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SELECTED ISSUES

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November 4, 2021

Approved By
Asia and Pacific Department

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CONTENTS

REIGNITING PRODUCTIVITY GROWTH IN AUSTRALIA[1]

Unprecedented macro policy stimulus and relatively quick suppression of the virus in 2020 helped the Australian economy recover strongly from the recession induced by the COVID-19 pandemic. Although recent outbreaks pose new near-term challenges, attention is also increasingly turning towards the need to reignite productivity growth, which had slowed significantly before the pandemic. A strong structural reform push can help address long-standing challenges that constrain productivity growth. Key priorities include increasing productivity-supporting investments in R&D and information and communication technology (ICT) and renewed product market reforms to enhance competitive forces.

A. Introduction

1. **Productivity growth, the key driver of improvement in living standards, had slowed in many advanced economies heading into the pandemic.** As discussed in Adler and others (2017), the widespread slowdown in total factor productivity has been attributed to various factors, including hysteresis effects from the global financial crisis (weak corporate and financial sector balance sheets, combined with elevated uncertainty, held back productivity-enhancing investments) as well as structural headwinds that pre-dated the financial crisis (waning of the ICT boom, slowdown in global trade, and headwinds from demographic changes).

2. **Australia has also witnessed a productivity slowdown.** While Australia avoided a recession during the global financial crisis (GFC), and a mining boom initially supported productivity growth, there has been a marked deterioration in productivity dynamics in Australia in recent years. Spillovers from the weak global environment have potentially contributed to Australia's weak performance. At the same time, country-specific factors have also played a role in Australia's productivity slowdown.

3. **This paper takes a medium-term view in analyzing Australia's productivity performance, zooming in on the role of productivity-enhancing investments and competition in explaining the productivity slowdown.** The paper finds that a decline in R&D and ICT investment—which tend to be more productivity-enhancing than other types of investments—is likely contributing to the productivity slowdown in Australia. Firm level analysis suggests that tax incentives can promote R&D investment, especially among smaller firms. In addition, reducing uncertainty, stepping up direct spending by government on R&D, and incentivizing university-business collaboration can help promote innovation. Various metrics of product market competition (markups, concentration, and form entry and exit rates) have also deteriorated in Australia (Bakhtiari, 2020; Hambur 2021), potentially adding to productivity headwinds. Enhancing product market competition through continued deregulation and promoting efficient resource allocation by reducing entry barriers and financing constraints for SMEs can help promote productivity growth.

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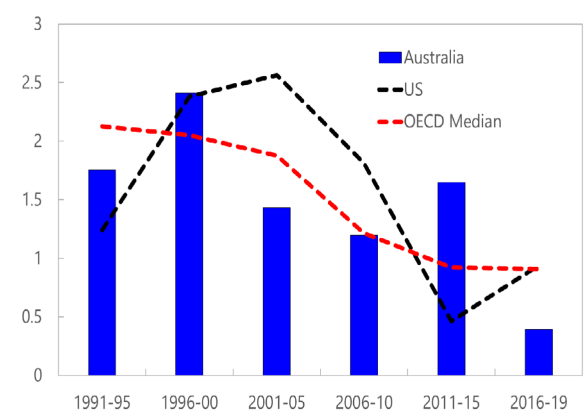
[1] Prepared by Yosuke Kido and Siddharth Kothari (both APD). The chapter benefited from valuable comments from Commonwealth Treasury of Australia, Department of Industry, Science, Energy and Resources, Reserve Bank of Australia, and participants at a virtual seminar.

4. The rest of the paper is structured as follows. Section B takes a deeper look at Australia's productivity dynamics, including at the industry level. Section C explores the role of lower investments in R&D and ICT in explaining the productivity slowdown in Australia. Section D focuses on the decline in competition in Australia in recent years. Section E explores the potential impact of the COVID-19 pandemic on productivity in the medium term. Finally, Section F discusses policy considerations for reigniting productivity growth.

B. Australia's Productivity Performance

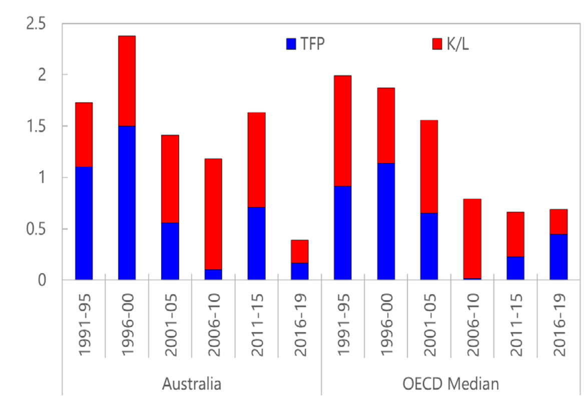
5. Labor productivity growth in Australia has slowed in recent years. Australia witnessed strong productivity growth through the 1990s, supported by significant structural reforms. And while many advanced economies witnessed a decline in productivity growth after the global financial crisis, Australia initially avoided a slowdown, in part due to a mining boom. However, labor productivity growth has weakened significantly in recent years, from an average growth of 1.6 percent between 1990 and 2015, to only about 0.4 percent between 2016 and 2019, falling below the OECD median.

Labor productivity growth in Australia has slowed…
Labor Productivity Growth
(Percent)



Sources: OECD and IMF staff calculations.

…driven by lower TFP growth and a smaller contribution of capital deepening
Contribution of TFP and Capital Deepening to Labor Productivity growth
(Percent)



Sources: OECD and IMF staff calculations.

6. There has been a decline in total factor productivity growth as well as the extent of capital deepening. Total factor productivity, which captures technological progress and efficiency of resource allocation, has followed a similar trend to labor productivity, with a sharp slowdown in TFP growth witnessed after 2015.[2] Preliminary estimates suggest a further slowdown in TFP growth

[2] ABS identifies 2011-12 as the start of the latest productivity cycle. As our focus is to compare Australia's productivity trends to international peers, and as productivity cycles are not synchronized across countries, we simply look at productivity growth over five-year periods rather than over Australia's productivity cycles. Table 1 reports utilization-adjusted productivity growth for Australia, which controls for capacity utilization.

to -0.7 percent in FY2019/20 driven by COVID disruptions.[3] The fall in investment rates from an average of almost 27 percent of GDP between 2010 and 2015 to about 23 percent of GDP in 2019, has also contributed to the slowdown in labor productivity by reducing the role of capital deepening. Kido and others (2020) analyzed in detail the factors driving the decline in aggregate investment in Australia. In this paper, we focus on the slowdown in total factor productivity growth.[4]

Productivity Performance at the Industry Level and Adjusting for Input Utilization

7. **To analyze dispersion of total factor productivity growth across sectors, we look at industry-level data.** Utilizing ABS KLEMS industry data, which provides inputs and gross output of 16 market industries, industry-level productivity is analyzed. While data coverage is limited to market sectors, this exercise sheds light on whether the productivity slowdown stems from non-mining sectors or the mining sector, which tends to behave differently from other sectors.

8. **We also adjust for utilization of inputs in measuring industry level productivity.** The standard measure of total factor productivity (Solow residual) may reflect resource utilization in addition to technological progress (Fernald, 2014; Basu and others, 2006; and IMF, 2015). Thus, in this section, using industry-level output and input data, we isolate the role of utilization and construct a more accurate measure of productivity. In particular, we control for overall input utilization, including capital utilization and labor hoarding (labor efforts) based on the theoretical framework proposed by Basu and others (2006) and measure industry-level utilization-adjusted productivity.[5] With firm's cost-minimization conditions, they predict that the change in hours per worker proxies for capital and labor utilization (see Annex I for the methodology).

Table 1. Utilization-Adjusted Productivity Growth Rates for Mining and Non-Mining Sectors
(Average growth rates, percent)

		1995/96-2000/01	2001/02-05/06	2006/07-10/11	2011/12-15/16	2016/17-18/19
Non-Mining Market Sectors	Solow residual	0.65	0.32	0.04	0.45	0.16
	Utilization Adj. TFP	0.81	0.33	0.22	0.67	0.36
Mining Sector	Solow residual	0.83	-2.58	-2.42	-0.27	1.11
	Utilization Adj. TFP	0.82	-2.54	-2.44	-0.28	1.15

Sources: ABS and IMF staff estimates.
Notes: For non-mining market sectors, weighted average productivity growth rates of 15 non-mining market industries are reported, and productivity growth rates are weighted by gross value added Domar weights (two-period average weights). Solow residuals do not consider input utilization, while utilization-adjusted TFP controls for input utilization following Basu and others (2006).

[3] As noted in Productivity Commission (2021a), there was some increase in labor productivity in FY2019/20 as the sharp decline in hours worked led to temporary capital deepening.

[4] While not focusing on aggregate investment, we do take a more detailed look at the drivers of intangible investment in Australia, which we consider to be an important contributor to the TFP slowdown.

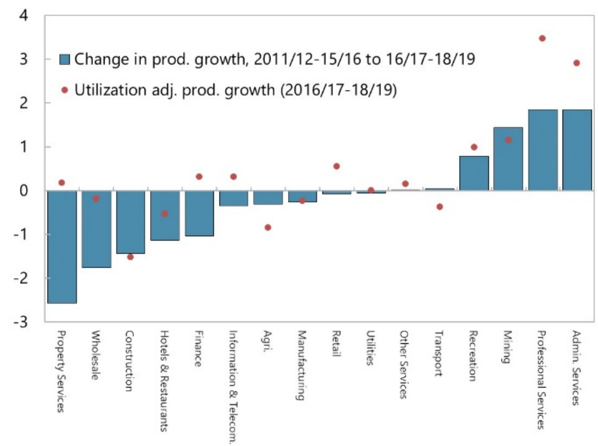
[5] Labor effort (labor utilization) reflects firms' efforts to utilize labor for a given length of hours. For example, in downturns, firms tend to hoard labor because they do not want to fire workers who have valuable skills that they will need in the future (Fernald, 2014). It should be noted that the average growth rates of utilization adjusted productivity measures do not necessarily equal the growth of Solow-residual-based TFP measures as the framework for utilization-adjusted productivity (Basu and others, 2006) estimates returns-to-scale in a production function, which is assumed to be 1 in standard growth accounting used to calculate Solow residuals.

9. A productivity slowdown in non-mining sectors is observed in recent years, even with the utilization-adjusted measure.[6] For both the simple Solow residuals and the utilization-adjusted measure, a slowdown in non-mining sector productivity growth is observed (Table 1). The utilization-adjusted productivity measure shows that the slowdown was broad based, with slowdowns in manufacturing, construction, and some services including accommodation and food services and wholesale trade. In the meanwhile, productivity in the mining sector picked up in recent years.[7]

Broad-based productivity declines were seen across industries in recent years…

Change in Average Growth Rates of Utilization-Adjusted Productivity

(Percentage points)

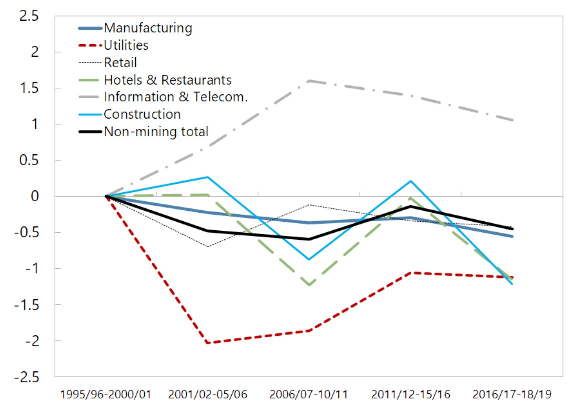


Sources: IMF staff estimates.
Notes: The bars show the change in average growth rates of utilization-adjusted productivity from 2011/12-15/16 to 2016/17-18/19. The dots show average growth rates of utilization-adjusted productivity for 2016/17-18/19. See Annex I for full results in a table format.

…and also in the long run in utilization-adjusted terms

Average Growth Rates Compared to 1995/96-2000/01

(Percentage points)



Sources: IMF staff calculations
Notes: The chart show the difference of average growth rates of utilization-adjusted productivity compared to 1995/96-2000/01. See Annex I for full results in a table format.

C. The Role of Declining R&D and ICT Investment in the Productivity Slowdown

10. Productivity-enhancing investment, especially in R&D and information and communication technologies (ICT), has declined to below that of peers. R&D investments are essential for the creation and adoption of new technologies and are thus considered to be a key driver of productivity growth (Griffith and others, 2004). In Australia, investments in R&D declined

[6] While the productivity of non-market sectors (e.g. health, education and public administration) is not analyzed in this section due to data availability, Productivity Commission (2021b) reports that a productivity slowdown has been observed also in the non-market sectors. While their share of employment in the economy has increased in recent years, their share of gross value added has declined.

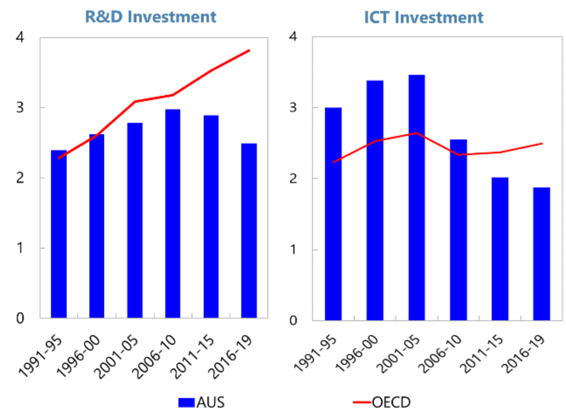
[7] There is high uncertainty around the estimates of utilization-adjusted productivity for the mining sector. A simple capital utilization adjusted productivity measure suggest slowdown in recent years (see Annex I for detail).

from about 3 percent of GDP in 2010 to less than 2.5 percent of GDP in 2019, falling well below the OECD median.[8] At the same time, investment in ICT has fallen from a peak of 3.5 percent a year between 2001-05 to below 2 percent of GDP in recent years, with both software and hardware investments having declined in recent years. By contrast, housing investment, which is potentially less productivity-enhancing, remains higher than in peers, in part reflecting Australia's relatively high population growth. Other building investment, including mining investment, also remains high, in part reflecting Australia's comparative advantage in the resource sector.

R&D and ICT investments have declined, falling below the OECD median…

Investment Rate

(Percent of GDP)

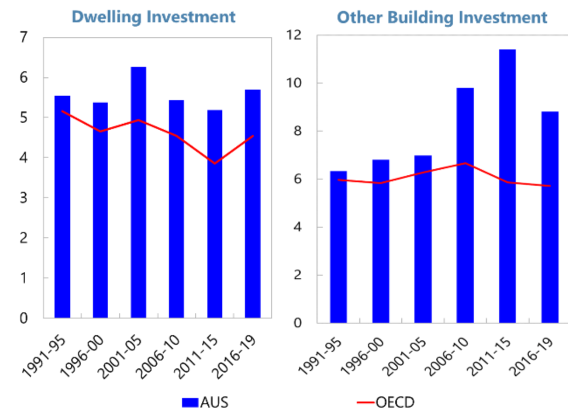


Sources: OECD and IMF staff calculations.

…while housing and other building investments remain high

Investment Rate

(Percent of GDP)

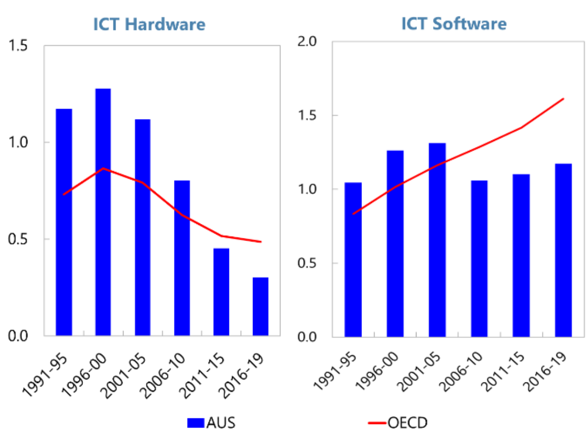


Sources: OECD and IMF staff calculations.

Software and hardware investment are now below the OECD median

ICT Spending

(Percent of GDP)



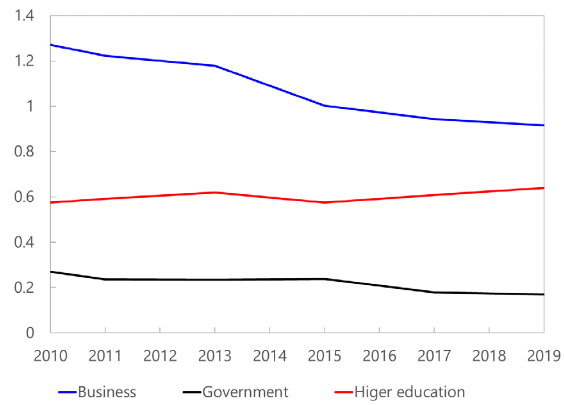
Sources: OECD and IMF staff calculations.

[8] We use the term R&D investment broadly. It includes all investments in intellectual property, including business research expenditure, mineral exploration, artistic originals, etc.

Lower business and government investment drove the decline in R&D…

R&D Spending

(Percent of GDP)

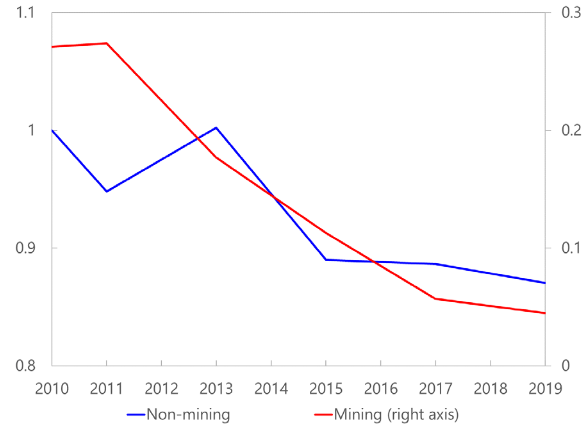


Sources: OECD and IMF staff calculations.

Both mining and non-mining business R&D declined

R&D spending

(Percent of GDP)

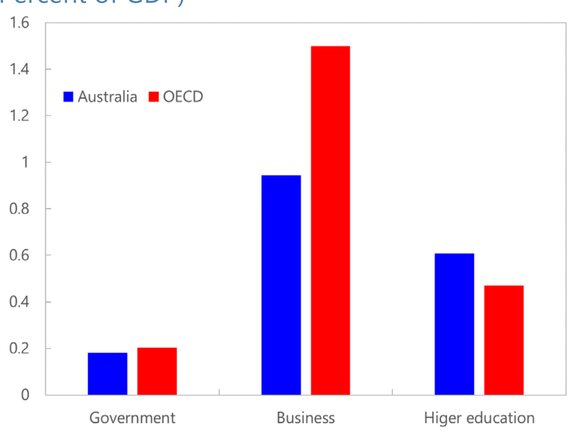


Sources: OECD and IMF staff calculations.

University R&D spending is above peers, but business and government spending are low

R&D Spending

(Percent of GDP)

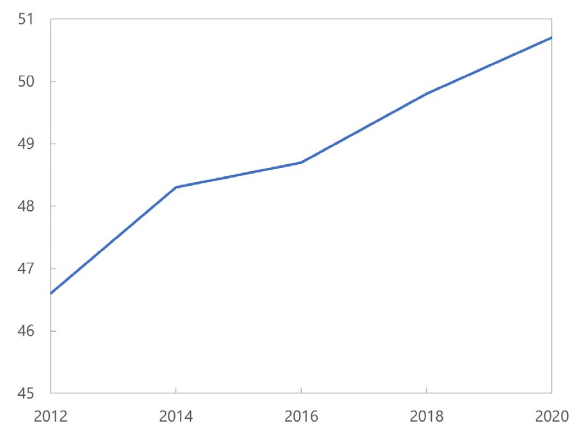


Sources: OECD and IMF staff calculations.

The share of firms undertaking innovative activities has increased

Innovation-Active Businesses

(Percent)



Sources: ABS, DISER.

11. Lower business and government R&D drove the overall decline in R&D spending, while measures of non-R&D innovative activities show mixed trends. Business R&D spending fell from over 1.2 percent of GDP in 2009-10 to less than 1 percent of GDP in 2019-20. The end of the mining boom and the resultant fall in exploration activity was a significant contributor to the overall decline in business expenditure in R&D. However, non-mining R&D investment also declined, as did government spending on R&D (which declined by almost 40 percent as a share of GDP, from about 0.27 percent of GDP in 2010-11 to 0.17 percent of GDP in 2019-20).[9] On the other hand, R&D

[9] While total R&D spending in the non-mining sector has declined, the trend across sub-industries is heterogenous, with some increase in R&D intensity seen in manufacturing and professional, scientific, and technical services. In

spending by universities has been maintained at about 0.6 percent of GDP over the last decade. Furthermore, while both government and business R&D are below those of peers, university R&D spending is higher than the OECD median. Spending on non-R&D innovative activities, such as investments in organization capital and in improving process efficiency, is almost as large as R&D spending in Australia.[10] There has also been a steady rise in the share of firms that are undertaking innovative activities. At the same time, total spending on non-R&D innovative investment is Australia lags behind the OECD average (AlphaBeta, 2020).

Impact of R&D and ICT Investment on TFP: Cross-country Industry Level Evidence

12. We use cross-country industry level data to assess the potential impact of R&D and ICT investment on total factor productivity. Exploiting EU KLEMS data on investment of different types (R&D, ICT, etc) and TFP growth for 40 industries (spanning agriculture, industry and service sectors) from 21 countries between the period 1995 and 2017, we run the following regressions:[11]

$$g_{c,s,t} = \alpha_{ct} + \alpha_{cs} + \alpha_{st} + \sum_{k=1}^{2} \beta_k * g_{c,s,t-k} + \gamma^j * x^j_{c,s,t-i} + \varepsilon_{c,s,t} \qquad (1)$$

where $g_{c,s,t}$ is the growth rate of productivity in country *c*, sector *s*, at time *t*, while $x^j_{c,s,t-i}$ is the investment to value added ratio with *j* indexing R&D, ICT and other capital investment. The regression controls for lagged productivity growth, as well as a comprehensive set of fixed effects including: country-time fixed effects (α_{ct}) to control for business cycle shocks impacting all sectors in a country in a year, country-sector fixed effects (α_{cs}) to control for time-invariant characteristics of each sector in each country, as well as sector-time fixed effects (α_{st}) to capture annual shocks that impact a sector across all countries (e.g. commodity price shocks which may impact the mining sector specifically). The coefficient γ^j can be used to assess the extent to which each type of investment is associated with productivity growth. Standard errors are clustered two-way at the country and industry level.[12]

addition, business R&D has also moved away from less R&D-intensive firms to more R&D-intensive firm, especially in professional and technical services. Majeed and others (2021) find that innovation and R&D are especially important in driving the performance of high-growth-firms.

[10] As noted in Satorra and Paunov (2021), relying solely on R&D as a share of GDP as a measure of innovation can be misleading given the role of non-R&D innovative investment and because the ratio can be impacted by developments related to GDP which do not impact innovation directly.

[11] While EU KLEMS does not have data for Australia, the relation between R&D and ICT investment and productivity that holds in other advanced economies is likely to be relevant for Australia as well.

[12] Despite controlling for a variety of factors through fixed effects, residual endogeneity concerns may remain. For example, firms may be able to predict future TFP growth based on current information and may adjust investment decision based on this leading to a correlation between $x^j_{c,s,t-k}$ and $\varepsilon_{c,s,t}$. This is likely to be of less concern for our regressions where investment is lagged by up to 5 years. Nickell bias (Nickell, 1981) is also unlikely to severely impact our coefficients of interest as the bias is of the order 1/T which is less than 4 percent given the long time-series component of our dataset.

13. The empirical analysis confirms the stronger positive association of R&D and ICT investment with TFP growth compared to other types of investment. Columns 1 through 3 of Table 2 report estimation results for equation 1 for different lags of R&D investment as a share of value added as the independent variable. While the coefficient on R&D investment is insignificant at lag one (column 1), it is positive and significant at lag three (column 2) and at lag five (column 3), indicating that R&D investments are associated with higher TFP growth though the effect takes a few years to materialize. A similar pattern is seen for ICT investment (columns 4 through 6) and other (non-R&D and non-ICT) investment (columns 7 through 9). Interestingly, the coefficients on R&D and ICT investment are larger than the coefficient on other investment, indicating that a 1 percentage point increase in R&D and ICT investment has a bigger positive effect on TFP growth in the medium-term compared to other types of investment. The results hold under several robustness checks (see Annex II for details).

Table 2. Impact of R&D and ICT Investment on TFP Growth

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	R&D	R&D	R&D	ICT	ICT	ICT	Other Investment	Other Investment	Other Investment
R&D Investment (lag 1)	0.0598								
	(0.115)								
R&D Investment (lag 3)		0.0386***							
		(0.005)							
R&D Investment (lag 5)			0.0983***						
			(0.027)						
ICT Investment (lag 1)				0.0739					
				(0.075)					
ICT Investment (lag 3)					0.0305*				
					(0.016)				
ICT Investment (lag 5)						0.0883**			
						(0.037)			
Other Investment (lag 1)							0.0143**		
							(0.006)		
Other Investment (lag 3)								0.0054***	
								(0.002)	
Other Investment (lag 5)									0.0237*
									(0.014)
L.TFP_gwth	-0.0701***	-0.0718***	-0.0764***	-0.0674***	-0.0698***	-0.0741***	-0.0673***	-0.0706***	-0.0739***
	(0.018)	(0.017)	(0.022)	(0.017)	(0.017)	(0.021)	(0.017)	(0.017)	(0.021)
L2.TFP_gwth	-0.0409***	-0.0469***	-0.0436***	-0.0415***	-0.0471***	-0.0459***	-0.0417***	-0.0510***	-0.0481***
	(0.006)	(0.007)	(0.009)	(0.006)	(0.006)	(0.009)	(0.006)	(0.007)	(0.008)
Constant	0.0071*	0.0079***	0.0056***	0.0065**	0.0081***	0.0056***	0.0065***	0.0082***	0.0042
	(0.004)	(0.000)	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.000)	(0.003)
Observations	9,570	9,570	8,640	9,486	9,486	8,556	9,486	9,486	8,556
R-squared	0.319	0.319	0.330	0.320	0.320	0.331	0.320	0.321	0.331
Country-Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Ind FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: IMF staff estimates.

Notes: Data from EU KLEMS at the country-industry-year level. Reports results for estimates of equation 1. Dependent variable in each regression is TFP growth. Column 1-3 have industry level R&D investment as a share of industry value added as the dependent variable at lags one, three and five respectively. Columns 4-6 similarly use ICT investment to value added at different lags as the independent variable, while columns 7 through 9 use other (non-R&D and non-ICT) investment as a share of value added as the independent variable. All regressions include country-time, country-industry, and industry-time fixed effects. Outliers in TFP growth (below 1 percentile and above 99 percentile) are excluded. Standard errors are clustered two-way at the country and industry level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.

14. Closing the investment gap in R&D and ICT investment between Australia and the OECD median can potentially raise TFP growth significantly. Back of the envelope calculation using coefficient estimates from Table 2 column 3 and column 6 suggest that raising R&D and ICT investment in Australia to the OECD median can be associated with an increase in TFP growth of about 0.1 and 0.05 percentage point respectively. Increasing R&D and ICT investment to the OECD top 5 average can increase TFP growth by about 0.3 and 0.2 percentage point respectively. While these estimates for productivity growth are only illustrative, they provide a sense of magnitudes involved.[13]

Determinants of Innovative Investment: Cross-Country Evidence from Aggregate Data

15. In this section, we analyze the drivers of innovative investment at the aggregate level. The literature generally points to the effectiveness of government support to stimulate innovation-related investment. Hall and Van Reenen (2000) and Becker (2014) conclude in their survey of the literature that tax credits have a significant positive effect on R&D expenditure. With cross-country data on the manufacturing sector of nine OECD countries for 1979–1997, Bloom and others (2002) estimate a long-run elasticity of R&D with respect to its user cost and find that R&D tax incentives are generally effective. Using European firm-level data, Hussinger (2008) and Cerulli and Poti (2012) find positive effects of government-funded R&D on private R&D investment. Other strands of literature point to adverse effects of uncertainty on R&D investments, including Bloom (2007) and Aghion and others (2012).

16. A simple regression model points to positive effects of tax incentives on innovative investment. We employ the following simple model:

$$RD_{i,j,t} = \alpha_{i,j} + \alpha_t + \beta_1 GAP_{i,t-1} + \beta_2 Incentive_{i,t-1} + \varepsilon_{i,t} \quad (2),$$

where $RD_{i,j,t}$ denotes log-scaled real business R&D in country i, industry j at time t, $GAP_{i,t}$ denotes output gap, and $Incentive_{i,t-1}$ denotes R&D tax incentives in percent of GDP. Table 3 reports estimated parameters for regressions both at industry level and aggregate level. Consistent with previous literature, the results point to positive effects of tax incentives on R&D investment. An increase in R&D tax incentive of 0.1 percentage point of GDP (nearly doubling) would be associated with a boost in innovative investment of about 11-16 percent, depending on the specification.

[13] While this exercise is based on cross-country sector-level data, Majeed and others (2021) also find positive effects of innovative investment on productivity using Australian firm-level data.

Table 3. Determinants of Innovative Investment at Aggregate Level

	Industry-level	Aggregate-level
Dependent Variable: Business-funded R&D Investment (in logarithm)		
Gap (-1)	0.0084 (.0101)	-0.0036 (.0111)
R&D Incentive (-1)	1.640** (.6599)	1.139* (.6282)
Country Fixed effects	No	Yes
Country-Industry Fixed effects	Yes	No
Year Fixed Effects	Yes	Yes
R-squared	0.005	0.047
Sample Period	2000-2019	2000-2019
Number of Observation	4,017	351

Source: IMF staff estimates.
Notes: Data from OECD STAN database. Reports results for estimates of Equation 2 and its variants for robustness checks. R&D tax incentives are in percent of GDP. Standard errors are clustered at country-industry or country levels. * and ** indicate significance at the 10 and 5 percent level respectively.

Determinants of Intangible Investments: Firm Level Evidence from Australia

17. **Next, we use Australian firm-level data to shed light on the heterogenous impact of uncertainty and government tax incentives on intangible investment of different firm groups.** Specifically, we employ an R&D investment model similar to Bloom (2007) and augment it with the R&D tax incentive, interacted with firm characteristics. The model can be written as follows:

$$\begin{aligned} ITA_{i,t} = \alpha_i + \alpha_t + \beta_1 \Delta Sales_{i,t} + \beta_2 \sigma_{i,t} + \beta_3 \sigma_{i,t} * \ \Delta Sales_{i,t} + \beta_4 \, ITA_{i,t-1} + \beta_5 \sigma_{i,t} * \ ITA_{i,t-1} \\ + \beta_6 ExternalFinance_{i,t} * Incentive_{t-1} \ + \beta_7 Manufacturing_{i,t} * Incentive_{t-1} \\ + \beta_8 Small_{i,t} * Incentive_{t-1} + \beta_9 High\ Future\ Growth_{i,t} * Incentive_{t-1} + \varepsilon_{i,t} \quad (3), \end{aligned}$$

where $ITA_{i,t}$ denotes the growth rate of intangible capital for firm i at time t, $\Delta Sales_{i,t}$ denotes the growth rate of sales, $\sigma_{i,t}$ denotes firm-level uncertainty proxied by volatility in weekly stock returns of the firm (annualized).[14] In addition, the model incorporates lagged government tax incentives as a share of GDP $Incentive_{t-1}$, interacted with various dummy variables capturing firm characteristics. $ExternalFinance_{i,t}$ dummy takes value 1 if firms have higher external finance dependence (above median), and $Manufacturing_{i,t}$ and $Small_{i,t}$ are dummy variables for the manufacturing sector and smaller firms (asset size below 25th percentile of the sample). High future growth firms ($High\ Future\ Growth_{i,t}$) are proxied with firms with higher-than-median Tobin's Q.[15] We employ annual Australian firm level data obtained from IMF Corporate Vulnerability Unit Database, which is based on the Thomson Reuters Worldscope database. Data are from 2001 to 2018, with the financial sector removed.[16]

[14] Intangible capital includes R&D, computer software, databases and mineral exploration. In addition, it includes some items not capitalized in the national account, such as firm-provided training, expenditures for design and branding, and organizational capital.

[15] For example, Banerjee and Hoffman (2020) use Tobin's Q to identify zombie firms.

[16] It should be noted that this database only covers listed firms. Similar to Equation 1, the specification may cause Nickell bias as it includes a lagged dependent variable. However, the size of bias is likely to be small given the length

18. The results point to positive impacts of tax incentives, with some heterogenous impacts across firm groups. The firm-level regression suggests that the effects of tax incentives depend on firms' size, sectors, financing structures, and viability (Table 4). In particular, when aggregate tax incentives are higher, these tend to benefit smaller firms who increase intangible capital by a larger amount. This result is consistent with the existing literature, such as Lach (2002), OECD (2020), and Bakhtiari (2021b), which find that subsidies for small firms have a strong stimulative effect after the first year of subsidies, and Hall and others (2009), who argue that SMEs that have not conducted R&D before are more likely to start investing in R&D if they receive a subsidy. Quantitatively, our result suggests that the positive impact of increasing tax incentives by 0.1 percentage point of GDP (nearly doubling) on the growth of intangible capital next year is about 10.2 percentage points stronger for SMEs. The results also suggest that industry type and financing structures play a role, with the manufacturing sector and firms more dependent on external financing seeing a bigger increase in intangible capital when aggregate incentives increase. In addition, firms with higher expectations for growth (proxied by higher Tobin's Q) tend to increase intangible investment more in response to government tax incentives than less viable firms.

Table 4. Determinants of Firm-Level Intangible Investments

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Growth Rate of Intangible Capital					
Sales Growth	.2464*** (.0609)	.2486*** (.0610)	.2510*** (.0612)	.2509*** (.0611)	.2497*** (.0612)
Uncertainty	-0.0251 (.0516)	-0.0333 (.05067)	-0.0230 (.05072)	-0.0360 (.05094)	-0.0186 (.0514)
Sales Growth * Uncertainty	-.3318*** (.1071)	-.3347*** (.1071)	-.3354*** (.1076)	-.3332*** (.1075)	-.3358*** (.1076)
Lagged Dependent Variable	-.0000 (.0000)	-.0000 (.0000)	-.0000 (.0000)	-.0000 (.0000)	-.0000 (.0000)
Uncertainty * Lagged Dependent Variable	1.5171*** (.0655)	1.5174*** (.0653)	1.5183*** (.0653)	1.5212*** (.0654)	1.5173*** (.0653)
High Ext. Finance Dep. * RD tax incentives (-1)	.3279*** (.1094)	.3267*** (.1097)			
Manufacturing * RD tax incentives (-1)	1.1048* (.6241)		1.1420* (.6479)		
Small * RD tax incentives (-1)	1.0199*** (.4211)			1.1134*** (.4310)	
High Exp. Growth * RD tax incentives (-1)	0.2529*** (.1221)				0.2823*** (.1245)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.7597	0.7614	0.7588	0.7606	0.7623
Sample Period	2001-2018	2001-2018	2001-2018	2001-2018	2001-2018
Number of Observation	4,006	4,006	4,006	4,006	4,006

Source: IMF staff estimates.
Notes: Data from IMF CVU firm database. Reports results for estimates of Equation 3 and its variants for robustness checks. R&D tax incentives are in percent of GDP. High External Finance Dependence is a dummy variable for firms with higher external finance dependence (measured as Rajan-Zingales finance dependence index), Manufacturing is a dummy variable for manufacturing firms, Small is a dummy variable for smaller firms (sales size below 25 percentile of the sample), and High Expected Growth is a dummy variable for firms with higher expectations for future growth (Tobin's Q above median of the samples). Some outliers of dependent variables and independent variables are excluded. Standard errors are clustered at firm level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.

of time series. For robustness, Annex III also reports the results for the specification that excludes the lagged dependent variable (to avoid Nickell bias) and uncertainty (similar to Bloom, 2007). The benchmark results are robust to this change.

19. In addition, the results highlight some effects of uncertainty on intangible investment. As Bloom (2007) suggests, uncertainty tends to make intangible investment less responsive to changes in business situations and make firms reluctant to change their investment plans (makes intangible investment more persistent).[17] In this context, this implies that heightened uncertainty could weaken firms' intangible investment in the recovery phase, and cautious stance toward intangible investments could persist while uncertainty remains high, therefore warranting policy interventions.[18]

D. Is Declining Competition Contributing to Lower Productivity Growth?

20. The level of competition can have a significant impact on innovation and resource allocation, thus impacting productivity growth. The relation between productivity and competition is complex. Many traditional models of industrial organization and endogenous growth predict that an increase in product market competition reduces the incentive to innovate due to a decline in post-entry rent (Romer, 1990; Aghion and Howitt, 1992). At the same time, the empirical evidence points to a positive or a non-monotonic relation between innovation and competition (Nickell, 1996; Blundell, Griffith, and Van Reenen, 1999). For example, Aghion and others (2005) find an inverted-U-shaped relation between competition and innovation—an increase in competition from low levels increases innovation as it reduces the pre-innovation rent of incumbents, making the incremental payoff from innovation larger. However, as competition increases, the Schumpeterian effect starts dominating and an increase in competition can reduce innovation by reducing the post-innovation payoff (payoff from successful innovation). In addition to its impact on innovation, competition can also impact productivity by spurring improvement in resource allocation (by reducing entry barriers and allowing young productive firms to grow and replace less productive incumbents) or by providing greater incentive to incumbents to enhance efficiency.

21. Measures of competition have generally weakened in Australia, in line with global trends. There is no single metric which captures the extent of competition in an industry or country, and data constraints add to the difficulty of assessing the degree of competition in an economy. Using various data sources, we find that several different metrics point towards reduced levels of competition in Australia, echoing the results found in the recent literature using Australian administrative data (Bakhtiari, 2020; Hambur, 2021).

- **Concentration:** The degree of concentration of a sector is often viewed as a measure of competition, as a few large firms dominating a sector is likely to inhibit competitive forces.[19] We

[17] As discussed in Bloom (2007), the effects of uncertainty are interacted with sales growth and the lagged dependent variable, and the coefficient of the un-interacted uncertainty term is not significant.

[18] For example, without uncertainty, 10 percent growth in sales would boost the growth rate of intangible capital investment by 2.7 percentage points. However, 10 percentage points increase in the uncertainty measure (the firm's stock volatility) would shave the growth of intangible capital by 0.4 percentage point contemporaneously.

[19] A growing literature points to the difficulty of interpreting aggregate trends in concentration. Using US census data, Ganapati (2021) finds that concentration increases are positively correlated with productivity growth, and argues that this can be explained by expansion of output by productive industries with growing oligopolies while

measure concentration as the ratio of operating revenue in the four largest firms relative to the ten largest firms within 2-digit industries using data from Orbis. Taking the median across all industries, the results suggest that the concentration ratio in Australia has increased from about 74.5 percent in 2013 to 77 percent in 2018. Furthermore, concentration ratios in Australia are above the median for advanced economies. However, these results should be interpreted with caution due to data constraints—data coverage in Orbis differs significantly across countries, and for Australia coverage is usually limited to large, listed firms.[20]

- **Markups:** Markups, measured as the ratio of price to marginal cost, are often viewed as a direct measure of competition as they reflect the extent to which firms can charge prices that are above costs. Estimates of markup in Australia, based on sales-weighted average of firms included in the Worldscope dataset, have been rising, suggesting that competition environment has been deteriorating (De Loecker and Eeckhout, 2020).[21] The increase in markups in Australia is in line with global trends.

- **Firm entry and exit rates:** Firm entry-exit dynamics, an important source of productivity growth, have also slowed. Although still relatively high in international comparison, the entry rate of new firms has been lower than the level recorded before the global financial crisis. The exit rate of firms has been on a declining trend and low compared to peer advanced economies. A recent cross-country study suggests that the share of "zombie" firms in Australia has been increasing, which, along with weakening of firm dynamics, tends to be associated with weak productivity growth (Banerjee and Hoffman, 2020).[22]

22. A growing literature using high-quality Australian administrative data also finds evidence of reduced competition. Hambur (2021) uses confidential data from the Business Longitudinal Analysis Data Environment (BLADE), which covers the universe of Australian firms, and finds that concentration ratios and markups have trended upwards since the early 2000s, though to a lesser degree than documented above using publicly available data. There is also evidence of reduced reallocation of resources towards more productive firms in recent years, potentially as a result of reduced competition, which may be contributing to the productivity slowdown (Andrews and Hansell, 2021). Bakhtiari (2021a) also finds an increase in aggregate concentration, although

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holding down prices. Covarrubias and others (2020) find that there exists both good concentration and bad concentration and argue that bad concentration is associated with barriers to competition, weak investment and low exit rates. Rossi-Hansberg and others (2021) show that an increase in concentration at the national level may be accompanied by a decline in concentration at the local level.

[20] Due to the limited data coverage of small firms for Australia, we do not compute traditional measures of concentration such as Herfindahl indices or share of top four firms in the total turnover of the industry. Furthermore, the number of Australian firms for which data is available only improves after 2012.

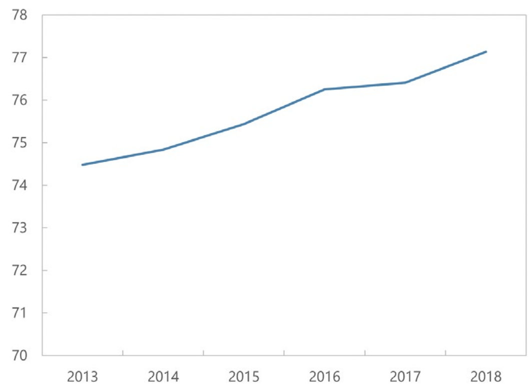
[21] Markups for other countries are also estimated from Worldscope dataset. It should be noted that the database mainly covers publicly traded firms.

[22] In their analysis, zombie firms are defined as firms with low profitability (low interest coverage ratio) and low future growth potential (measured by Tobin's Q),

with heterogeneity across sectors and some evidence that higher concentration in some sectors may be driven by technological change.

The concentration ratio has increased in recent years…

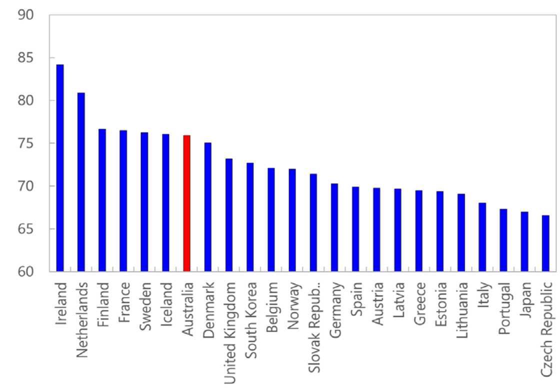
Within-Industry Ratio of Operating Revenues for Top 4 Firms Relative to Top 10 Firms
(Percent)



Sources: Orbis and IMF staff calculations.

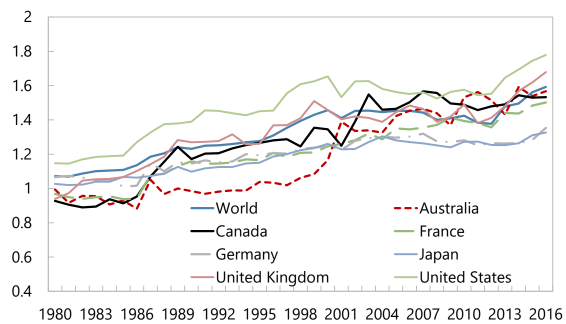
…and is above the advanced economy average

Within Industry Ratio of Operating Revenues for Top 4 Firms Relative to Top 10 Firms
(Percent)



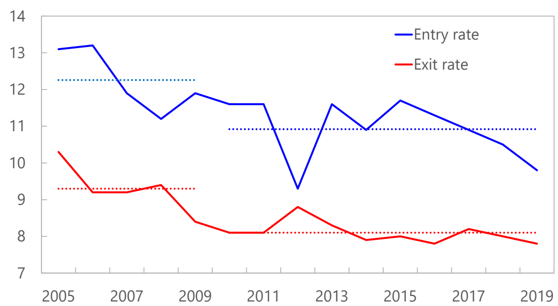
Sources: Orbis and IMF staff calculations.

Markups Have Been on a Rising Trend
(Markup)



Source: De Loecker and Eeckhout, 2020.

Firm Entry and Exit Rates Have Declined
(Percent, employing firms)



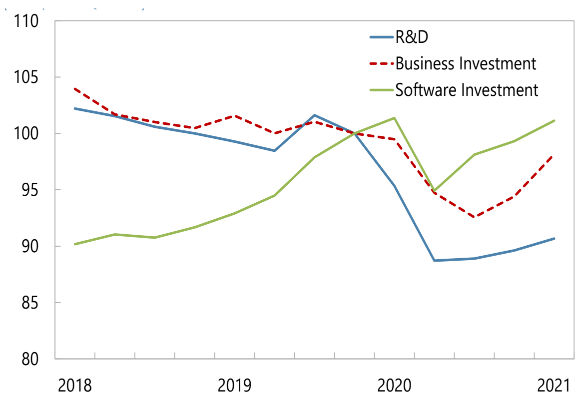
Source: ABS.
Notes: Dotted lines show the average entry and exit rate for the period 2005 to 2009 and 2010 to 2019.

E. The Outlook for Productivity Growth

23. The outlook for productivity remains highly uncertain, especially due to the unprecedented nature of the COVID-19 shock. As discussed in Bannister and others (2020) and IMF (2021), the pandemic can have positive or negative effects on medium-term productivity growth, and its medium-to-long term impacts remain highly uncertain.

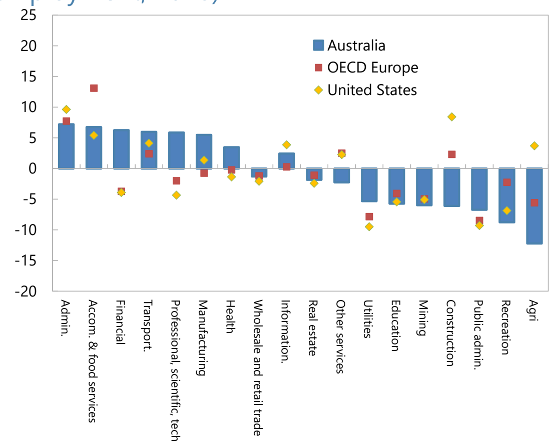
24. On the downside, subdued R&D, low exit of firms, shortage of skilled workers due to the border closure and skill erosion could adversely affect medium-term productivity trends. R&D investment declined after the pandemic and the recovery has been slow compared to other investment, which could potentially undermine medium-term productivity growth. Continued uncertainty, including regarding COVID-19 developments, may continue to impinge upon intangible investments. In addition, exit of firms has been low compared to previous recessions in Australia, in part due to strong government policy support introduced after the pandemic which provided an important lifeline during the acute phase of the pandemic (Productivity Commission 2021a). However, once the economy reopens, a prolonged delay in exit of low-productivity firms may have

R&D Has Been Weak After thePandemic, While Sofware Investment Hs Recovered
(Level 2019Q4 = 100)



Source: ABS.

Share of Migrants in Employment
(Difference with overall share of migrants in employment, 2018)



Source: OECD.

unintended adverse effects on aggregate productivity in the medium term.[23] The ongoing international border closure has limited the access to foreign labor, including skilled workers. Compared to other advanced economies, Australia tends to rely more on foreign labor in some high-productivity sectors. Shortage of skilled labors in these sectors could hinder innovation in the long run.[24] Finally, the quality of human capital accumulation, both through formal education and on the job training, can play an important role in determining productivity dynamics going forward (Black and Lynch, 1996). In this regard, a deterioration in the quality of the education system and potential disruptions to education during lockdowns could hurt education outcomes, with potential negative effects on productivity in the long term (Chevalier and others, 2004; Fernald and Li, 2021). Furthermore, skill erosion due to the rise in long-term unemployment could further hinder human capital accumulation and reduce productivity levels in the economy.

25. On the upside, acceleration of digitalization and resource reallocation toward more productive sectors could boost productivity. Amid the urgent need to reduce in-person interactions, the pandemic has propelled investment in digital technologies globally (IMF 2021). As ICT-related investment is associated with productivity growth, positive spillover from the frontier markets could lift Australia's medium-term productivity growth, while faster take up of digital

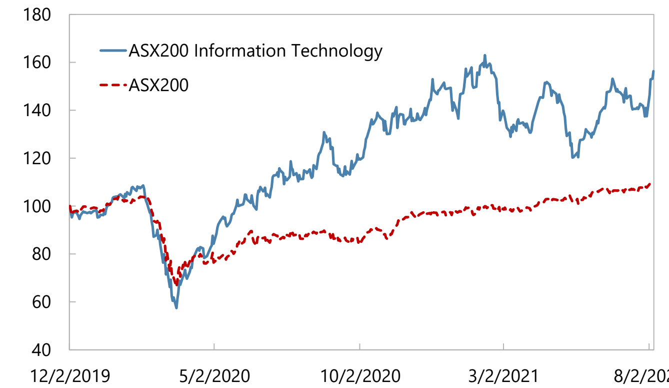
[23] Encouragingly, Andrews and others (2021) find that during the pandemic employment growth was significantly higher and the probability of exit was significantly lower for more productive firms, suggesting that high productivity firms were more resilient to the shock.

[24] IMF (2020) discusses positive impact of migration on productivity growth.

technologies by Australian firms could also boost productivity.[25] In addition, as argued by Bannister and others (2020), resource reallocation from low productivity sectors toward more productive sectors could take place as a result of structu

26. ral changes induced by the pandemic. Indeed, Productivity Commission (2021a) reports that labor shifts from some services to more productive sectors boosted labor productivity during the pandemic. However, such effects are likely to revert once restrictions are lifted, like they did after the previous lockdowns in 2020.

Tech Equities Have Been Strong After the Pandemic
(Index, 2019 Dec = 100)



Source: S&P Global.

F. Policy Considerations

27. Strong policy actions to boost productivity growth will be essential to raise living standards. Unprecedented macro policy stimulus and relatively quick suppression of the virus in 2020 helped the Australian economy recover strongly from the recession induced by the COVID-19 pandemic. And while recent outbreaks pose new near-term challenges, many factors that constrain productivity in Australia pre-date the current crisis. A strong structural reform push is essential for reigniting productivity growth.

28. Promoting productivity-enhancing investments in R&D and ICT can help support productivity growth.

- **The R&D tax incentive**: With an annual cost of about 0.1 to 0.2 percent of GDP to the budget, the tax incentive is an important policy tool for promoting R&D in Australia. Changes were introduced to the tax incentive in the 2018-19 budget which aimed at improving the targeting of the incentive by continuing to provide support for smaller companies while refocusing support for larger companies to those undertaking higher intensity R&D. These changes would have made the incentive less generous; however, the implementation was delayed several times, potentially adding to uncertainty and holding back R&D investment. As part of the COVID-19 response package, the 2020-21 budget amended the incentive, making it more generous, which is welcome and should support R&D investment going forward, especially for smaller firms who tend to respond more to R&D incentives (Table 4). Monitoring the impact of these changes to the R&D tax incentive and working towards better targeting incentives to young innovative

[25] See Sparque (2021) for discussion on how ICT investment, ICT-producing and using industries have contributed to productivity trends in the US. Apart from that, acceleration to the digital economy would exacerbate mismeasurement of productivity (IMF 2021).

firms, including by reducing the administrative burden of the tax incentive, can help further boost R&D expenditure.[26]

- **Other innovation policy:** In addition, there remains scope for scaling up government spending in R&D (which is below that of peers), including to directly fund business R&D expenditures in priority areas.[27] While spending on R&D by higher-education institutions is relatively high in Australia, there remains scope to further incentivize university-business collaboration in research and development.[28] Encouraging greater managerial focus on innovation, for example through the government's Entrepreneurs Program, can also help boost innovative activity (Majeed and others, 2021), as can greater integration into global value chains, including through foreign direct investment.

- **Promoting ICT investment:** Swift implementation of the A$1.2 billion Digital Economy Strategy is essential to build skills and infrastructure for digitalization, including opportunities for regions and SMEs.

29. Macroeconomic stabilization promotes innovative investment. As innovative investment is susceptible to uncertainty, policies to reduce economic volatility are important for supporting innovative investment. In this respect, a quick vaccine rollout, in addition to supporting activity by reducing the need for lockdowns, is also likely to reduce uncertainty around virus developments and thus support intangible investment. As R&D investment tends to be more susceptible to long run uncertainty (Barrero and others, 2017), developing a more integrated approach to energy and climate change policies would also help reduce policy uncertainty and catalyze innovative investment.

30. Enhancing product market competition can help improve resource allocation and further boost productivity. Australia compares favorably to peers on various measures of product market efficiency, including in the World Economic Forum's 2020 Competitiveness Report. At the same time, further reforms along several dimensions can support greater competition and promote productivity growth:

- **Further product market deregulation:** While generally performing well in international comparison, Australia's product market regulations are more restrictive in some areas, suggesting that there is a scope for improvements, such as streamlining administrative burdens

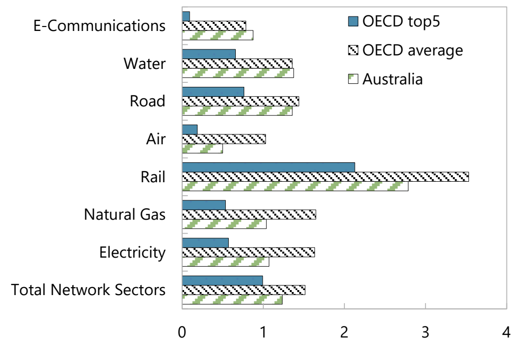
[26] The government announced a review of the dual-agency administration model of the R&D tax incentive in May 2021, with a view to simplify administrative processes and reducing compliance costs.

[27] A large body of recent literature suggests that government R&D would stimulate private R&D, rather than crowd out private R&D (Beker, 2015). For example, using European firm-level data, Hussinger (2008) and Cerulli and Poti (2012) find positive effects of government-funded R&D on private R&D investment.

[28] The government has several ongoing programs aimed at improving university-business collaboration, such as the Innovation Connections program, Industrial Transformation Research Program, Cooperative Research Centres, and Industry Growth Centres.

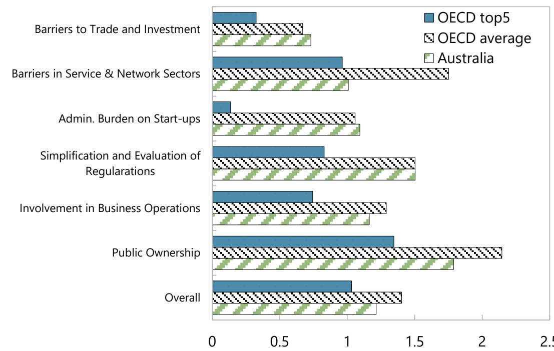
for start-ups and simplifying regulations. In this respect, recent government initiatives, including digitization of regulatory procedures and insolvency reforms for SMEs, are welcome.

Regulations in Network Sectors Are More Restrictive Than International Frontiers
(Indicator, 0 is best, as of 2018)



Source: OECD.

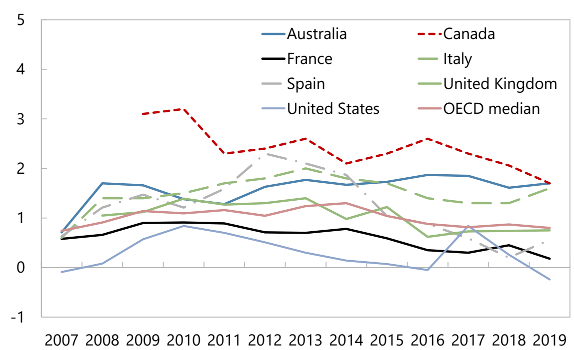
There Is Scope for Improving Product Market Regulations
(Indicator, 0 to 3, 0 is best, as of 2018)



Source: OECD

- **Alleviating financing constraints of SMEs:** Globally, small firms tend to be riskier and face larger uncertainties and capital constraints (e.g. Dhawan 2001). Like other countries, small firms in Australia often have difficulties accessing finance (Kent, 2021) and tend to hold relatively more cash than large companies, as they have an increased precautionary saving motive to avoid potential financing constraints (La Cava and Windsor 2016). Relatedly, Kido and others (2020) also find that financing constraints could be more binding in investment decisions for smaller firms. OECD cross-country data suggests that loan interest rate spreads between SMEs and large firms in Australia are relatively wide compared to other countries. Alleviating financing constraints faced by SMEs can help productive firms grow and adopt new technologies, thereby improving resource allocation and promoting productivity growth. Measures aimed at improving the matching efficiency of business and investor needs and financial literacy among SMEs by providing financial training can help in this regard (OECD 2018).[29] The proposed reduction in risk weights for SMEs, from relatively high levels, would also help reduce the interest spread between large firms and SMEs. Other government initiatives that

Loan Interest Rate Spreads Between Large Firms and SMEs
(Percentage points between)



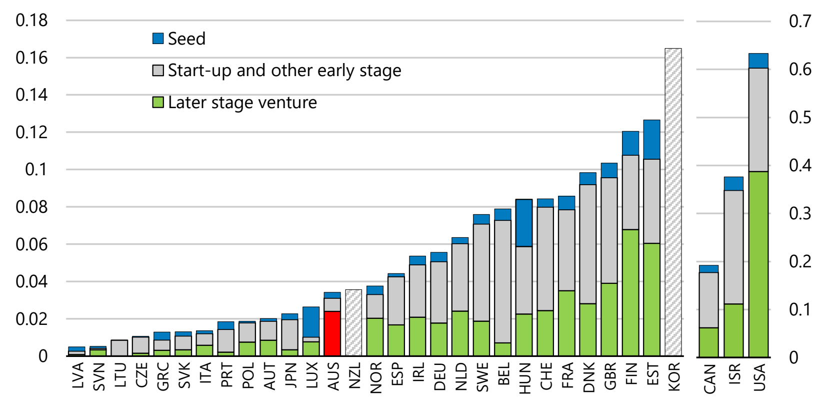
Source: OECD.

[29] Related to this, in UK, British Business Bank is delivering resources to support SME awareness of their financial options.

facilitate more SME lending include the SME Recovery Loan Scheme, the Australian Business Growth Fund, and the Australian Business Securitisation Fund.

- **Promoting venture capital (VC).** In some advanced economies, VC is an important source of funding for start-ups and innovative firms. Indeed, the evidence in the United States suggests that the overall efficiency of VC-backed firms is higher than non-VC-backed firms and the difference arises from both screening and monitoring effects that VC can bring (Chemmaur and others, 2011). VC in Australia has been smaller than in many other advanced economies, and especially at early stages of investment. The government is encouraging VC growth through programs like the Venture Capital Limited Partnerships and Early Stage Venture Capital Limited Partnership, and VC funding continued to grow through the COVID shock. However, scope remains to further deepen venture capital markets, for example, by expanding government-sponsored funds or co-investment funds and removing potential barriers to investment, which could improve young firms' access to finance while promoting productivity growth.[30]

There Is Scope for Expanding Venture Capital Investment
(Venture capital as % of GDP, 2019 or latest available year)



Source: OECD.

- **Recognition of occupational licenses across jurisdictions:** Expanding the newly implemented national Automatic Mutual Recognition of Occupational Registrations scheme (curently in place in New South Wales, Victoria, the Australian Capital Territory and the Northern Territory) to more occupations and across all states and territories can help reduce entry barriers and improve labor mobility, further enhacing productivity.

31. Additional reforms in the following areas can further boost productivity:

- **Education:** A strong education system and a skilled workforce have traditionally been a pillar of strength for the Australian economy. In this regard, Australia has generally performed better than peers in the OECD's Programme for International Student Assessment (PISA). However,

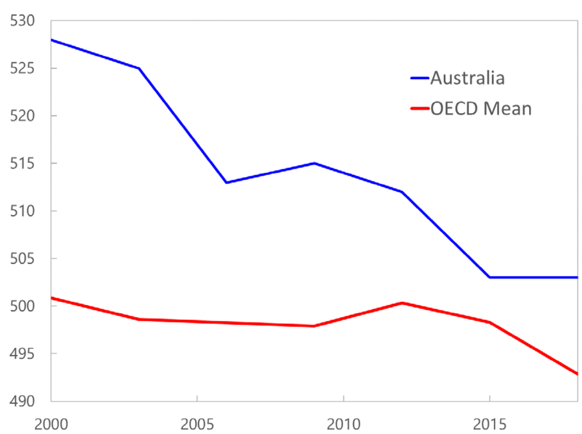
[30] For example, with international data, Brander and others (2015) show that enterprises funded by both government-sponsored venture capital and private venture capital obtain more investment than enterprises funded purely by private venture capitals. They also find a positive association between mixed government-private funding and successful exits. See Detter and others (2020) for a discussion about government equity investment in the COVID context. In Australia, the government has established some co-investment venture capital funds, for example, the Biomedical Translation Fund, the CSIRO Innovation Fund (Main Sequence Ventures) and the Clean Energy Innovation Fund.

average PISA scores have declined, and Australia now trails the OECD average in Math. Furthermore, there is evidence of high dispersion in PISA scores in Australia, pointing to inequalities in the education system (OECD, 2021). Reforms in the education sector, aimed at improving teacher training and student outcomes can support productivity growth in the long term.

PISA reading scores have declined in Australia…

PISA Reading

(Mean score)

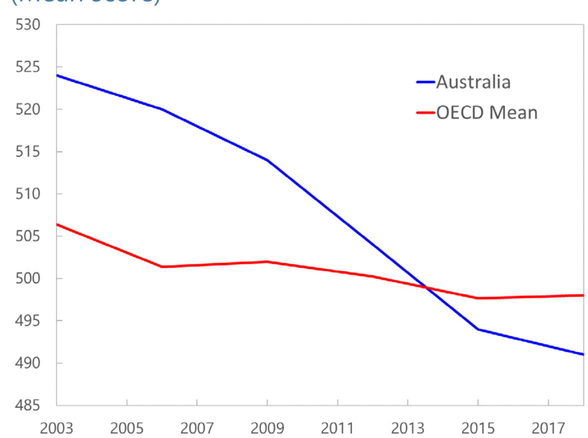


Sources: OECD and IMF staff calculations.

…and Math scores are now below the OECD average

PISA Math

(Mean score)



Sources: OECD and IMF staff calculations.

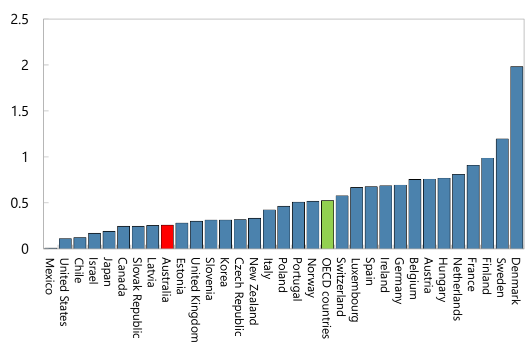
- **Labor market policies:** The government deployed large-scale policy measures in the context of the pandemic, most notably the JobKeeper Payments, a wage subsidy program which helped cushion the pandemic's impact on the labor market. Other policies, such as wage subsidies for apprentices and trainees have had high take up although the JobMaker Hiring Credit has played a relatively minor role. Going forward, there is scope for further scaling up active labor market policies, which have been relatively small compared to other advanced economies, to address elevated long-term unemployment and promote human capital accumulation.[31] Training, especially in digital areas, would help unemployed individuals transition to new jobs. Job search assistance is also an important tool to promote reallocation of workers. In this context, the JobTrainer Fund supports free or low-fee training in areas of high labor demand, and the New Employment Services Model, which commences from July 2022, will help to connect job seekers with employment opportunities. Given very low take-up, the effectiveness of Job Maker Hiring Credit should be reviewed, and parameters of the scheme such as scope, length, and benefit level can be recalibrated depending on labor market conditions.[32] The effectiveness of the scheme may be strengthened by including disadvantaged workers such as the long term unemployed.

[31] It should be noted that the gap with other countries will be smaller after the size of unemployment is controlled for.

[32] For example, Cahuc and others (2019) argue that hiring credit can be more effective if it is temporary and for jobs with rigid wages.

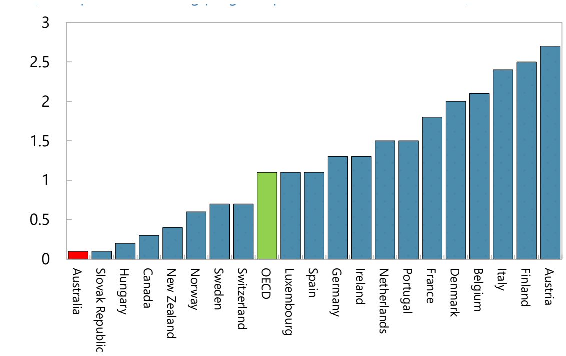
- **Mental health:** Studies have shown that poor mental health is associated with weak productivity performance and absenteeism (e.g. Bubonya and others, 2017 for studies on Australia). A considerable share of Australians reported having experienced a mental disorder according to data from the Institute for Health Metrics and Evaluation, and the economic costs of mental

ALMP spending in AUS is relatively low
Spending on Active Labor Market Policies
(Percent of GDP, average of 2010-18)



Source: OECD.

Coverage of training program is limited
Participation in Training Program
(Percent of labor force, 2017)

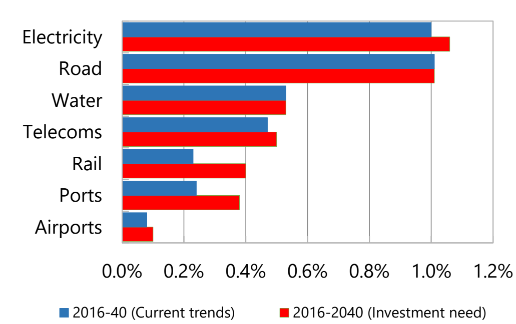


Source: OECD.

illness is estimated to be sizeable (Productivity Commission 2020a).[33] Thus, addressing mental illness problems would help productivity growth while improving wellbeing. These include, for example, measures to reduce job stress, address workplace bullying, and alleviate adverse impacts from deterioration in job conditions. In this respect, recent government initiatives including National Mental Health and Suicide Prevention Plan are welcome.

- **FDI regime:** FDI inflows into Australia have traditionally been higher than the OECD average and have helped support investment, with potentially positive productivity spillover occurring through technology transfers. While Australia has a relatively open FDI regime in terms of limited restrictions on equity ownership for foreigners, it has more onerous screening and approval restrictions (Mistura and Roulet, 2019). The government also has recently introduced changes to the approval process, introducing a new national security test requiring approval for foreign investments in 'sensitive national security business', regardless of the value of the investment. Clear policy guidance on the use of the national security test and its judicious use (e.g. excluding risks that can be attenuated through other national policies like competition policy) can

Infrastructure Investment Gaps
(% GDP)



Source: G20

[33] Cross country data from Institute for Health Metrics and Evaluation suggests that prevalence of mental illness in Australia is relatively high. However, cross-country comparison may be influenced by differences in survey methods and reporting.

ensure that the FDI policy regime remains simple and transparent and supports productivity growth (Productivity Commission, 2020b).

- **Infrastructure**: Infrastructure gaps remain in areas such as electricity, telecoms and transportation. In this respect, the recent increase in infrastructure spending is welcome and should help close the infrastructure gap.

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Annex I. Utilization-Adjusted Productivity Measures

In this annex, we discuss approaches to estimate utilization-adjusted productivity at industry level. There is large literature that argues that simple Solow residual (TFP) is not a good measure of productivity or change in technologies as it is heavily influenced by input utilization, namely capital and labor utilization, which typically reflects cyclical components.[1]

Our main approach reported in Section B is based on popular approach by Basu and others (2006). For comparison, we also estimate a simpler capital-utilization-adjusted productivity and compare to the main results in this Annex.

Main Approach

In this approach, we control for input utilization, namely time-variable labor effort and capital utilization, following Basu and others (2006).

We assume that each industry has a following production function F^i for gross output $Y_{i,t}$

$$Y_{i,t} = F^i(KU_{i,t}\, K_{i,t}, E_{i,t}H_{i,t}L_{i,t}, X_{i,t}, A_{i,t}) \qquad (A1.1),$$

where $KU_{i,t}$ denotes capital utilization for industry i at time t,, $K_{i,t}$ denotes capital stock, $E_{i,t}$ denotes labor efforts, $H_{i,t}$ denotes hours worked per worker, and $L_{i,t}$ denotes number of workers, $X_{i,t}$ denotes intermediate goods, and $A_{i,t}$ denotes technology (utilization-adjusted productivity).[2]

With cost minimization and output growth related to input growth, the following relationship related to the growth rates of output, inputs, utilization and productivity is obtained.

$$\Delta lnY_{i,t} = \gamma_i\left(\Delta lnI_{i,t} + \Delta lnU_{i,t}\right) + \Delta lnA_{i,t} \quad (A1.2),$$

where cost share weighted input $I_{i,t}$ is given as

$$\Delta lnI_{i,t} = \alpha_{i,K}\Delta lnK_{i,t} + \alpha_{i,L}(\Delta lnH_{i,t} + \Delta lnL_{i,t}) + \alpha_{i,X}\Delta lnX_{i,t} + \Delta lnA_{i,t} \quad (A1.3),$$

and unobservable resource utilization $U_{i,t}$ is the weighted average of capital utilization and labor efforts.

$$\Delta lnU_{i,t} = \alpha_{i,K}\Delta lnKU_{i,t} + \alpha_{i,L}\Delta lnE_{i,t} \qquad (A1.4),$$

[1] For example, firms may reduce the workweek of capital given weak demand and the cost of depreciation. Firms may hoard labor in downturn to preserve valuable skills for the recovery phase in the future. See Fernald (2014) for discussion.

[2] More precisely, in our analysis, we use quality adjusted labor available in ABS KLEMS database.

In the above, γ_i denotes returns to scale, $\alpha_{i,L}$, $\alpha_{i,K}$, and $\alpha_{i,X}$ denote cost share of labor, capital and intermediate goods.[3]

For capital and labor utilization, Basu and others (2006) apply the theoretical prediction that the changes in both capital utilization and labor efforts are proportionate to the change in hours worked per worker $H_{i,t}$. With these theoretical relationships, the following equation is estimated to estimate industry-level utilization-adjusted productivity growth $\Delta lnA_{i,t}$.

$$\Delta lnY_{i,t} = \gamma_i \Delta lnI_{i,t} + \beta_i \Delta lnH_{i,t} + \Delta lnA_{i,t} \quad (A1.5),$$

By controlling for the change in hours worked per worker $\Delta lnH_{i,t}$, we can obtain change in utilization adjusted productivity, which is the residual in Equation A1.5 ($\Delta lnA_{i,t}$).[4]

We estimate Equation A1.5 to obtain utilization-adjusted productivity measures. Given potential correlation between input growth and residuals (utilization-adjusted productivity growth $\Delta lnA_{i,t}$), the two-stage-least square approach is employed to address potential endogeneity. For instrument variables, similar to Basu and others (2006), we use the growth rate of spending in national defense in real terms, the growth rate of imported fuel prices deflated by the GDP deflator, the growth rate of rural commodity prices deflated by the GDP deflator, economic policy uncertainty in the United States and China. To conserve parameters, following Basu and others (2006), we restrict the utilization coefficients within two groups (the first group includes mining, utilities and manufacturing, and the second group includes other industries). In addition, we assume constant return to scale (γ_i=1) for the mining sector and retail sector. Finally, for the change in hours worked, we use the change in detrended data to capture cyclical change in hours worked per worker.[5] Table 1 in Section B show the estimated residuals (including constant), which is utilization-adjusted productivity.

Alternative Approach (Capital Utilization-Adjusted TFP)

Given the unobservable nature of input utilization and uncertainty around the estimates of the main utilization-adjusted productivity measures, we also analyze a simpler productivity measure that controls for capital utilization. In this approach, labor utilization (labor efforts given hours worked) is not adjusted, however hours worked are controlled.

First, the benchmark Solow residual is obtained with a following standard industry-level production function:

$$Y_{i,t} = z_{i,t} * K_{i,t}^{\alpha_{i,K}} * (H_{i,t} L_{i,t})^{\alpha_{i,L}} * X_{i,t}^{\alpha_{i,X}} \quad (A1.6),$$

---

[3] In our estimation, we use time-varying cost share rather than constant cost share, based on ABS KLEMS database.

[4] In A1.5, $\Delta lnA_{i,t}$ includes constant, in addition to the residual in the regression.

[5] We use average weekly hours worked by industry and apply the Hodrick-Prescott filter (with λ=6.25).

where $Y_{i,t}$ denotes industry *i's* gross output at time *t*, $K_{i,t}$ denotes capital input, $H_{i,t}$ denotes hours worked per worker, $L_{i,t}$ denotes the number of workers, $X_{i,t}$ denotes intermediate goods, and $z_{i,t}$ denotes Solow residuals. α_K, α_L, and α_X are associated input elasticities. As discussed, this Solow residual reflects utilization of inputs in addition to technologies.

Next, we consider time-varying capital utilization $KU_{i,t}$ to isolate its component from Solow residual. When it comes to measurement of capital input, consider capital service $M_{i,t}$, which consists of capital stock $K_{i,t}$ and capital utilization $KU_{i,t}$.

$$M_{i,t} = KU_{i,t}K_{i,t} \quad (A1.7).$$

Using this $M_{i,t}$, we obtain the productivity measure $A_{i,t}$ that controls for capital utilization.

$$Y_{i,t} = A_{i,t} * \left(M_{i,t}\right)^{\alpha_{i,K}} * (H_{i,t}L_{i,t})^{\alpha_{i,L}} * X_{i,t}{}^{\alpha_{i,X}} = A_{i,t} * \left(KU_{i,t} * K_{i,t}\right)^{\alpha_{i,K}} * (H_{i,t}L_{i,t})^{\alpha_{i,L}} * X_{i,t}{}^{\alpha_{i,X}} \quad (A1.8),$$

where $A_{i,t}$ denotes a utilization-adjusted productivity measure, based on capital services used as an input, which removes the utilization component included in Solow residuals and reflects technological progress.

In growth rates, the relationship between Solow residuals and utilization-adjusted productivity can be written as follows based on Equation A1.7 and A1.8.

$$\Delta lnA_{i,t} = \Delta lnz_{i,t} - \alpha_{i,K}\, \Delta lnKU_{i,t} \quad (A1.9).$$

Capital utilization is not directly measurable, and the literature has examined different approaches. In this approach, we employ a simple approach following Burnside and others (1995), Fueki and Kawamoto (2009) and assume that the growth rate of intermediate goods is equal to the growth rates of capital service.[6] That is, the growth rate of capital utilization can be expressed as the difference between growth rates of intermediate goods and capital stock.

$$\Delta lnKU_{i,t} = \Delta lnX_{i,t} - \Delta lnK_{i,t} \quad (A1.10).$$

Thus, productivity measure controlled for capital utilization is obtained from Solow residual and the estimated capital utilization in Equation A1.10 (the difference between input growth and capital stock growth).

Annex Tables 1.1 and 1.2 report utilization-adjusted productivity measures based on two approaches in addition to simple Solow residual. For overall non-mining market sectors, the slowdown in recent years is even larger with the capital utilization-adjusted productivity measure, highlighting the importance of addressing productivity slowdown in these sectors. For the mining sector, however, the capital-utilization adjusted productivity measure show a different picture, suggesting some uncertainty around the productivity measurement of the sector.

[6] This approach tends to work better for the sectors with continuous process, such as manufacturing (Gorodnichenko and Shapiro, 2011).

Annex Table I.1. Utilization-Adjusted Productivity Growth Rates

(Average growth rates, percent)

		1995/96-2000/01	2001/02-05/06	2006/07-10/11	2011/12-15/16	2016/17-18/19
Non-Mining Market Sectors	Solow residual	0.65	0.32	0.04	0.45	0.16
	Utilization Adj. TFP	0.81	0.33	0.22	0.67	0.36
	Cap.Utilization Adj. TFP	0.77	0.45	0.35	0.43	0.08
Mining Sector	Solow residual	0.83	-2.58	-2.42	-0.27	1.11
	Utilization Adj. TFP	0.82	-2.54	-2.44	-0.28	1.15
	Cap.Utilization Adj. TFP	1.67	-1.04	0.59	3.31	-0.62

Source: ABS and IMF staff estimates.

Notes: For non-mining market sectors, weighted average productivity growth rates of 15 non-mining market industries are reported, and productivity growth rates are weighted by gross value added Domar weights (two-period average weights). Solow residuals do not consider resource utilization. For utilization adjusted TFP, broad input utilization is adjusted following Basu and others (2006). For capital utilization adjusted TFP, capital utilization is isolated from Solow residuals based on information on intermediate goods, following Burnside and others (1995).

Annex Table I.2. Industry Level Breakdown of Utilization-Adjusted Productivity Measures

(Average growth rates, percent)

		1995/96-2000/01	2001/02-05/06	2006/07-10/11	2011/12-15/16	2016/17-18/19
Solow residual	Agriculture, Forestry & Fishing	2.82	1.25	0.53	-0.29	-0.60
	Mining	0.83	-2.58	-2.42	-0.27	1.11
	Manufacturing	0.29	0.07	-0.06	0.00	-0.20
	Electricity, Gas, Water & Waste Services	0.73	-1.54	-1.76	-0.49	-0.54
	Construction	-0.18	1.29	-0.15	0.32	-1.01
	Wholesale Trade	2.23	0.76	-0.26	1.64	0.26
	Retail Trade	0.96	0.27	0.85	0.63	0.55
	Accommodation & Food Services	0.71	0.73	-0.58	0.64	-0.51
	Transportation & Storage	0.71	0.78	-0.24	-0.19	-0.02
	Information Media & Telecommunications	-0.37	0.20	0.97	0.87	0.52
	Financial & Insurance Services	1.24	0.45	0.83	1.52	0.47
	Rental, Hiring & Real Estate Services	-1.21	-1.68	-2.08	1.83	-0.01
	Professional, Scientific & Technical Services	0.17	0.03	0.55	-0.33	1.02
	Administrative & Support Services	-0.49	1.36	-0.23	0.12	2.24
	Arts & Recreation Services	-0.06	-0.50	0.09	-0.34	0.44
	Other Services	0.93	-0.50	-0.40	-0.01	-0.25
Utilization adj. TFP	Agriculture, Forestry & Fishing	1.02	1.58	1.18	-0.53	-0.85
	Mining	0.82	-2.54	-2.44	-0.28	1.15
	Manufacturing	0.31	0.09	-0.06	0.02	-0.24
	Electricity, Gas, Water & Waste Services	1.13	-0.90	-0.74	0.07	0.00
	Construction	-0.30	-0.03	-1.18	-0.09	-1.52
	Wholesale Trade	1.40	-0.19	-0.94	1.56	-0.19
	Retail Trade	0.97	0.27	0.85	0.63	0.55
	Accommodation & Food Services	0.62	0.64	-0.61	0.59	-0.54
	Transportation & Storage	0.47	0.40	-0.57	-0.42	-0.37
	Information Media & Telecommunications	-0.74	-0.06	0.86	0.66	0.31
	Financial & Insurance Services	0.82	-0.02	0.66	1.35	0.32
	Rental, Hiring & Real Estate Services	0.13	-0.13	-1.59	2.75	0.17
	Professional, Scientific & Technical Services	3.97	1.66	2.77	1.62	3.47
	Administrative & Support Services	1.68	2.15	1.27	1.06	2.91
	Arts & Recreation Services	0.66	0.45	0.89	0.20	0.99
	Other Services	1.26	-0.04	0.15	0.14	0.15
Cap. Utilization adj. TFP	Agriculture, Forestry & Fishing	2.05	1.31	1.28	-0.48	-0.80
	Mining	1.67	-1.04	0.59	3.31	-0.62
	Manufacturing	0.47	0.11	0.09	0.03	-0.34
	Electricity, Gas, Water & Waste Services	0.75	-0.43	-0.65	-0.35	-0.30
	Construction	0.27	1.06	-0.10	0.40	-0.98
	Wholesale Trade	1.78	0.68	-0.22	1.79	0.39
	Retail Trade	1.64	1.19	1.27	1.27	0.31
	Accommodation & Food Services	0.86	0.75	-0.31	0.53	-0.72
	Transportation & Storage	0.77	0.89	0.19	0.13	-0.14
	Information Media & Telecommunications	0.29	0.08	1.19	0.35	0.92
	Financial & Insurance Services	0.80	-0.20	0.93	0.87	-0.35
	Rental, Hiring & Real Estate Services	-0.20	-0.31	-0.30	1.35	0.99
	Professional, Scientific & Technical Services	0.28	0.23	0.79	-0.26	0.96
	Administrative & Support Services	-0.28	1.50	-0.18	0.05	2.18
	Arts & Recreation Services	0.51	-0.22	0.40	-0.16	0.66
	Other Services	1.47	0.24	0.04	0.56	0.05

Sources: ABS and IMF staff estimates.

Notes: Solow residuals do not consider resource utilization. For utilization adjusted TFP, broad input utilization is adjusted following Basu and others (2006). For capital utilization adjusted TFP, capital utilization is isolated from Solow residuals based on information on intermediate goods, following Burnside and others (1995).

Annex II. Additional Results for the Impact of R&D and ICT Investment on TFP

Several robustness tests confirm the significant association between R&D and ICT investment and TFP growth documented in Table 2. Column 1 of Annex Table 2.1 shows results when R&D investment and other investment are included in the same regression, while column 2 simultaneously includes ICT investment and other investment in the regression. In both cases, the coefficients on R&D and ICT investment remain positive and significant and are larger in magnitude than other investment. Column 3 includes R&D and ICT investments separately in the same regression. The coefficients on R&D and ICT investment remain larger than for other investment, though all coefficients are now insignificant, potentially due to multicollinearity. Column 4 combines R&D and ICT investment into one variable, the coefficient for which is positive, significant and larger than that of other investment. Annex Tables 2.2 and 2.3 report several additional robustness checks. Results are robust to: excluding the G-7 countries from the sample; only including the manufacturing or services sector in the sample as well as services sector excluding ICT industries; and including lags one through five of various investment types together in the regression (with the sum of coefficients across lags being positive and significant for R&D and ICT investment).

Annex Table II.1. Impact of R&D and ICT Investment on TFP Growth: Multiple Investments

	(1)	(2)	(3)	(4)
VARIABLES	R&D	ICT	R&D and ICT	R&D and ICT
R&D Investment (lag 5)	0.0668*		0.0619	
	(0.033)		(0.052)	
ICT Investment (lag 5)		0.0465**	0.0224	
		(0.020)	(0.051)	
R&D and ICT Investment (lag 5)				0.0431***
				(0.008)
Other Investment (lag 5)	0.0163	0.0197**	0.0161	0.0162
	(0.014)	(0.009)	(0.012)	(0.012)
Observations	8,640	8,556	8,556	8,556
R-squared	0.331	0.331	0.332	0.331
Country-Time FE	Yes	Yes	Yes	Yes
Country-Ind FE	Yes	Yes	Yes	Yes
Industry-Time FE	Yes	Yes	Yes	Yes

Source: IMF staff estimates.

Notes: Data from EU KLEMS at the country-industry-year level. Table reports robustness checks for estimates of equation 1. Dependent variable in each regression is TFP growth. Two types of investments are included simultaneously in the regressions. All regressions include country-time, country-industry, and industry-time fixed effects. Outliers in TFP growth (below 1 percentile and above 99 percentile) are excluded. Standard errors are clustered two-way at the country and industry level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.

Annex Table II.2. Impact of R&D and ICT Investment on TFP Growth: Different Samples

VARIABLES	(1) Exclude G7	(2) Exclude G7	(3) Exclude G7	(4) Industry	(5) Industry	(6) Industry	(7) Services	(8) Services	(9) Services excl. ICT sectors	(10) Services
R&D Investment (lag 5)	0.1022***			0.1337**			0.1435***			
	(0.032)			(0.058)			(0.039)			
ICT Investment (lag 5)		0.1117***			0.1267			0.0779*	0.0888*	
		(0.028)			(0.156)			(0.041)	(0.048)	
Other Investment (lag 5)			0.0229			-0.0024				0.0338
			(0.015)			(0.005)				(0.022)
Observations	5,379	5,295	5,295	3,156	3,154	3,242	2,597	2,579	1,846	2,516
R-squared	0.362	0.364	0.364	0.417	0.416	0.416	0.350	0.348	0.362	0.371
Country-Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Ind FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: IMF staff estimates

Notes: Data from EU KLEMS at the country-industry-year level. Table reports robustness checks for estimates of equation 1. Dependent variable in each regression is TFP growth. Column 1-3 exclude G7 countries from the sample. Columns 4-6, restricts the sample of the industrial sector only. Columns 7-10 restricts the sample to services sector only. R&D, ICT and other investments are lagged by 5 years. All regressions include country-time, country-industry, and industry-time fixed effects. Outliers in TFP growth (below 1 percentile and above 99 percentile) are excluded. Standard errors are clustered two-way at the country and industry level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.

Annex Table II.3. Impact of R&D and ICT Investment on TFP Growth: Multiple Lags Together

VARIABLES	(1) R&D	(2) ICT	(3) Other
Lag 1	0.0444	0.0352	0.0171*
	(0.122)	(0.073)	(0.010)
Lag 2	0.0125	0.0032	0.0012
	(0.023)	(0.022)	(0.002)
Lag 3	0.0331***	0.0229	0.0042*
	(0.009)	(0.020)	(0.002)
Lag 4	0.0945**	0.0277	0.0178
	(0.045)	(0.041)	(0.023)
Lag 5	0.0488	0.0746	0.0168
	(0.040)	(0.044)	(0.014)
Observations	8,640	8,556	8,556
R-squared	0.331	0.331	0.333
Country-Time FE	Yes	Yes	Yes
Country-Ind FE	Yes	Yes	Yes
Industry-Time FE	Yes	Yes	Yes

Source: IMF staff estimates.

Notes: Data from EU KLEMS at the country-industry-year level. Table reports robustness checks for estimates of equation 1. Dependent variable in each regression is TFP growth. Columns 1 includes lags 1 through 5 of R&D investment, while columns 2 and 3 do the same for ICT and other investment. All regressions include country-time, country-industry, and industry-time fixed effects. Outliers in TFP growth (below 1 percentile and above 99 percentile) are excluded. Standard errors are clustered two-way at the country and industry level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.

Annex III. Additional Results for the Firm-Level Determinants of Innovative Investment

Annex Table III.1. Determinants of Firm-Level Intangible Investments

	(1)	(6)
Dependent Variable: Growth Rate of Intangible Capital		
Sales Growth	.2464***	.2652***
	(.0609)	(.0519)
Uncertainty	-0.0251	
	(.0516)	
Sales Growth * Uncertainty	-.3318***	-.3600**
	(.1071)	(.0870)
Lagged Dependent Variable	-.0000	
	(.0000)	
Uncertainty * Lagged Dependent Variable	1.5171***	1.5090***
	(.0655)	(.0577)
High Ext. Finance Dep. * RD tax incentives (-1)	.3279***	.3697***
	(.1094)	(.0878)
Manufacturing * RD tax incentives (-1)	1.1048*	0.9972*
	(.6241)	(.5465)
Small * RD tax incentives (-1)	1.0199***	0.9682**
	(.4211)	(.3843)
High Exp. Growth * RD tax incentives (-1)	0.2529***	0.3057***
	(.1221)	(.1016)
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
R-squared	0.7597	0.7633
Sample Period	2001-2018	2001-2018
Number of Observation	4,006	5,435

Source: IMF staff estimates.

Notes: Data from IMF CVU firm database. Reports additional results for Table 4. R&D tax incentives are in percent of GDP. High External Finance Dependence is a dummy variable for firms with higher external finance dependence (measured as Rajan-Zingales finance dependence index), Manufacturing is a dummy variable for manufacturing firms, Small is a dummy variable for smaller firms (sales size below 25 percentile of the sample), and High Expected Growth is a dummy variable for firms with higher expectations for future growth (Tobin's Q above median of the samples). Some outliers of dependent variables and independent variables are excluded. Standard errors are clustered at firm level. *, **, and *** indicate significance at the 10, 5 and 1 percent level respectively.