States in the 1800's, Japan in the 1900's, and China today. Convergence can also provide a rationale for the relatively strong productivity growth in states outside of NSW over recent decades.

There is limited evidence that countries or jurisdictions absolutely converge on the best performing economies or industries. That is, that they converge fully on the frontier. There is more evidence of conditional convergence or club convergence, which acknowledges there are some barriers to absolute convergence. Countries or jurisdictions with inherently similar economic or social characteristics will converge on each other.

Economic convergence theory therefore relies on those relatively lower-productive economies' willingness, capability and capacity to adopt and adapt best practice institutions, technologies, management processes and regulatory settings as well as develop and retain skills, increase involvement in global value networks, improve opportunities for all citizens, and promote transparency, openness and democratic freedoms.

Each of the state economies within in Australia have relatively similar settings, which allows for conditional convergence to occur. Differences in industry structures, relative sizes of economies and natural endowments will likely prevent absolute convergence from eventuating, despite the re-distributive nature of many Commonwealth policies (for example GST).

The international jurisdictions at the frontier

Northern European countries (for example, Norway) and the United States are currently at the frontier of productive economies in the world. The United States has long been considered the international productivity benchmark given its promotion of free markets and driving technological innovations.

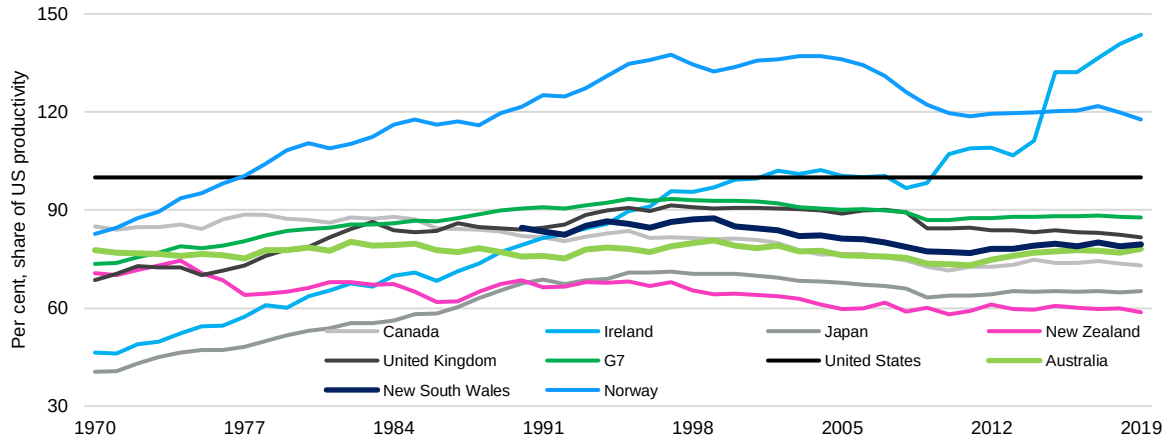
Whilst countries like Norway have benefited from natural endowments, the European Union's single marketplace has also supported greater openness and access to labour and capital which, in turn, has promoted competition and trade.

These countries at international productivity frontier tend to have high proportions of firms at the frontier. These firms tend to be "larger, more profitable, younger and more likely to patent and be part of a multinational group than other firms."[22] The large size of these firms allows for meaningful investments in R&D. They also tend to be heavily involved in global value networks, which increases the potential scale of their high value-added products.

OECD member countries have seemingly benefited from conditional convergence with the United States over the past century. The drivers of this convergence appear to have peaked since the 1980s, with several OECD member countries largely maintaining their relative productive levels since. Australia's productivity levels (as measured by GDP per hour worked) have held the most stable relationship with the United States of any OECD country having hovered around 80 per cent of the United States' productivity levels since 1950. Over this period, productivity levels peaked at 81 per cent in 1999 and troughed at 73 per cent in 2010. [23]

The New South Wales economy has experienced a similar relationship with the United States (Chart 6). The strength of this relationship highlights that over the long run Australia is generally a productivity taker from the rest of the world. As a small, open economy Australia will more than likely continue to rely on the technological and organisational advancements of the rest of the world to drive domestic productivity growth.

Chart 6: Selected economies productivity level relative to the United States[(a)]



[(a)]AUS and NSW data back cast using ABS growth rates of GDP per hour worked in constant prices, due to anomalies between the OECD and the ABS data.
Source: OECD, ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

The New South Wales economy is highly productive by international standards. In 2018, NSW produced US$56 per hour worked (in 2015 prices, PPP basis), this is equivalent to the 15th most productive economy among the 36 OECD member countries (a collection of highly productive economies). [24] New South Wales has the preconditions for high productivity growth, including: access

[22] Andrews, D. et al. (2015).
[23] Guillemette, Y., Turner, D. (2018).
[24] OECD Stat. (2020).

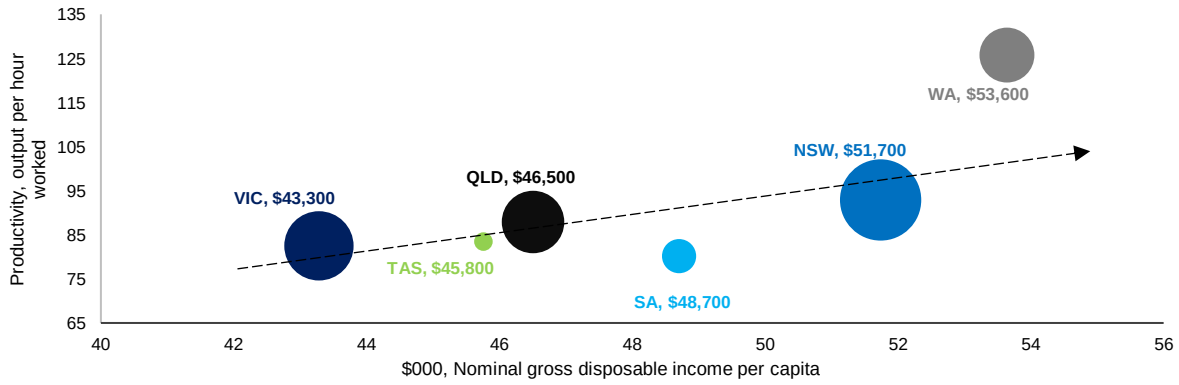
to high-quality human and physical capital; widespread use of new technology; openness and economic freedom; high functioning markets; property rights; a rule of law; and, good government. It remains unlikely that New South Wales will absolutely converge with the United States in the foreseeable future due to constraints including: a relatively small population that is distant from major world markets,[25] limiting economies of scale and access to global value networks; low R&D intensity, limiting innovation; and an industrial structure with relatively fewer capabilities in the high value-added ICT manufacturing industries.[26]

NSW Productivity Context

NSW has high productivity levels within Australia

As of 2018-19, the average NSW worker produced AUD$93 per hour worked,[27] making NSW the second most productive state in Australia, behind commodities driven Western Australia. NSW households have accrued significant benefits from this high-level productivity, with disposable income per capita significantly higher than all other states, except Western Australia (see Chart 7). NSW finance and insurance services have been the strongest contributors to these high levels of income and productivity. The mining sector contributes 40 per cent to Western Australia's economic output. Mining in Western Australia currently has high labour productivity returns, given output is driven by capital and the resources being extracted are high value commodities such as LNG and iron ore.

Chart 7: High productivity is an important determinant of high incomes[(a)]



[(a)]The size of the bubbles indicates the size of the economy
Source: ABS 6202.0, 5220.0 and NSW Treasury

NSW productivity growth is below the national average

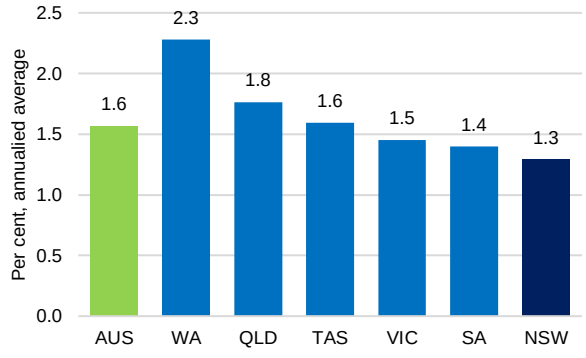
Australian and NSW productivity growth rose strongly in the 1980s and 90s, both relative to history and to international peers.[28] Wide-ranging macro and micro economic reforms and rapid technological advancements are associated with driving this growth. The reforms undertaken during this period were once in-a-generation initiatives. They included: trade liberalisation; reviewing the country's competition policy; floating the currency; deregulating the banking sector; changes to taxation; industrial relations; and, an adoption of inflation-rate targeting within a regime of central bank independence.

[25] Battersby, B. (2006); Boulho. H. et al. (2008).
[26] Productivity Commission. (2019).
[27] Current prices, Australian Dollars
[28] Parham, D. (2003); Parham, D. (2003a).

Since the early 2000s, NSW (and Australian) productivity growth has generally slowed, averaging 1.0 per cent per annum. NSW productivity growth between 2004 and 2012 averaged just 0.8 per cent a year, with non-market sectors experiencing negative productivity growth. The current (incomplete) productivity cycle from 2012 continues this trend of relatively low productivity growth, averaging 0.7 per cent per annum. This is despite several complimentary factors, including the strong rise in commercial and residential property prices.

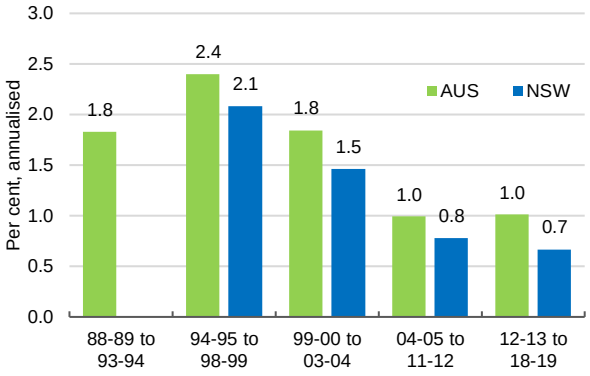
NSW productivity growth of 1.3 per cent per annum since 1989-90 is the lowest average growth rate among the states and below the national average of 1.6 per cent over the same period (Chart 8). Productivity growth in the State has been lower than the national average in each of the recorded productivity cycles since 1989-90 (Chart 9). The past four years have averaged 0.2 per cent productivity growth per annum, with negative productivity growth recorded in each year except 2016-17, when productivity growth rose by 2.5 per cent partially due to favourable weather conditions in the agricultural industry.

Chart 8: Productivity growth since 1989-90



Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

Chart 9: Productivity growth cycles slowing[(a)]



[(a)]No state estimates available for 1988-89
Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

Relatively slower productivity growth in NSW relative to Australia can be assessed by both its **relative industry structure** and its **industry performance**.

The influence of industry structure on NSW productivity growth

Over several decades, the New South Wales economy has undergone a transition away from goods production—mainly manufacturing and agriculture—towards a more broad-based services economy. Service industries account for around 90 per cent of NSW GVA (current prices), an increase of around 17 per cent since the early 1980s.[29] This transition towards services has been common amongst other highly productive economies and largely reflects improvements in consumer's incomes and wealth. Meanwhile, NSW businesses have increasingly outsourced functions to improve internal efficiencies, increasing the demand for business services (including information, media & telecommunications and professional, scientific and technical services).

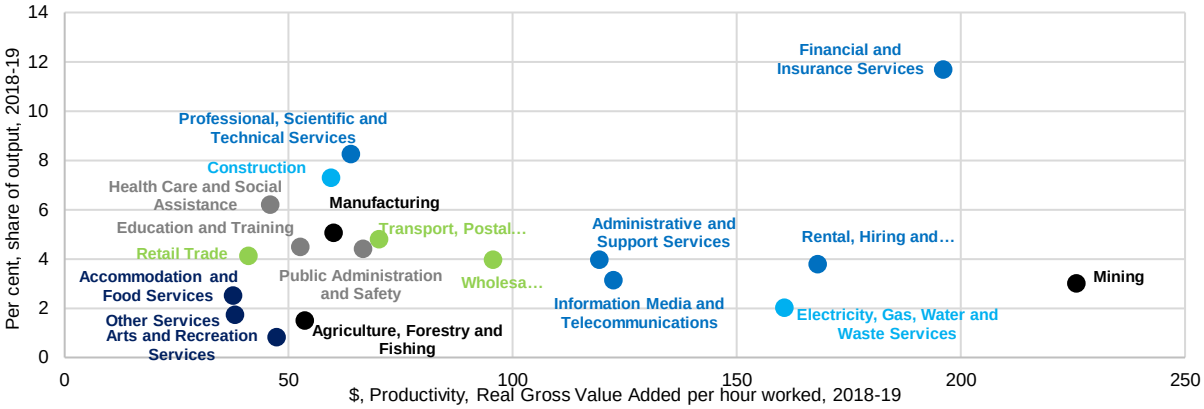
This growth in services has corelated with growth in education levels, with New South Wales having access to a highly skilled workforce. Australians living in New South Wales can expect to go through

[29] ABS. (1994).

21 years of education between the ages of 5 and 39, more than the OECD average of 17.2 years and the highest level in the OECD. [30] With younger generations overall more educated than older generations, human capital accumulation should continue to add to growth (assuming the quality of education does not fall over this time).

This shift to service industries can be viewed as a headwind for productivity growth, as services are generally higher labour intensive (less capital intensive), which is often associated with lower productivity levels and growth. This is often true for personal services (accommodation & food services, arts & recreation services and other services) and social services (public administration & safety, education & training and health care & social assistance). However, business service industries often have a high level of productivity and experience strong productivity growth (see chart 10).

Chart 10: Business services stand out as the most productive industries in New South Wales[(a)]



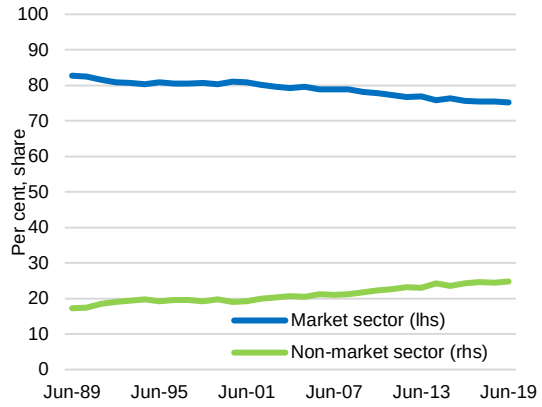
[(a)]Colours indicate a group of similar industries. Dark blue: personal services; blue: business services; light blue: Construction & utilities; black: goods production; green: goods distribution and grey: social services.
Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

The largest service industries in New South Wales are Financial & Insurance, and Professional, Scientific & Technical services, Health Care & Social Assistance, Transport Postal & Warehousing, and Education & Training. Combined, these services contribute almost 40 per cent of NSW total output, yet Finance and Insurance services is the only industry in this group recording high productivity levels. While New South Wales' mining industry, primarily coal, is not as productive as the mining of iron ore in Western Australia, it remains a highly productive industry with New South Wales.

The ongoing shift towards non-market sector industries has posed challenges for NSW measured productivity growth, given it has seen little improvement in measured productivity since 1989-90. Total measured productivity growth has slowed as higher proportions of workers transition into these industries (Charts 11 and 12). Emphasising the word *measured* is important in this context as measuring the productivity performance of non-market sectors is particularly challenging. Productivity benefits from non-market services, such as Education, Skills, Health Care and Transport, are inherently difficult to measure and are also likely partially captured through other industries (Appendix 1).

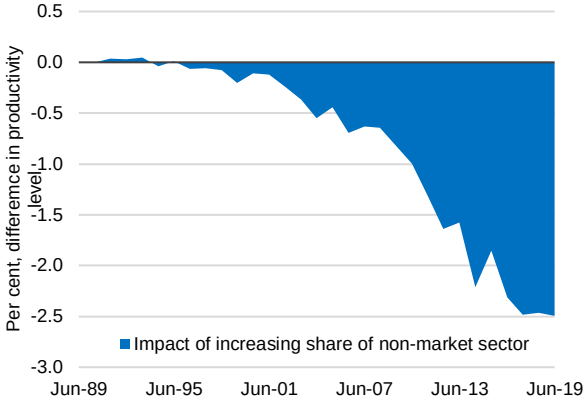
[30] OECD Better Life Index.

Chart 11: The shift in hours worked from the market to non-market sector



Source: ABS 6202.0 and NSW Treasury

Chart 12: The cumulative impact of labour resources shifting to the non-market sector



Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

Box 1: Non-market sectors and productivity performance

The ABS defines Health care and social assistance, Education and training, and Public administration and safety as non-market sector industries. Non-market economic activity occurs when goods and services are provided free of charge or sold at highly subsidised prices. These three industries make up around 15 per cent of the NSW economy and employ 17 per cent of the workforce. These industries are of great importance to the community with the services they provide.

Given the increasing importance of government spending in health and education, and against the backdrop of an aging population, the share of employment and economic growth represented by these industries is expected to continue to grow. As labour shifts towards these non-market service sectors there is projected to be an associated drag on measured productivity growth. This is largely because output from non-market sectors is difficult to measure due to a lack of price information. As a result, productivity growth is measured as low or zero in these sectors.

However, sectors such as education, skills and healthcare support the quality of human capital and contribute to the labour productivity performance in the market sector, acting as facilitators for productivity improvements in the broader economy. Moreover, education, healthcare and social services are fundamental to supporting and improving living standards. For these reasons, non-market service sectors do not implicitly represent an undesirable drag on productivity growth.

More accurately measuring the productivity of these industries would improve the government's understanding of how effectively these essential services are being delivered. Some international statistic agencies publish productivity statistics for non-market sector industries, such as health and education[31]. As part of the Enhancing Economic Statistics New Policy Proposal, the ABS Economic Research Hub is undertaking work to enhance measures of non-market activity. The work is currently focused on building robust and sustainable indicators of output volumes for the health and education industries. The goal is for these indicators to reflect the impact of technological progress and innovation underpinning the delivery of these services.[32]

While presenting a drag on productivity growth, this transition to non-market services has been consistent with that in other Australian States and territories and has not been a major contributor to New South Wales' relatively poor productivity growth. In level terms, New South Wales' industry structure has actually been a relative strength compared with other states. Since 1989-90, the State's

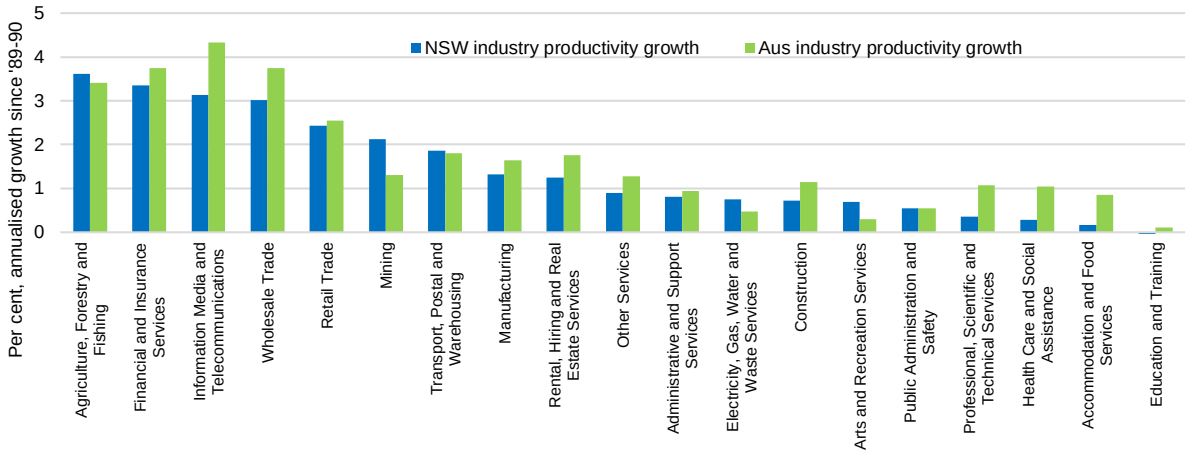
[31] OECD Better Life Index. (2019)
[32] Australian Bureau of Statistics. (2019a).

reliance on productive business services has delivered a compositional growth advantage relative to the national average of around 0.05 percentage points a year since 1989-90.

The influence of industry performance on NSW productivity

Weakness in NSW productivity compared to the national average can therefore be attributed to softer productivity growth within specific industries. New South Wales has seen relatively weaker productivity growth in 14 out of Australia's 19 industries since 1989-90 (see Chart 13). This difference within industries accounts for almost -0.3 percentage points[33] of the productivity growth difference annually. The two largest industries weighing down relative productivity growth in New South Wales are Professional, Scientific & Technical services, and Health Care & Social Assistance, reducing NSW relative productivity growth by around 0.2 per cent since 1989-90. These industries have seen little productivity growth locally and represent a large share of economic output.

Chart 13: Lower productivity growth across NSW industries is a long run trend



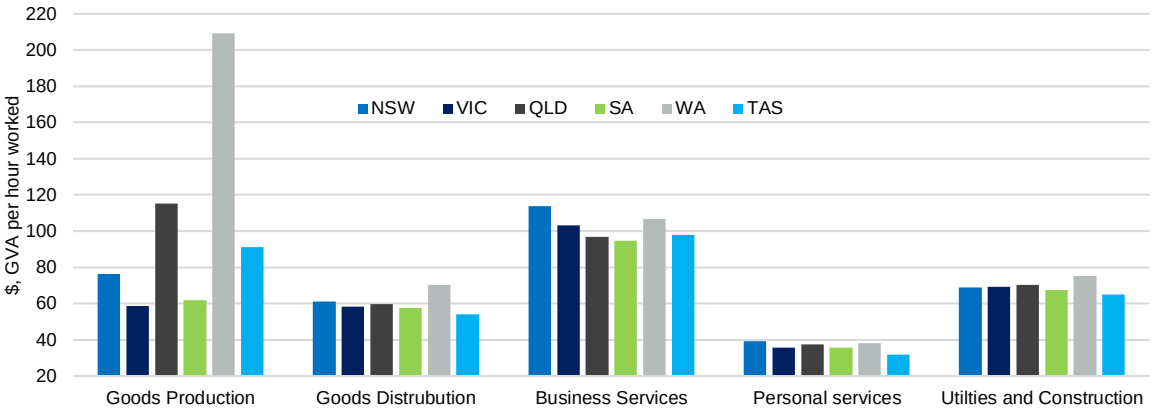
Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

Relative within-industry productivity weakness across NSW industries can partly be explained by conditional convergence. New South Wales tends to be the most productive in service industries, particularly business services, where it is more productive than any other state (Chart 14). Service industries, and particularly personal and business services, are relatively open to dispersion through network effects and therefore lend themselves to convergence.[34] This compares to goods services (for example Mining and Transport) that provide larger barriers to convergence (for example natural endowments and capital costs).

[33]Based on applying NSW industry productivity to the national industry structure, calculation includes ownership of dwellings, taxes and less subsides

[34] Dolman, B. et al. (2007).

Chart 14: New South Wales is the most productive in business and personal services[(a)]

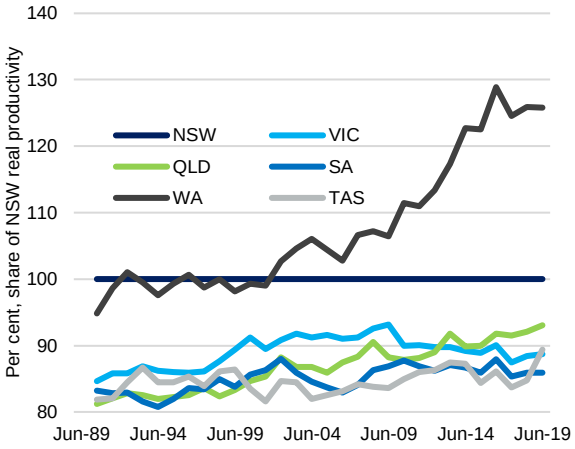


[(a)]Goods production: Agriculture, forestry & fishing, Mining, Manufacturing; Goods distribution: Wholesale trade, Transport, postal & warehousing, retail trade; Business services: Finance & insurance, Rental, hiring & real estate, Professional, scientific & technical, Information media & telecommunications, Administrative & support; Personal services: Accommodation & food, Arts & recreation, Other services; Utilities and Construction: Electricity, gas, water & waste, Construction

Source: ABS 5202.0, 6202.0 and NSW Treasury

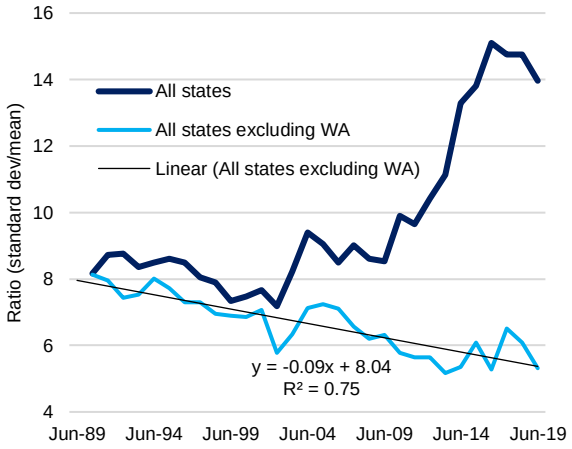
The convergence within Australia is highlighted in Charts 15 and 16. Chart 16 represents the dispersion of state productivity levels through a coefficient of variation[35] where a move down the y-axis indicates convergence. As Western Australia's economy has deepened its focus on mining activity, its productivity levels have accelerated away from the other States (see chart 15). When Western Australia is excluded from the dispersion measure (see Chart 16), a steady rate of convergence emerges across the rest of Australia.

Chart 15: State productivity levels relative to New South Wales shows Western Australia diverging from the pack



Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

Chart 16: Measure of convergence across the states shows the more diversified economies are converging[(a)]



[(a)]Convergence is measured as the coefficient of variation. It is calculated as the ratio of the standard deviation to the mean at each point in time of labour productivity.

Source: ABS 6202.0, 5206.0, 5220.0 and NSW Treasury

[35] The standard deviation divided by the mean, an unweighted mean was used, Capeluck (2014) provides justification for using an unweighted mean.

Several structural constraints will likely prevent other states from achieving absolute convergence with New South Wales productivity levels, for example the relative scale of the NSW economy and the State's established finance district; however, continued conditional convergence is expected. Further research is required to identify the likely level at which other states will converge. The analysis in this chapter suggests that convergence could plausibly result in New South Wales productivity growth below the national average by about 0.1 to 0.2 percentage points per annum, should historical trends continue. This deficit could be mitigated, or potentially removed, through productivity enhancing reforms or technological innovations that disproportionally benefit New South Wales.

4. Structural Shifts within Productivity Growth

Chapter Highlights

NSW productivity growth is subject to several long-term structural shifts underneath the headline figure. Some of these are positive, including the new opportunities for technological change and automation to boost productivity, while previous innovations may not have yet fully been realised in productivity growth. Given the domestic reliance on global innovations and economic growth to drive local productivity, the majority of shifts are weighted towards the downside and would support a softening of the long-run productivity assumption.

Multi-factor productivity growth (MFP) has accounted for most of the State's productivity growth over the past 30 years. MFP growth has been supported by improvements in labour force quality, through lifts in education, skills, and R&D. Over the past two decades, MFP growth has been in line with that of the late 1980s. There is little rationale for the future to be different in the absence of a structural break in education levels and quality or a significant pick up in what has been declining national R&D investment (as a percentage of nominal GDP).

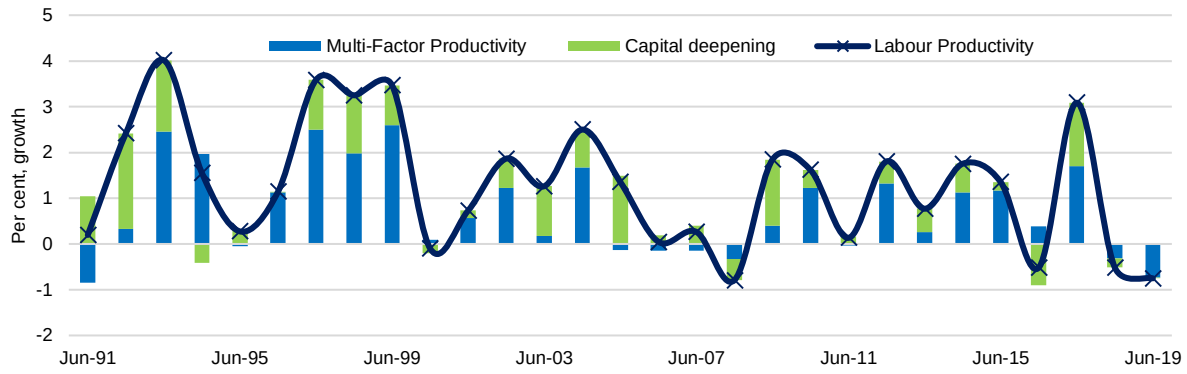
Once-in-a-generation economic reforms, including policy and trade liberalisation, and broad-based improvements in technology during the 1980s and 1990s led to a decade-long surge in national labour productivity growth. When this period of exceptional growth is excluded from trend data, annual labour productivity growth averages around 1.3 to 1.4 per cent nationally and around 1.1 to 1.2 per cent in New South Wales.

Multi-factor productivity and capital deepening in New South Wales

Labour productivity can be decomposed into contributions from capital deepening and multi-factor productivity. New South Wales' mature service-centred economy relies more on MFP, while capital deepening has traditionally played a secondary role in driving productivity growth (see Chart 17). Whole economy MFP growth has averaged 0.9 per cent a year in New South Wales since 1989-90, representing about 60 per cent[36] of the growth in GVA labour productivity[37]. The State's reliance on MFP growth over capital deepening for productivity growth reflects the State's shift towards a service-driven economy,[38] as has been discussed, and is consistent with a long-run trend in advanced economies.[39]

[36] This estimate broadly aligns with the ABS's published NSW MFP market sector contribution of 53 per cent since 1994-95. Noting this market sector estimate does not include the labour-intensive public-sector industries, which tend to rely less on capital deepening to improve productivity growth.
[37] Russel, D., Vaira-Lucero, M, M. (2017).
[38] Productivity Commission. (2020).
[39] Lowe, P. (2013).

Chart 17: Multi-factor productivity has been the key driver of labour productivity in New South Wales[(a)]



[(a)]Based on NSW Treasury calculations.
Source: ABS 6202.0, 5206.0, 5220.0, Russel and Vaira-Lucero, 2017 and NSW Treasury

MFP growth is generally considered the result of efficiency gains, organisational changes, improvements in managerial practices and technical innovation. The rate at which these innovations arise or diffuse across the economy is influenced by factors such as reduced barriers to trade and competition, domestic R&D, and labour quality (Appendix B). [40]

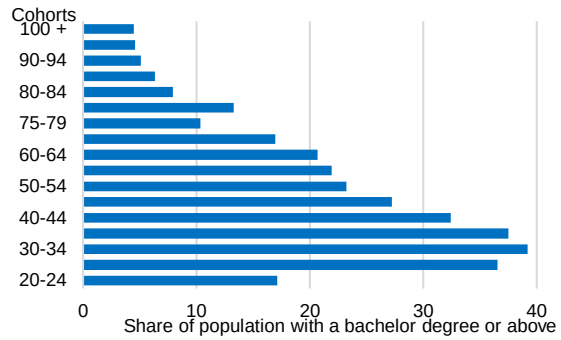
Labour quality and ideas as drivers of multi-factor productivity growth

The ABS provides a measure for assessing the influence of improving labour quality on productivity growth outcomes. Labour quality is measured by adjusting hours worked in the economy for their quality[41]. This involves weighting hours worked based by a population's educational achievement and experience. This adjustment is generally seen in productivity statistics by allocating more (of the unexplained) MFP growth to improvements in labour composition. The ABS estimates the improving quality of labour has contributed around 0.25 percentage points annually to national market sector MFP growth since 1994-95. [42] While this equates to only 15 per cent of annual market sector labour productivity growth, it has been a consistent contributor to a relatively volatile measure.

From 1994-95, improvements in Australia's labour quality have been most strongly reflected in productivity contributions in manufacturing, finance & insurance services, professional, scientific & technical services and wholesale trade (Chart 19). While, state level measures for the benefits of labour composition are not available, it is reasonable to assume a large share of the benefits have been realised within New South Wales, given the State's industry composition. Additionally, the increasing rate of education attainment and experience in the labour force has seen quality adjusted hours worked grow faster than total hours worked. Given younger generations are overall more highly educated than older generations, productivity growth should continue to receive support from a change in labour composition (see Chart 18).

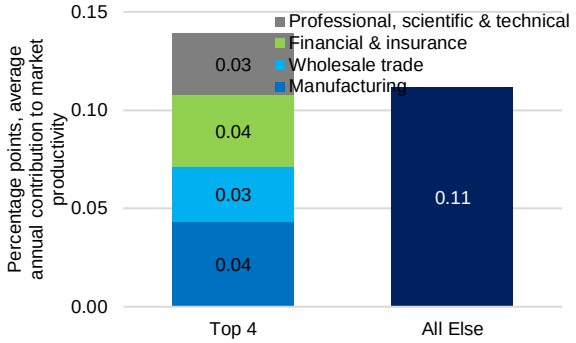
[40] Andrews, D. and Westmore. B. (2014).
[41]On an unadjusted basis, total hours worked equates an hour worked by a highly skilled surgeon with a new entrant into the workforce. Under the quality adjusted framework, however, lower quality hours have a reduced weighting and higher quality hours are more heavily weighted.
[42] ABS. (2019b).

Chart 18: The NSW workforce is becoming increasingly higher skilled



Source: ABS Table Builder and NSW Treasury

Chart 19: Composition of Australia's productivity growth



Source: ABS 5260.0.55.002 and NSW Treasury

R&D as a driver of multi factor productivity growth

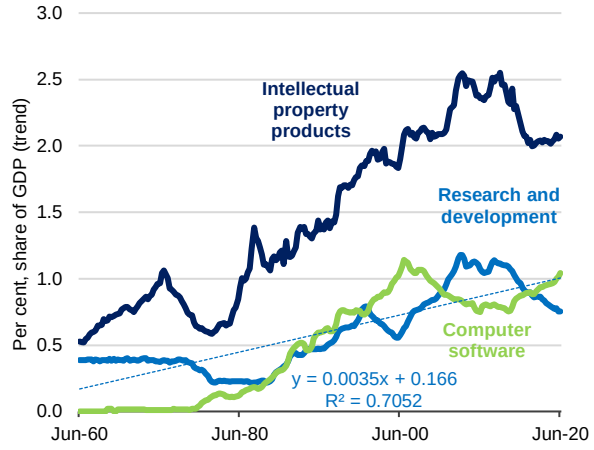
Appendix B discusses how New Growth Theory relies on the production of ideas to stimulate productivity growth. Alongside an educated workforce, R&D is a key driver of innovative ideas and has been responsible for life-changing inventions such as the computer, the steam engine, antibiotics, the printing press, and CSIRO's own innovation, WiFi. It is generally accepted that R&D support productivity over time, yet its inherent uncertainty means econometric projections of this relationships (for example based on an elasticity of spending or intensity) lack reliability and external validity.[43]

Many studies suggest that while foreign R&D can positively impact domestic productivity, a stronger relationship exists with national and state R&D spending.[44] Despite these findings, Australia continues to produce relatively weak rates of R&D intensity as a share of GDP, compared to other OECD member countries (Chart 20). Some evidence also suggests investment in performance assessment (a key feature of good management) is declining.[45]

Australian R&D investment trends are out of step with other high productivity countries. The OECD average R&D intensity has been trending upwards for several decades, reaching 2.4 per cent of GDP in 2017, while Australia's R&D intensity has declined from 2.2 per cent of GDP in 2009 to 1.8 per cent of GDP in 2017. This decline has been broad based across industries and states, yet the steepness largely reflects a decline in engineering R&D intensity of over 50 per cent as Australia's mining boom completed its capital-intensive phase.[46] The NSW Government has tasked Parliamentary Secretary Gabrielle Upton with leading an initiative to accelerate R&D investment in NSW.

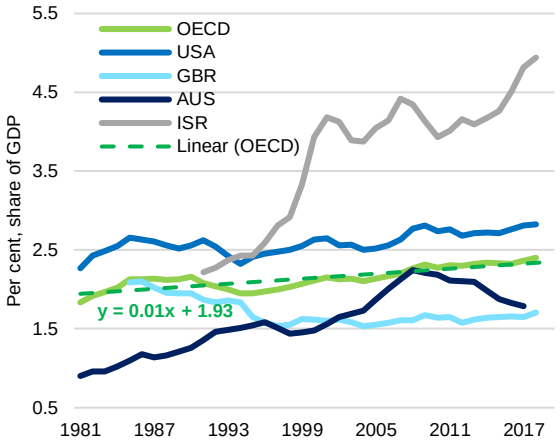
[43] Shanks, S. and Zheng, S. (2006).
[44] Williams et al. (2003) states "a 1 per cent increase in a state's own domestic business R&D stock would raise MFP by 0.056 per cent in that state [and] a 1 per cent rise in the R&D stock in the rest of Australia will on average raise MFP by 0.039 per cent in each state."
[45] Productivity Commission. (2019).
[46] Productivity Commission. (2019).

Chart 20: Research and development intensity has declined in Australia[(a)(b)]



[(a)]Intellectual property products include computer software, R&D, mineral & petroleum exploration and artistic originals
[(b)]Brand equity, firm-specific human capital and organisational capital are not treated as investment
Source: ABS 5260.0.55.002 and NSW Treasury

Chart 21: R&D spending has been increasing in other countries



Source: OECD and NSW Treasury

The outbreak of COVID-19, and the associated economic downturn is likely to supress near-term improvements in R&D intensity given it tends to decline with periods of uncertainty and low business confidence (Box 1). In the June quarter 2020, R&D spending fell to its lowest level in 16 years. This will suppress productivity improvements in the near to medium term nationally and within the state.

However, longer term opportunities remain for R&D growth, with Australian research investment in 'technology' increasing by 27 per cent between 2015-16 and 2017-18, and investment in medical and health sciences growing 56 per cent over the same period. These fields of research have strong fundamentals and should support a longer-term increase in national R&D intensity.

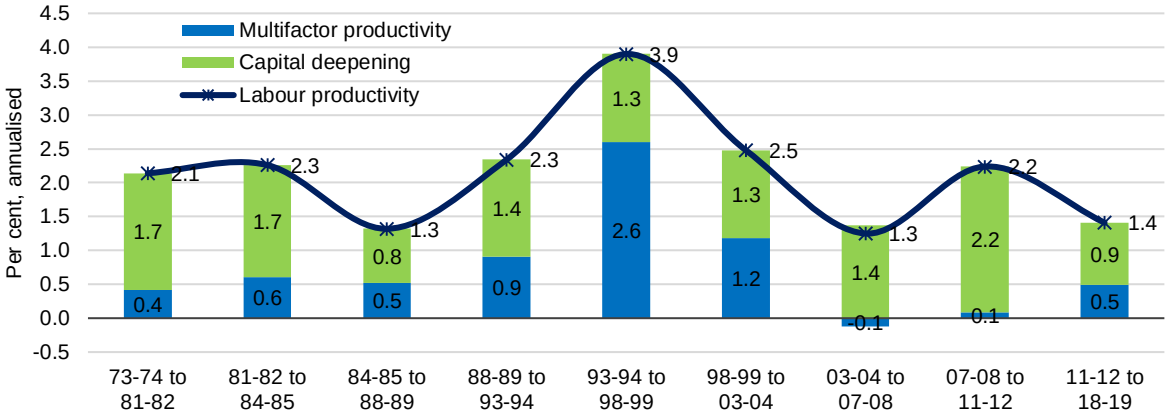
Identifying a market sector 'trend' rate of productivity growth in Australia

Productivity growth and multi-factor productivity growth are currently lower than the 'golden era' of productivity growth in the 1990s and is more aligned with growth in the mid-late 1980s. Chart 22 provides a long run view of Australia's labour productivity performance for selected market sector industries (15 of the 19 industries).[47] This market sector analysis highlights the consistent contribution of capital deepening to labour productivity growth for the market sector. It also highlights a slowdown in multi-factor productivity growth following the 1990's productivity surge.[48]

[47]Selected industries include *Agriculture, Forestry & Fishing, Mining, Manufacturing, Electricity, Gas, Water & Waste Services, Construction, Wholesale Trade, Retail Trade, Accommodation & Food Services, Transport, Postal & Warehousing, Information, Media & Telecommunications, Financial & Insurance Services, Rental, Hiring & Real Estate Services, Professional, Scientific & Technical Services, Administrative & Support Services, Arts & Recreation Services*

[48] State data limitations do not allow for a view of productivity growth as far back as national aggregates

Chart 22: A long run view of national productivity growth in 'selected industries' suggests MFP driven growth seen in the 1990s was an outlier



Source: ABS 5260.0.55.002 and NSW Treasury

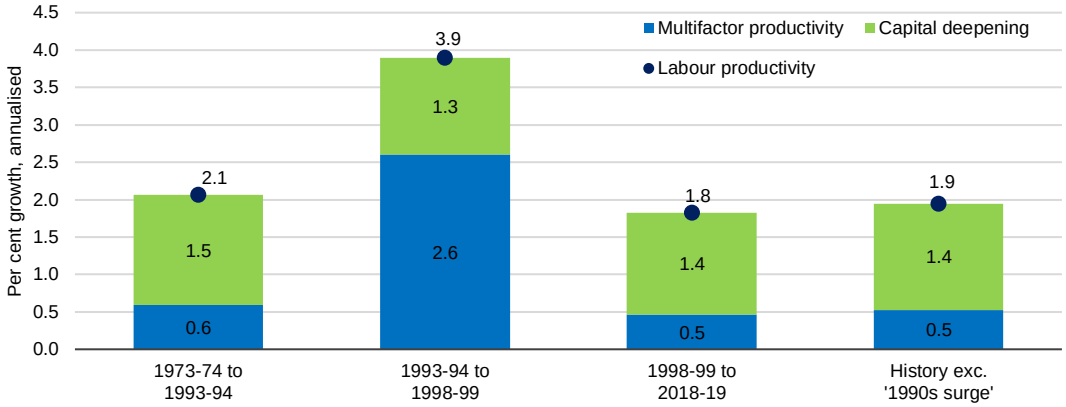
Multifactor productivity growth in the 1990s was an extraordinary period in Australia's (and New South Wales') economic performance over the past 50 years. This period was primarily the outcome of a series of once-in-a-generation macro and microeconomic reforms of the 1980s and 1990s.[49,50] These reforms included competition policy and trade liberalisation and far outweighed any potential gains from international convergence, a post-recession rebound, an education and skills dividend, or technological advances.[51] It is estimated that of the one percentage point acceleration in MFP growth in the 1990s, 0.5 percentage points can be attributed to increased openness, three-tenths to domestic R&D, and two-tenths to ICT-related innovation.[52]

It is therefore likely that this policy-driven productivity growth outlier has been positively skewing Australian and NSW long-run productivity assumptions for the past two decades. A common modelling approach to prevent time-series outliers (for example those resulting from extraordinary policy reforms) negatively impacting the validity of forward projections involves identifying and removing structural breaks.[53] This methodology for addressing outliers is particularly relevant for the NSW IGR, given all economic and fiscal projections are on a no policy change basis, so as to identify the underlying structural outlook.

Removing the 1990s productivity surge from the historical trend data may provide a more robust estimate of the long run 'trend' rate of MFP growth within the Australian and NSW market sector. Prior to the 1990s, productivity growth in the selected Australian market sector industries averaged 2.1 per cent per annum, MFP contributed 0.6 per cent and capital deepening 1.5 per cent (see chart 23). Similarly, in the period following the 1990s, productivity growth in these market sector industries has averaged around 2 per cent per annum with similar contributions from MFP and capital deepening.

[49] D'Arcy, P., Gustafsson, L. (2012).
[50] Commonwealth's Productivity Commission (2009); Parham, D. (2003); Parham, D. (2003a)
[51] Parham. (2003).
[52] Ibid
[53] Gordon R. (2014); Gordon R. (2015); Fernand G. J; Jones, C. I. (2014).

Chart 23: NSW productivity growth in selected industries has been relatively consistent outside of the '1990s surge'



Source: ABS 5260.0.55.002 and NSW Treasury

These results support the removal of the 1990s productivity surge from the historical time-series from which long-run productivity is projected. This would result in a long-run productivity growth rate of around 2.0 per cent per annum for these selected industries, with MFP contributing 0.5 per cent per annum and capital deepening 1.4 per cent. From 1979-80, productivity growth in the selected industries has outperformed the whole of the economy by 0.6 percentage points annually, on average, implying the non-market sectors receives less measured returns to innovation and policy reforms. Taken together, this would reduce the Australian long-run labour productivity assumption to 1.3 to 1.4 per cent per annum. For NSW this would result in a long-run productivity growth rate assumption of 1.1 to 1.2 per cent per annum, once the 0.1 to 0.2 percentage point discount from state-wide convergence is applied (see previous chapter).

Risks and Opportunities for Productivity Growth in New South Wales

Opportunities for an innovation and technology driven productivity recovery

The current rate of technological change is unprecedented, yet its influence on measured productivity is less clear. Over time, many technologies have transformed humankind's capacity, from the written word and paper, to the wheel and transportation, and more recently the internet, personal computers and internet search engines. While it seems logical and intuitive that these technological shifts would instantly boost productivity, given their impact on our lives, it is inherently difficult to predict the associated scale and timing of these impacts. Given we are living through the information age, characterised by digital technology and automation, understanding the scale, timing, and returns to productivity has critical implications for assessing future productivity growth.

Technology can automate or augment tasks, both of which can have quite different implications for productivity. Task automation reflects the technological replacement of a traditionally human task, for example car manufacturing production lines have evolved to rely much more on robotics. Automation therefore refers to the classic productivity situation of producing the same thing more cost efficiently. Augmentation discusses the process by which humans collaborate with technology to enhance the other's capabilities. Humans are therefore still involved in delivering the task but the strengths of both the machine and the human are utilised. Augmentation can mean both delivering a task more cost efficiently, whilst it can also lead to doing tasks that were previously not possible, for example the personal computer.

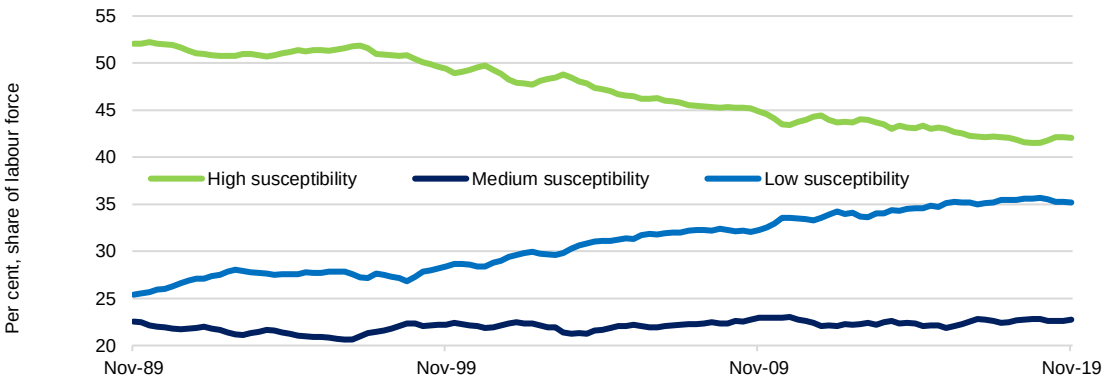
Brynjolfsson et al (2017) modelled the potential impacts of automation on productivity in using the example of autonomous vehicles on the United States' 2 million likely impacted motor vehicle

operator jobs.[54] They projected a potential productivity boost of 1.7 per cent higher after 10 years (0.17 per cent higher annually), assuming hours worked are fully replaced by automation and the economy was able to produce the same output. Applying this modelling framework to NSW, where 39 per cent of hours worked are considered at high risk of automation,[55] the economy would become 59 per cent more productive. Over the next forty years, this would see an average increase in productivity growth of 1.5 per cent a year from automation alone.

These projections are dependent on the highly variable assumptions made regarding jobs susceptible to automation over the medium-term. Some suggest the world is yet to go through its most significant automation period, with up to 45 per cent of United States labour force considered automatable.[56] Others suggest there may be as little as five per cent of tasks within susceptible occupations that can be entirely automated.[57] A task-based approach to automation, such as the OECD's, which considers the heterogeneity of workers' tasks within occupations appears to be a more effective approach for quantifying workforce automation. This will be explored further in the NSW 2021 IGR.[58] Additionally, economic, legal, regulatory and organisation constraints can act as barriers to automation potential being realised,[59] which can partially explain why growth in hours worked in NSW "high automation risk" occupations have exceeded that of "low automation risk" occupations over the past five years.[60]

Automation also carries some downside labour productivity risks. Automation tends to occur in lower paying manual jobs, requiring minimal education, that are highly routine. Should education and skills systems not be there for displaced employees, automation can increase inequality and a mismatch of skills to task, ultimately holding back productivity growth. Automation therefore must be coupled with augmentation and an adaptable workforce to maximise the productivity rewards. Fortunately, augmentation is seemingly having a greater impact on the labour market than automation, a trend that is expected to continue over time.[61] New South Wales' workforce is also becoming less susceptible to automation over time, with 37 per cent of women currently in "low automation risk" occupations, and 33 per cent of males (Chart 24).[62]

Chart 24: Automation susceptibility in New South Wales



Source: ABS 6291.0, Edmonds & Bradley (2015) and NSW Treasury

Predicting the time period and the scale of recent and future technologies on productivity remains challenging. The coexistence of unprecedented rates of technological change and historically low

[54] Brynjolfsson. E. et al. (2017)
[55] ABS 6291.0, Edmonds., Bradley. (2015) and NSW Treasury.
[56] Frey, C. B., Osborne, M.A. (2013)
[57] McKinsey Global Institute. (2017)
[58] Arntz, M.. et al. (2016).
[59] PwC notes. (2018),
[60] McKinsey Global Institute. (2015) Hours worked in high risk occupations have risen by 2.3 per cent annually over the five years to 2018-19. This exceeds the growth in low-risk occupations of 1.7 per cent growth over the same period.
[61] Miller, S. M. (2018).
[62] ABS (2020); Edmonds, D. and Bradley, T. (2015); NSW Treasury.

levels of productivity growth can be explained by one, or a combination of, relative impact, delayed impact, and mismeasurement. The relative impact theory suggests these technologies are relatively less productivity enhancing than those of previous decades.[63] Delayed impact theory hypothesises that the productive benefits of these technologies are yet to have fully been realised in measured productivity.[64] Finally, mismeasurement theory explains the benefits of these technologies are largely captured outside of measured productivity (Box 2). The combination of these factors can partially explain the productivity paradox currently being experienced today.[65]

Box 2: Productivity mismeasurement

The weakening global productivity growth this century appears at odds with rapid technological innovation over this period. This tension has led some commentators to token it the 'modern productivity paradox'.[66,67,68] This is in reference to Robert Solow's (1987) paradox where he noted, *"you can see the computer age everywhere but in the productivity statistics"*. This paradox was ultimately resolved in the late 1990s to early 2000s when the US underwent an 'ICT revolution' that boosted productivity growth locally and internationally for about a decade.

The modern productivity paradox raises the same question it did in 1987 - is productivity being underestimated? Specifically, where are the significant gains from innovation and information and communication technology (ICT), that are driving today's technological change, showing up in the productivity data?

The national accounts or gross domestic product (GDP), from which productivity estimates are based, does not include consumer surplus. That is the difference between the consumers' willingness to pay for a good and the amount that is actually paid. The significance of this is that many new ICT goods and services, like smartphones, social networks, and downloadable media involve little to no monetary cost, yet consumers spend large amounts of time with these technologies. Therefore, these digital technologies might deliver substantial utility even if they account for a small share of GDP due to their low relative price.

Many commentators have questioned the very nature of the productivity slowdown, putting it down to simple mismeasurement. Feldstein (2017) goes as far as suggesting that, *"the measurement problem has become increasingly difficult with the rising share of services … The official measures provide at best a lower bound on the true real growth rate with no indication of the size of the underestimation."*

Other studies suggest mismeasurement is not the entire or even a substantial explanator for the slowdown.[69] While there is evidence that some of the benefits of new digital technologies are not being reflected in the national accounts, earlier eras also had the same unmeasured quality component problems—welfare gains from telephones, antibiotics and teacher quality.

In summary, mismeasurements may be a partial explanator for low productivity growth and should be considered alongside the weakness present in related economic indicators such as wages and income growth.

Automation and augmentation are supported by growth in R&D intensity which is anticipated to continue to grow. Nations outside the US have also increased their R&D intensity rapidly over the past few decades, with China, India and South Korea notable contributors, while the private sector is stepping into research spaces previously held by government. The collection and utilisation of

[63] Gordon. (2012).
[64] Moore's law is the observation that computer power (the number of transistors in a dense integrated circuit) doubles about every 18 months. Brynjolfsson and McAfee link this with the current progress of technology in the economy.
[65] Brynjolfsson, E. et al. (2017).
[66] Derviş, K. et al. (2016).
[67] Brynjolfsson, E. et al. (2017).
[68] Remes, J. et al. (2018).
[69] Remes, J. et al. (2018).

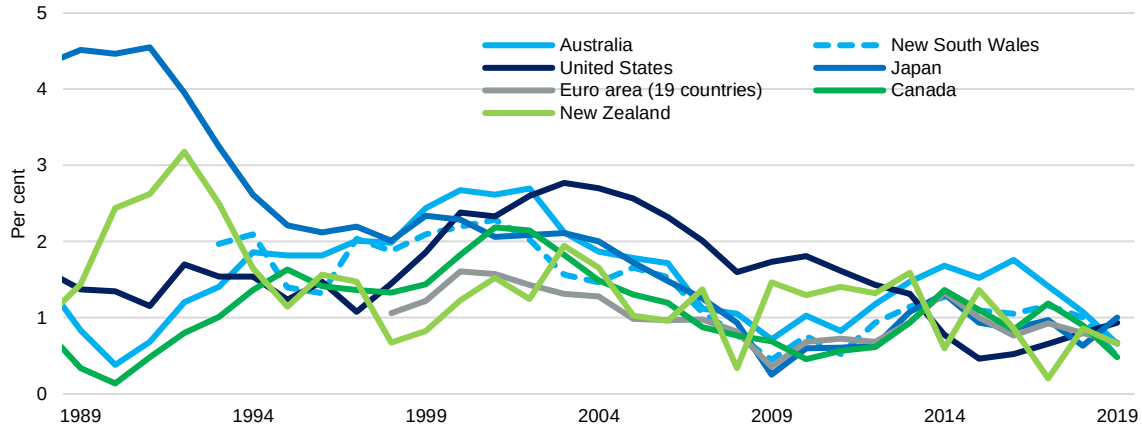
personal data has historically been dominated by government; however, this is no longer the case, with the business models of today's largest technology companies FAANG (Facebook, Amazon, Apple, Netflix and Google (Alphabet)) all heavily reliant on personal data. This has the potential to continue to push the technological frontier further out and create R&D competition within and across countries.

Over the next 40 years, the productivity risks from automation and augmentation are generally weighted towards the upside. The New South Wales economy will clearly undergo significant changes over this long period, with artificial intelligence, robotics, and smart technology likely to become more entrenched in the lives of people and business. The uncertainty around the size and scale of the implications on productivity lend themselves more towards sensitivity analysis, rather than being adopted in the IGR's baseline projections.

Downside risks to productivity growth

Sustained slow productivity growth in the international economy is the most significant risk to NSW productivity growth (Chart 25). Chapter 3 highlighted the importance of the United States and other highly productive economies in driving New South Wales productivity growth through innovations and R&D. Should productivity growth remain historically soft in these countries over the long-term, it is likely the New South Wales economy will experience this plight with them. This will be discussed in a future Treasury Technical Research Paper on Secular Stagnation and Long-Term Interest Rates.

Chart 25: Labour productivity growth, GDP per hour worked, 5-year rolling average



Source: OECD GDP per hour worked (USD, 2015 prices, PPP), New South Wales Treasury

There are several headwinds facing international productivity growth that provide downside risks for New South Wales. The world is currently in an economic and fiscal crisis as a result of the COVID-19 outbreak. While the global response will be crucial in how productivity growth recovers. Addressing the several underlying structural challenges to the global economy will be even more critical for sustainable productivity growth. These structural challenges include population ageing, inequality, rising debt, secular stagnation, climate change, and geopolitical concerns (such as protectionism).

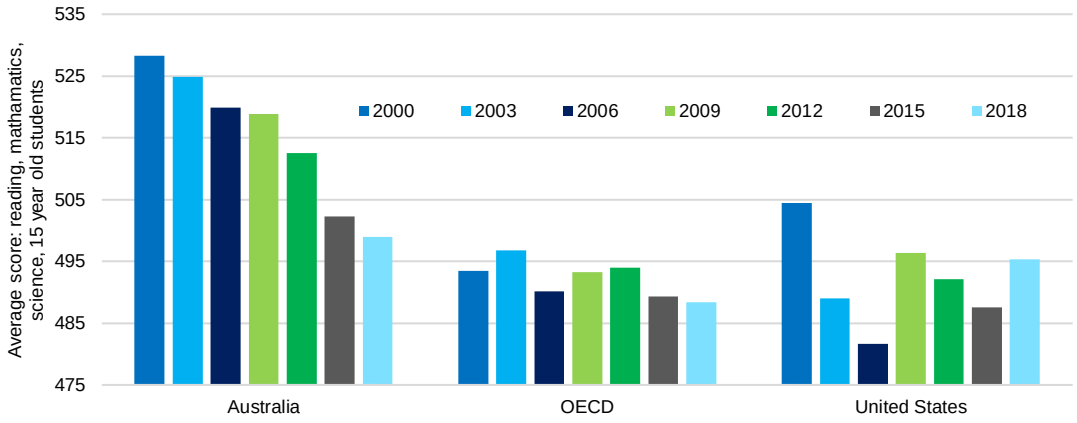
The United States faces strong economic challenges, which is concerning given the United State's role as a global productivity driver. Inequality is generally correlated with productivity to a point, as it acts as a motivator for hard work and innovation. Beyond this point it can negatively impact productivity,[70] particularly if inequality is entrenched over time. The IMF and OECD suggest a one point rise in the Gini coefficient can reduce economic growth by around 0.1 percentage points annually.[71] The Gini coefficient has risen by about 7 points in the United States in the 37 years to 2016. Real wage growth outside of the top 20 per cent of income earners has also been relatively stagnant for close to thirty years. For Australia, the Gini coefficient has risen by 2.6 points between

[70] Ostry, J. et al, (2014).
[71] Cingano. F. (2014).

1995 and 2018, suggesting trend growth could be around 0.25 percentage points below its 1995 rate.[72]

Plateaued education levels within the United States and Australia are also concerning (Chart 26). Human capital has been responsible for 20 per cent of United States productivity growth between 1950 and 1993.[73] Underpinning poor education outcomes are diminishing marginal returns from the education received, and the high costs of United States education. This has risen by 241 per cent compared to 145 per cent for GDP per capita and 77 per cent for the basket of goods and services in the CPI. The relevance of an ageing population on labour productivity is also a downside risk given labour productivity can decline after middle age, depending on factors such as the effectiveness of the skills system.[74]

Chart 26: Australia's relative performance over time in the OECD's Programme for International Student Assessment (PISA)



Source: OECD PISA and NSW Treasury

The changing climate and associated reduced demand for non-renewable energy provides a downside risk to New South Wales' productivity growth. As highlighted in Chapter 3, mining is currently New South Wales most productive industry, extracting $226 Real Gross Value Added per hour worked. Global coal demand is projected to decline over the next forty years. This will negatively impact productivity growth in the absence of New South Wales transitioning these workers into similarly productive industries. NSW Treasury has committed to costing the major economic and fiscal impacts of climate change for the 2021 IGR.

More recently, the COVID-19 health and subsequent economic and fiscal crisis could have some long-lasting impacts on productivity growth. It is, however, too soon to determine whether this is more weighted to the upside or downside. Some industries have seen significant challenges to both demand (for example inner city cafés experiencing weaker foot traffic) and supply (for example the arts sector being restricted from opening venues to the public).[75] Reallocation of labour has therefore occurred, with parts of the labour market exploring new industries and organisations.

Many businesses have re-evaluated and adjusted their product offering to remain viable and relevant to consumer demands.[76] Enforced or encouraged flexible working arrangements has also forced companies, employees and consumers to utilise and develop their capabilities in connective technologies.[77] Through innovation, and skill matching, aspects of these elements of creative destruction will likely support long-run productivity growth.

[72] ABS (2017). 6530.0 Household Expenditure Survey, Australia.
[73] Fernald, G. J. and Jones, C. I. (2014).
[74] Productivity Commission. (2005).
[75] Borland, J., Charlton, A. (2020).
[76] NSW Productivity Commission. (2020).
[77] NSW Innovation and Productivity Council. (2020)

Offsetting some of these upside productivity risks includes the possibilities of continued uncertainty and long-term scarring reducing investments in research & development and capital deepening.[78] NSW is an open economy, highly dependent on trade and overseas migration for economic growth and meeting skills shortages. The long-term impact of COVID-19 on global value chains and people flows is yet to be determined, and could pose a downside risk to productivity if connections between people and markets are reduced. Finally, government interventions, both locally and internationally may limit the extent to which creative destruction is realised.

Within New South Wales, there remain additional structural challenges. The New South Wales Government has been actively seeking to identify and address these through the NSW 2040 Economic Blueprint, the Review of Federal Financial Relations, and the Productivity Commissioners Green Paper. These paper's highlight structural weaknesses in the Australian and New South Wales tax systems, regulatory settings, skills system, and infrastructure, housing & planning. Addressing these could partially offset the international headwinds and continue to support New South Wales as a high productive economy, by international standards.

[78] Kozlowski, J. et al. (2020).

5. Conclusion

This paper analyses methodologies used by national and international economic and financial institutions to project economy-wide long-run labour productivity growth and assesses some of the key drivers of NSW productivity growth. The primary purpose of this exercise was to identify the most appropriate methodology for NSW Treasury to adopt in projecting long-run labour productivity growth in the next NSW IGR, to be published in 2021. This also served to enhance the public's understanding of long-run sub-national productivity growth, considering a majority of academic studies primarily focus on national growth.

Previous NSW IGRs have assumed long-run labour productivity would continue to grow at rates consistent with the average growth over the previous 30-years. This appeared a relatively crude approach to such an important component of the NSW LTFPM, where economic and fiscal drivers are often projected using complex and detailed methodologies. Additionally, NSW productivity growth has softened since the historically strong period in the 1990s, resulting in continued downward revisions in long-run productivity growth projections, from 1.75 per cent per annum in 2006, to 1.6 per cent in 2011, and 1.5 per cent in 2016. Applying this methodology to the data to 2018-19 would result in another downward revision to 1.3 per cent per annum.

A review of the methodologies used by economic and financial institutions locally and internationally to model long-run labour productivity growth found that the approach applied by NSW Treasury was in line with international best practice. While there are minor variations in technical details in how this methodology is applied, the use of a historical average growth rate to project long-run labour productivity is the primary methodology used by leading economic and fiscal institutions. The primary rationale for this methodology is the complexity and uncertainty surrounding long-run productivity growth. Therefore, a simplistic methodology that encompasses a long-time period of data is viewed as more robust than attempting to estimate the growth paths of individual drivers of economy-wide productivity growth.

Analysis of trends and impacts of the underlying drivers of NSW long-run productivity growth complimented the results from the top-down approach. Productivity growth in NSW is likely to remain relatively subdued in the long run in the absence of improvements in international productivity growth and significant macro and micro economic reforms. The extra-ordinarily high productivity growth rates of the 1990s are a historical outlier, given the significant reforms and technological transformations that defined much of this period. Whilst NSW has long been the non-mining frontier for Australian productivity, the past 30 years has seen NSW's productivity grow more slowly than all other Australian jurisdictions, including below national average growth in 14 of Australia's 19 industries. This conditional convergence is expected to continue into the future. Technological advancements could present an upside risks to future productivity growth, with the NSW increasingly high-skilled NSW labour market providing a platform for firms to utilise labour more effectively to deliver goods and services.

In summary, projecting future productivity growth at a national or sub-national level is an inherently difficult task. The 30-year historical average methodology used in previous NSW IGRs appears to effectively balance the upside and downside risks to future growth and presents a representative sample size of numerous economic cycles. This methodology is also consistent with the approaches used by leading economic and financial institutions. Retaining this approach for the 2021 NSW IGR presents as a relatively robust baseline methodology. Given the relatively soft NSW productivity growth seen over the past 20 years, the five-year transition period to this equilibrium state seems optimistic. A slower transition (e.g. ten years) to this state should be tested for the NSW 2021 IGR, at least for sensitivity analysis purposes.

Appendix A: Productivity and the theory of economic growth

Important insights into labour productivity can be obtained supposing the economy is summarized by a simple production function:

(1) $Y = AK^{\alpha}L^{1-\alpha};\ 0 < \alpha < 1$

where Y is output, K is capital input, L is labour input and A represents the level of technology. In this setting, technology is understood broadly, to reflect how capital and labour are combined to produce value. Technology can include firm management practices and policies (although some of these are increasingly being catagorised under capital as intangible or knowledge-based).

Expressing the production function relative to labour inputs, we obtain:

(2) $\Delta y = \Delta A + \alpha \times \Delta k$

where the lower-case letters denote quantities per unit of labour inputs, delta (Δ) indicates the rate of change, y is the amount of output produced per unit of labour input and k is the capital–labour ratio.

This equation tells us that the growth of labour productivity (Δy) is equal to the change in technology (ΔA) plus the rate of capital deepening (Δk) weighted by capital's share of the output (α).

Growth accounting literature separates out the changes in output due to capital deepening and multifactor productivity (MFP). In this literature, MFP is typically described as technology and technical innovation. MFP is not directly measurable, and is identified as a residual, being the part of the growth of per capita income which is not due to the (weighted) growth of capital per person.

Cobb-Douglas production function

The Cobb-Douglas production function set out in Equation (1) forms the basis of the Solow-Swan model of economic growth, which provides powerful insights into the role of capital accumulation in economic growth.

Empirically, capital accumulation has played an important part in driving economic growth. The model predicts this effect will diminish as economies approach the technological frontier (for example, use the world's most advanced technologies). In the very long run, the model predicts that changes in MFP are the only source of increases in output per person, so that rates of economic growth will slow as economies reach the frontier.

This in turn gives rise to a prediction that different countries' growth rates will 'converge' to the rate of growth of MFP. A simple notion of convergence suggests that developing countries should grow faster than the most developed countries, as their technology 'catches up'. In practice, institutional differences between countries provide reasons for divergence of national growth rates.

The theory of 'conditional convergence' controls for these institutional differences. This theory suggests that convergence of growth rates should be seen in countries or regions with similar institutional arrangements. There is evidence of conditional convergence between Organisation of Economic Cooperation and Development (OECD) member countries, given these countries are generally working towards comparable government institutional, economic and financial settings.

Issues with the simplest models

Through much of the twentieth century, it appeared that the returns to capital and labour represented relatively constant shares of the economy. The Cobb-Douglas function of equation (1) incorporates this idea, with the constant α determining the returns to capital as a share of output. Over recent decades, however, labour's share of output has diminished and studies looking over centuries of data have now provided evidence of great variation in factor shares (Piketty et al, 2014).

The production function of Equation (1) supposes that technology is 'Hicks-neutral', providing equal boosts to the marginal productivity of both capital and labour. Alternative specifications would permit technology to be capital-augmenting: Y = F(AK, L), or labour-augmenting Y=F(K,AL). The fact that capital and labour shares empirically vary greatly over the long-run means greater attention will need to be given to capital-augmenting technology. Economic growth in the Solow-Swan model is predicted to converge to the growth of MFP, however it does not explain why MFP grows.

Appendix B: New growth model—the role of ideas in production

This section presents a representation of the new growth model presented by Charles Jones (2002), in *"Sources of U.S. Economic Growth in a World of Ideas".* A key point of difference between the neoclassical growth model outlined in Appendix A and modern growth theory is that MFP (A) is calculated as a residual in the former while the latter explains that residual in terms of economic forces — the stock of ideas. Central to this production function is the non-rivalry of ideas, which leads to increasing returns. Economic output depends on the total number of ideas, not ideas per person. This contrasts sharply with capital or other rival inputs.

Starting with the representation of the Cobb-Douglas production function below:

(1) $Y = A^{\sigma}K^{\alpha}H^{1-\alpha};\ 0 < \alpha < 1;\ \sigma > 0$

K is physical capital, H is the total quantity of human capital employed to produce output, and A is the total stock of ideas available to this economy. For simplicity there are constant returns to scale in K and H, when holding the stock of ideas (A) constant, and increasing returns to K, H, and A together. This assumption reflects non-rivalrous nature of ideas.

An amount of capital (K) is determined by a depreciation rate and by how much consumption society is willing to forgo. Human capital employed (H) in producing output is determined by the amount of human capital per worker (educational attainment) and amount of raw labour used in production. Human capital per worker is produced by forgoing time in the labour force.

The final factor of production is A, the stock of ideas. This corresponds to the cumulative stock of ideas created anywhere in the world and is common to all economies. New ideas come from the below idea production function, which depends on the number of people looking for new ideas as well as the existing stock of ideas:

(2) $\mathring{A} = \mathrm{R}f(\mathrm{A}) = RA^{\phi}\ ;\ \phi < 0$

Where $\mathring{A}$ represents the flow of new ideas, and R represents the weighted sum number of researchers (the weighting adjusts for human capital). In the long run, the number of ideas is proportional to the number of researchers. Therefore, population and research scale matters for idea-based economies. Finally, $\phi < 0$ captures the possibility of duplication in research: if the number of researchers doubles at a point in time, the number of unique discoveries may less than double.

This representation of production highlights the importance of education (human capital), and research and development (research scale and intensity), to drive improvements in multi-factor productivity (through the stock of ideas).

The key idea of the Solow-Swan model (Appendix A) is that capital accumulation can be a source of economic growth. But capital accumulation runs into diminishing returns. Ultimately, the model's equilibrium growth rate is determined entirely by technological change, which the theory does not explain.

In the 1990s, theorists sought an economic explanation for the drivers of technological advances ('endogenous' sources of growth). Romer (1990) provided the key insight, that ideas are non-rivalrous: they can be used by any number of people simultaneously. As Jones (2019) explains, including non-rivalrous ideas as a factor of production is sufficient to generate an aggregate production function with increasing returns, and this in turn is sufficient to generate exponential growth.

Pursuing the central role of ideas in generating economic growth, theorists have examined the incentives to invest in research and development, international trade as a vector for the transmission of ideas, and Schumpeterian processes of new product creation, either replacing or improving the quality of earlier goods.

A difficulty with many endogenous growth models is that they predict that increased resources devoted to research and development will yield higher productivity growth rates. In the United States, the share of the economy devoted to research has greatly increased over the past century and total population has greatly increased, but total factor productivity growth has been relatively steady over the same period. A recent paper suggests that these facts can only be reconciled if research

productivity (ideas per researcher) is falling as the number of researchers increases[79]. The notion that new and original ideas are getting harder to find is still being debated.

[79] Bloom et al, 2020

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