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R&D, Innovation and Productivity: The Role of Public Support[†]

By AMANI ELNASRI, KEVIN J. FOX*

Research and innovation are widely agreed to be major driving forces behind long-term productivity and economic growth. However, the relationships have proven to be difficult to quantify. We make reference to the international literature and draw on recent research for Australia to advance our understanding of these relationships. Particular focus is on assessing the impact of publically financed R&D on productivity. The conclusions have implications for government innovation policies, providing insight into possible productivity gains from funding reallocations. Specifically, the findings suggest that government research agencies and higher education are areas in which investment leads to more potential productivity gains.

Key Word: Research and Development, Productivity, Innovation, Intangible assets, Public funding
JEL Code: O3, O4, H4

The role of government funding in supporting R&D and innovation has been a topic of persistent interest in both academic and policy circles. Much of this interest derives from the perceived, yet often unreliably quantified, relationship between R&D, innovation and productivity growth, which in turn is a significant contributor to long-term economic growth and well-being.

Productivity growth, as per the standard statistical agency definition, is the ratio of output growth to input growth, that is, the amount of growth in output that cannot be explained by the growth in measured inputs. Labour productivity is

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based solely on labour inputs (e.g., hours worked to produce the outputs), whereas multifactor productivity (MFP) takes into account the multiple inputs used in production (e.g., labour, capital and land).¹

The contribution to economic growth through resources utilisation is limited by the finite nature of resources; hence, sustained economic growth in the long term has to come from productivity enhancements. Many possible sources of productivity growth have been proposed and examined extensively in the literature; see, e.g., Rosenberg (1963, 1981), Schmookler (1966), Griliches (1998), Diewert (2001), Isaksson (2007), Wong *et al.* (2007), Hall and Rosenberg (2010), Soames *et al.* (2011) and Syverson (2011). The literature regards investments in research and innovation (such as information and communication technology (ICT), R&D, skills development, design and organisational improvements and other types of intangible assets) as central drivers of productivity; they create more efficient services and production processes, more effective workplace organisation and open up new markets (Hall 2011, Aghion *et al.* 2009, Gorodnichenko *et al.* 2010, Yaşar and Morrison Paul 2012).

Over the last few decades, productivity growth has played a key part in the growth of the Australian economy, with a particularly notable and well-documented role during the mid-1990s. This is generally attributed to microeconomic reform and the uptake of information and communications technology (ICT). However, there has been recent concern in Australia and other developed economies about the apparent slowdown in innovation and productivity growth; see, e.g., Parham (2012) and Connolly and Gustafsson (2013) for Australia, and Gordon (2012) and Phelps (2013) for the U.S. To illustrate the source of this concern, Figure 1 plots labour productivity for OECD countries, along with the OECD average, over the periods 1995-2004 and 2005-2012.²

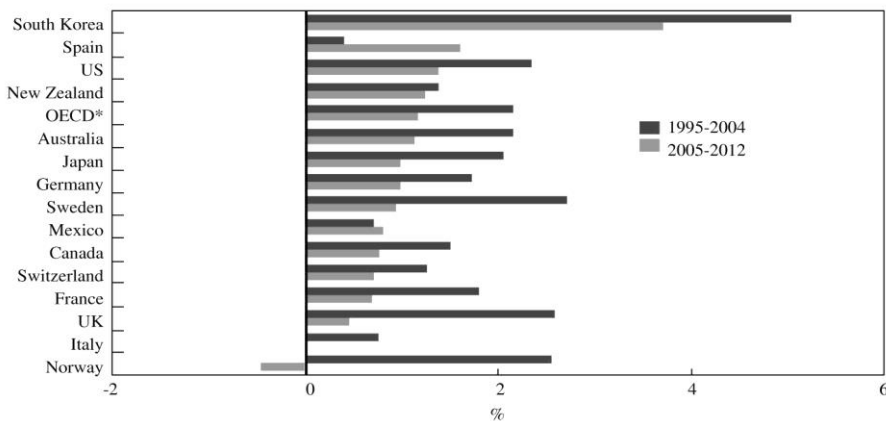


FIGURE 1. LABOUR PRODUCTIVITY GROWTH, REAL GDP PER HOUR WORKED, ANNUAL AVERAGE

¹MFP is sometime called total factor productivity (TFP). Many statistical agencies prefer the MFP terminology, as “total” factor productivity could be inaccurately interpreted as implying that all factors (i.e. inputs) related to production have been accounted for in the analysis.

²From a speech by Dr. Phillip Lowe, Deputy Governor, Reserve Bank of Australia: “Demographics, Productivity and Innovation,” the Sydney Institute, Sydney, 12 March 2014. <http://www.rba.gov.au/speeches/2014/sp-dg-120314.html>

Real gross domestic product (GDP) as a ratio to hours worked is a rough but standard measure of labour productivity growth.³ As labour productivity is a key determinant of wages, this pattern of generally lower productivity in the more recent period raises the question of whether or not this is driven simply by macroeconomic conditions, or if there are microeconomic policy responses which may encourage innovation and entrepreneurial effort to again achieve the productivity performance of the past.⁴

This paper reviews the productivity performance of Australia, and examines the role that public support may have in fostering higher future productivity growth through funding support for R&D and innovation.

I. Productivity Performance: The Australian Experience

For a better understanding of the productivity performance of Australia, it is useful to refer to the detailed Estimates of Industry Multifactor Productivity produced by the Australian Bureau of Statistics (ABS). These take into account additional inputs, in particular, capital and land, and adjust labour for compositional changes; see ABS (2007, 2013). These accounts report annual results for sixteen “market” (i.e. non-government) sectors of the economy. Here, the focus will be on the original twelve industries (ABS 2007) for which the longest time series is available.

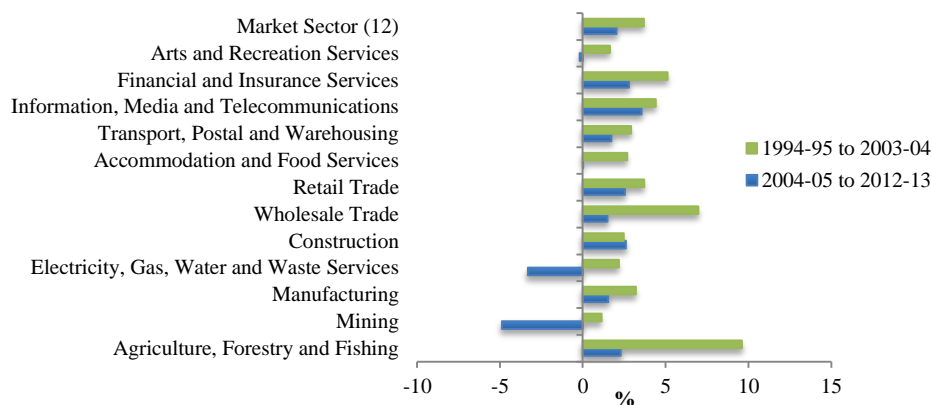


FIGURE 2. LABOUR PRODUCTIVITY GROWTH SLOWDOWN

Notes: Annual average growth between 1994–95 to 2003–04 and 2004–05 to 2011–13. Derived from ABS Cat. No. 5260.0.55.002 - Estimates of Industry Multifactor Productivity, 2012-13, Table 6. Labour productivity indexes, Gross value added per hour worked.

³Note that by using hours worked as the labour measure, there is no adjustment for variations in work intensity or changes in the composition of the labour force due to education and training; such adjustments to labour input may be of interest for an analysis of productivity, but they require additional assumptions and more data, posing problems for the international comparability of results.

⁴While Gordon (2012) and Phelps (2013) have been pessimistic in their assessment of the future of innovation and productivity, it is worth noting the following from Griliches (1988), commenting on an earlier productivity slowdown: “But what about the evidence of a decline in “inventiveness”?” “I interpret most of the proffered evidence as reflecting the impact of reduced aggregate demand and less favourable economic prospects for inventive activity in the late 1970s, rather than as the result of technological springs running dry.”

First, using the labour productivity series from these accounts, it is possible to see the productivity decline by sector by comparing the average productivity growth from 1994-95 to 2003-04 to that from 2004-05 to 2012-13, as plotted in Figure 2.

It is clear that there was a significant slowdown in productivity growth for all sectors except for the construction sector.

From the multifactor productivity statistics from the ABS accounts for these industries over the period of 2003-04 to 2012-13, the level of market-sector multifactor productivity declined by around 5 percent. Given the importance of both labour and multifactor productivity in determining living standards in the long run, such periods of declining productivity are of significant public policy concern.

To provide further insight, Figure 3 plots the multifactor productivity performance for each of the twelve core market-sector industries, as well as for the aggregate of the twelve market sectors, “market-sector” (12), over the period of 1989-90 to 2012-13. Although market-sector productivity grew by 16 percent over this period, there have been significantly different experiences over time and across industries; mining is 35 percent less productive in 2012-13 than in 1989-90, while agriculture, forestry and fishing were 72 percent more productive, with most of the productivity gains coming before 2004-05.

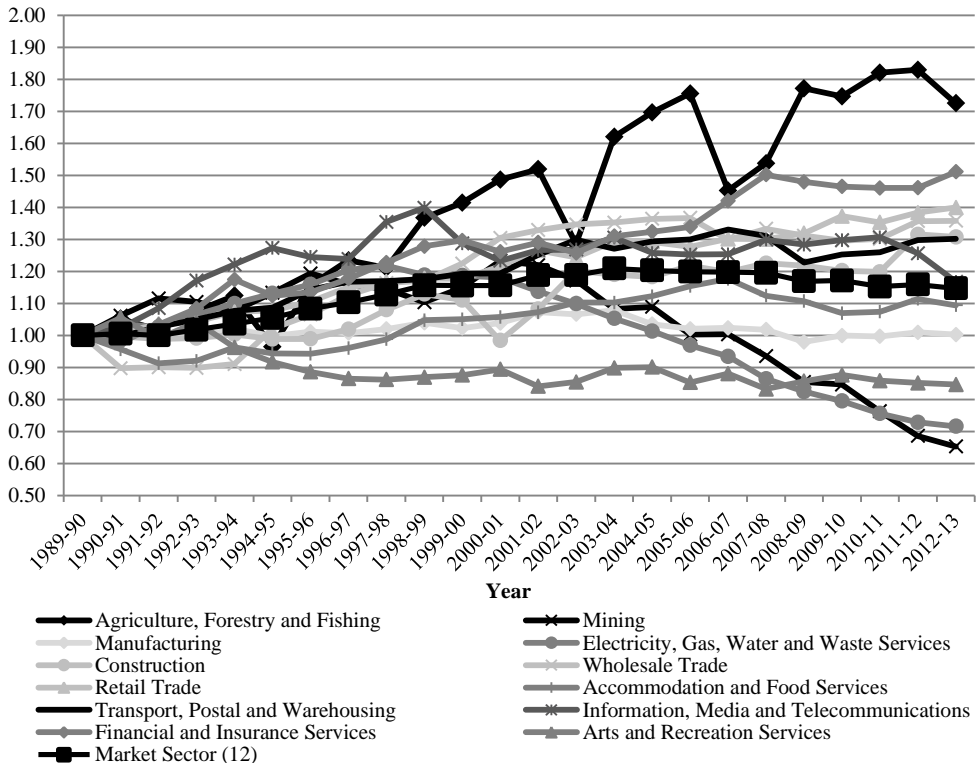


FIGURE 3. MARKET-SECTOR PRODUCTIVITY INDEXES

Source: ABS Cat. No. 5260.0.55.002 - Estimates of Industry Multifactor Productivity, 2012-13, Table 1. Gross value added based multifactor productivity indexes, quality-adjusted hours worked basis.

Much of this dispersion in productivity performance can be explained. For example, the mining industry has made long-term investments in infrastructure, which take years to complete, and more time must elapse before they result in higher levels of output. The electricity, gas, water and waste services industry also experienced a significant decline in productivity over the period (28 percent). This can be partially explained by the electricity sector making catch-up investments in infrastructure following privatisation, without corresponding increases in outputs; some commentators have suggested that this was “gold plating” on the part of the networks. Such investments do not immediately result in increased production and therefore have a downward impact on annual productivity figures. As might be expected from these examples, labour productivity growth (on an hours-worked basis) generally paints a more positive picture, with 76 percent growth over the same period for the market sector (12), although labour productivity in mining has fallen by almost 100 percent since the peak in 2001-02, reflecting the large increase in employment in this sector without, however, a corresponding increase in output.

Other factors may have also contributed to the mixed productivity performance over time and over sectors. Reducing trade barriers, increasing competition and privatising large public-sector organisations may have had productivity impacts on some sectors more than others. In addition, improvements in public infrastructure, changes in public support for R&D, unmeasured quality changes in outputs, workplace relations, new regulation and legislation, and a possible slide in Australia’s take-up of productivity-enhancing technologies all may have had differential effects on sectors. See Connolly and Gustafsson (2013)⁵ and Parham (2012),⁶ two recent studies that assessed some possible explanations of the recent productivity performance.

With such potentially diverse contributing factors, there are obvious complexities in disentangling the influences on productivity at this level, which in turn impedes an analysis of the fundamental drivers of productivity. A better understanding of the transmission of public policy and innovation through to measured productivity growth is thus important for informing effective innovation policy.

II. Innovation and Productivity

While there are many possible influences on productivity, innovation is recognised as being key to increasing productivity in the economy. Productivity has been shown to be positively correlated with innovation performance.⁷ The OECD

⁵“The current labour-intensive mining investment phase is beginning to wind down and is expected to be followed over the period ahead by a substantial pick-up in mining output, which should boost measured productivity in the mining industry and the economy more generally.” “Looking ahead, there is reason to believe that productivity growth will return to being the main driver of improved living standards.” Connolly and Gustafsson (2013).

⁶Parham (2012) considers volatility and cyclical effects, compositional shifts, adjustment pressures, and measurement error as sources of the productivity slump. He concludes as follows: “The key point is that, to the extent that such explanations are at work, a drop in measured productivity growth does not represent a prosperity-sapping misallocation of resources or loss of knowledge or efficiency.”

⁷See, for example, Hall (2011), Crepon *et al.* (1998), Janz *et al.* (2003), Mairesse and Robin (2010), Siedschlag, Zhang and Cahill (2010), Criscuolo and Haskel (2003) and Loof and Heshmati (2006).

(2005) defines innovation as follows:

The implementation of a new or significantly improved product (good or service), or process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations.

It is important to understand that R&D is just one input to innovation. Not all science, research and technology contribute to productivity growth, and not all innovations arise from R&D. Innovations contribute to productivity growth either by lowering the cost of production or by improving the quality of goods and services. Some innovations, such as those that lead to improvements in quality of goods and services, may make only a small contribution to improving measured productivity. However, some of these lead to improved well-being and quality of life, such as technological improvements in aged care. Increasing the stock of knowledge may, at times, make large and unexpected contributions to productivity.

Sometimes productivity gains are captured by innovating firms, but often the benefits of innovation also flow to firms copying the ideas or using new products that have been developed by others. Put another way, the rationale for governmental intervention in the area of research and innovation is the existence of market failure associated with research and innovation. This type of market failure is typically due to the diffusion of knowledge beyond the control of the inventor, which implies that the private rate of return to research and innovation is lower than its social return. Additionally, the high risks involved in innovation discourage firms from engaging in such activities. For both reasons, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level. Thus, there is a potential role for governments to intervene to eliminate this gap between private and social returns.

Information and communications technology (ICT) has been shown to be a major factor in productivity gains experienced towards the end of the 20th century; see, e.g., Oliner, Sichel and Stiroh (2007) and Connolly and Fox (2006). These gains have been described as spectacular in ICT-producing industries and more modest in ICT-using industries (Syverson 2011). Like most countries, Australia has only a small ICT-producing industry, and most of the productivity gains from ICT are via the use of ICT. For example, Australia's banking sector now operates with fewer tellers and relies extensively on Internet transactions.

III. Knowledge and Other Intangibles

In general, economic growth can be decomposed into two components: the growth of factor inputs (such as capital, labour and land) and the growth of productivity. Productivity is a measure of how efficiently an economy utilises finite resources to produce goods and services. There are several ways to improve productivity, but knowledge capital (through new technology, skills, R&D and efficient services and production processes) is a significant factor. New technology enables the same level of output to be produced with fewer inputs.

The effect of knowledge capital on productivity may work through various

channels depending on the source of the knowledge. For example, R&D, a major component of knowledge capital, can be performed either by the business sector, the public sector or beyond the borders of a country. Each of these types of R&D performers can be a source of significant domestic technological change. R&D performed by the business sector results in new goods and services, a higher quality of output, and new production processes. These are sources of productivity growth at the firm and national levels.

Many empirical studies confirm the positive impact of business R&D on productivity; see, e.g., Griliches (1998), and Nadiri (1993). Business-performed R&D may be funded by business itself or by the government. Accordingly, business R&D may have a different effect on productivity, depending on its source of funding (which affects the research agenda and the incentive structure). For example, Lichtenberg (1993) tests whether government-funded R&D performed by firms had a different impact than business-funded R&D. The author's evidence suggests that while privately funded R&D investment has a significant positive effect on productivity, government support for business R&D has a negative impact.

Besides their support for business R&D, governments are major R&D performers through their funding of government research agencies and higher education R&D. Research agencies and university R&D have been shown to have a strong effect on scientific and basic knowledge and on public missions. Basic research performed by universities enhances the stock of knowledge available to society (Mowery and Sampat, 2010). It may open new opportunities for business research, which in turn may improve productivity. Nevertheless, there have been few attempts to measure the impact of public R&D on productivity. In a group of studies, only some components of public research have been used in empirical frameworks. For example, Adams (1990) examines the contribution of fundamental stocks of knowledge, proxied by accumulated academic scientific papers, and finds significant contributions to productivity growth in manufacturing industries in the U.S. Another example is Poole and Bernard (1992), who examine military innovations and find a negative impact on total factor productivity in Canada.

The knowledge originating from abroad is a third source of new technology for any national economy. Evidence demonstrates many avenues through which knowledge can cross the borders of a given country and, depending on the absorptive capacity, how it can improve productivity in other countries (Mohnen 2001).

The Australian literature has a limited number of studies that have quantitatively examined Australia's innovation system and its impact. Most of these studies focused on the link between productivity and R&D, ignoring other types of innovation, such as management and organisational arrangements. The R&D measures employed by these studies largely relate to business R&D (e.g., Shanks and Zheng 2006 and Louca 2003). Moreover, the empirical evidence obtained by these studies was mixed or generally not supportive of the productive role of business R&D. For example, Shanks and Zheng (2006) find that despite the advances in data collection and methods used, they were unable to find a consistently robust result with regard to the impact of R&D on productivity:

“At this point in time, there remains no precise, robust estimate of the effect of increases in domestic business R&D on Australia's productivity performance.

Standard models and estimation methods, grounded in theory, tended to generate unreliable results, as well as estimates that were sensitive to seemingly modest changes in specification. A comprehensive investigation of alternative specifications and estimation techniques brought new insights, but proved unable to arrive at any definitive estimate.” (Shanks and Zheng 2006, p. XLI)⁸

There are a small number of cases in which the role of higher education R&D is assessed. One example is a study by Burgio-Ficca (2004), who finds evidence of a positive relationship between higher education R&D and gross state product. With the exception of the Productivity Commission study (2007), there is no study which has explicitly scrutinised the effects of publicly funded R&D for Australia.⁹ Although the results suggest significant aggregate economic, social and environmental benefits from publicly supported science and innovation, the Productivity Commission (2007) study finds that the quantitative estimates are statistically unreliable.

Despite its importance, R&D is not the only source of new technology. Innovation can result from the contributions made by other types of intangible capital, and extends beyond physical capital accumulation. We now consider this broader class of intangibles.

Despite the increase in their prominence, in many countries research and innovation, among a large set of intangible assets, are largely ignored in National Accounts and corporate financial reports because they are difficult to understand and measure. Two recent studies by Corrado, Hulten and Sichel (2005, 2006), henceforth collectively referred to as CHS, have drawn attention to the importance of measuring and capitalising intangibles. Using U.S. data, CHS developed a methodology with which to capitalise a broad range of intangibles and, by applying a growth accounting framework, demonstrated how the conventional growth rates of inputs, output and productivity measures changed as a consequence; see Table 1 for the CHS classification of intangibles assets, and the corresponding summary statistics for estimates for Australia from Elnasri and Fox (2014). Following CHS, researchers in a number of other advanced countries (e.g., the United Kingdom, Japan, Netherlands, Canada and Australia) have conducted similar studies, finding results similar to those of CHS.¹⁰

Following the recommendations of the System of National Accounts (SNA) 1993, Australia was one of the first countries to capitalise computer software, artistic originals and mineral exploration in 1993, rather than treating them as intermediate inputs. In addition, as part of the revisions to implement the recommendations contained in SNA 2008, Australia started to capitalise scientific R&D from 2009. However, as shown in Table 1, intangible assets are not restricted

⁸For a concise summary and discussion of this and related work, see Parham (2006).

⁹A small number of studies have partially addressed this question with data on the gross expenditures on R&D: Gross Expenditure on R&D (GERD), an aggregate measure of business, government and higher education R&D. However, using GERD as a measure will not isolate the effects of government or higher education R&D. Thompson (2009) uses firm-level data to examine the effectiveness of the R&D tax concessions as an effective policy tool, but does not consider other types of support for R&D.

¹⁰While this approach is becoming widely accepted, there are alternatives to the CHS approach to capitalising intangibles; see, e.g., Griliches (1981), Webster and Jensen (2006) and Diewert and Huang (2011).

TABLE 1—ESTIMATES OF NOMINAL INTANGIBLE INVESTMENTS IN THE AUSTRALIAN MARKET SECTOR

Categories	1974- 1975	1984- 1985	1994- 1995	2004- 2005	2012- 2013
				millions of dollars	
Computerised information	26	627	3,512	7,262	9,948
Innovative property	917	3,857	9,342	19,414	38,624
Scientific R&D; Social sciences R&D (Business R&D)	199	614	2,782	7,010	14,483
Mineral exploration	203	1,271	1,567	2,074	7,849
Copyright and licence costs (Artistic originals)	35	172	256	1045	2,450
Other product development, design and research	480	1,800	4,737	9,286	13,841
New product development in financial industry	342	1,310	3,133	5,311	8,338
New architectural and engineering designs	137	490	1,604	3,975	5,504
Economic competencies	1,259	4,926	11,276	23,374	33,428
Brand equity	653	2,830	4,679	8,365	10,362
Advertising	648	2,774	4,420	7,391	9,463
Market research	5	56	260	974	899
Firm-specific human capital	301	1,024	2,669	3,870	5,791
Organisational capital	306	1,073	3,927	11,138	17,276
Purchased	21	232	1,944	7,058	9,143
Own account	284	840	1,983	4,081	8,133
Total intangibles investment	2,202	9,410	24,130	50,050	82,000
New intangibles	1,739	6,726	16,013	32,659	47,270
National Accounts intangibles	463	2,684	8,118	17,391	34,730
Tangibles	9,251	32,333	54,984	10,6195	227,751
Total investment	11,453	41,743	79,114	156,245	309,751
Share of computerised information %	1	7	15	15	12
Share of innovative property %	42	41	39	39	47
Share of economic competencies %	57	52	47	47	41
Share of intangible investment%	19	23	31	32	26
Share of tangible investment%	81	77	69	68	74
Ratio intangible to tangible investment	0.24	0.29	0.44	0.47	0.36

Notes: The share of tangible (intangible) investment is the ratio of tangibles (intangibles) to total investment. The shares of computerised information, innovative property, and economic competencies are calculated relative to all intangibles.

to these four elements, with firms also investing in other types of intangible assets which may represent a source of economic growth; these investments are still treated in the National Accounts as current expenses. Excluding investment in intangibles underestimates total investment, which in turn may misrepresent the measures of output, capital services, factor income shares and consequently productivity.

For Australia, Elnasri and Fox (2014) extend the work of Barnes and McClure (2009) and de Rassenfosse (2012) in applying the methodology of CHS to measure and classify a range of ‘new’ intangibles. However, as they state, “Given the experimental nature of the methodology, the assumptions required, measurement challenges and data limitations, the estimates should be interpreted as only indicative” (Barnes and McClure 2009, p. XIII).¹¹

From Table 1, we see that investment in intangibles has increased over time,

¹¹The following results are drawn from Elnasri and Fox (2014).

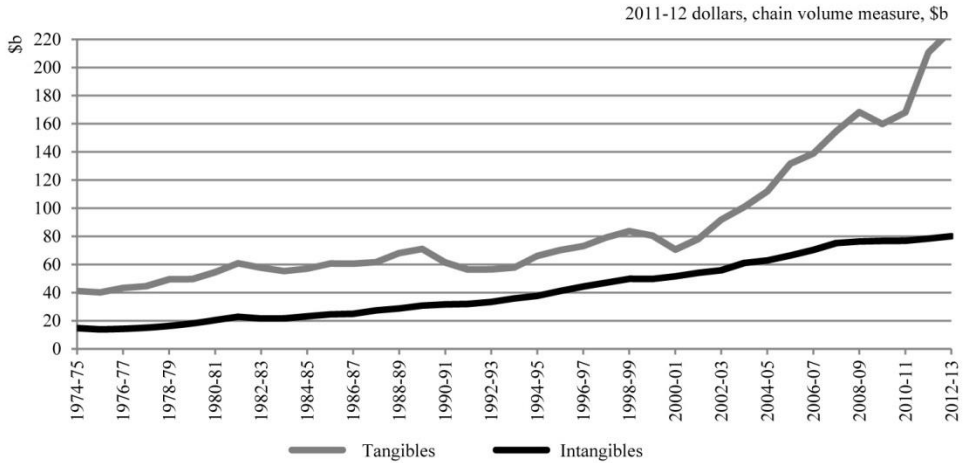


FIGURE 4. MARKET-SECTOR REAL TANGIBLE AND INTANGIBLE INVESTMENTS (1974-75 TO 2012-13)

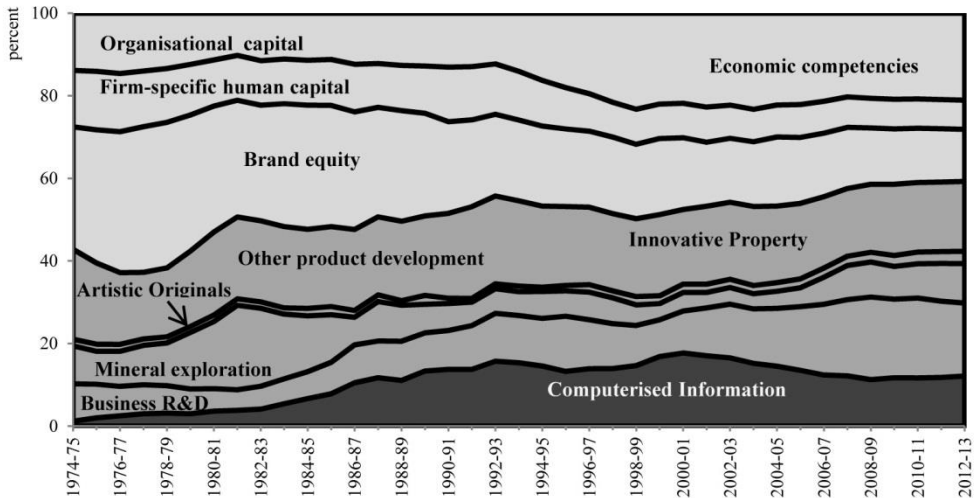


FIGURE 5. SHARES OF NOMINAL TOTAL INTANGIBLE INVESTMENT, BY ASSET TYPE PERCENT

reaching \$82 billion in 2012-13 and constituting around 26 percent of all investment in the market sector for that year. With the exception of the last few years, total investment in intangibles grew more rapidly than investment in tangibles, as shown in Figure 4. The ratio of intangibles to tangibles increased continuously from 0.24 in 1974-75 to 0.47 in 2004-05; however, it decreased to 0.36 by 2012-13. Only computer software, artistic originals, mineral exploration and R&D have been capitalised in the Australian System of National Accounts, and these constitute less than half of the total amount of intangible investment. In 2012-13, National Accounts intangibles accounted for 42 percent of the total amount of intangible investment, while new intangibles accounted for 58 percent.

Table 1 and Figure 5 show that the composition of intangible investments has changed considerably over the last three and a half decades. For the first four years

presented in Table 1, the component of economic competencies is the largest component of intangible investment, with an average share of 51 percent. The second largest component was innovative property, with an average share of 40 percent. However, by 2012-13, these two categories of intangibles had reversed their contribution ranking; economic competencies decreased to 41 percent while the share of innovative property increased to 47 percent. Investment in computerised information has dramatically increased over time, although remaining the smallest component of intangibles. Figure 5 illustrates the extent of the shift towards investment in computerised information and organisational capital over time. The share of organisational capital has increased, while that of economic competencies as a group has decreased, influenced by the decrease in brand equity and firm-specific human capital. The share of innovative property decreased slightly but started to recover by the end of the period, as the involvement of firms in business R&D has increased noticeably in recent years.

Elnasri and Fox (2014) use the CHS methodology to capitalise the new, broader class of intangibles, and compare the impact on multifactor productivity (MFP) growth for the market sector from different treatments of intangibles investment. Figure 6 shows that capitalising expenditures on intangibles changes the rate of MFP growth. In particular, the figure indicates that MFP growth decreases as more knowledge, innovation and other intangible assets are accounted for. This can be explained by the fact that the inclusion of intangibles has raised output growth by a lower rate than it has raised the growth in inputs. Although the rate of MFP growth has decreased across the period, the pattern of the growth remains unchanged. Specifically, the improvement in productivity during the productivity growth cycle of 1998-99 to 2003-04 and the overall decline during the recent productivity growth cycle is still present after capitalising intangibles. Hence, enhanced measurement by capitalising intangibles in this way does not resolve the recent productivity decline.

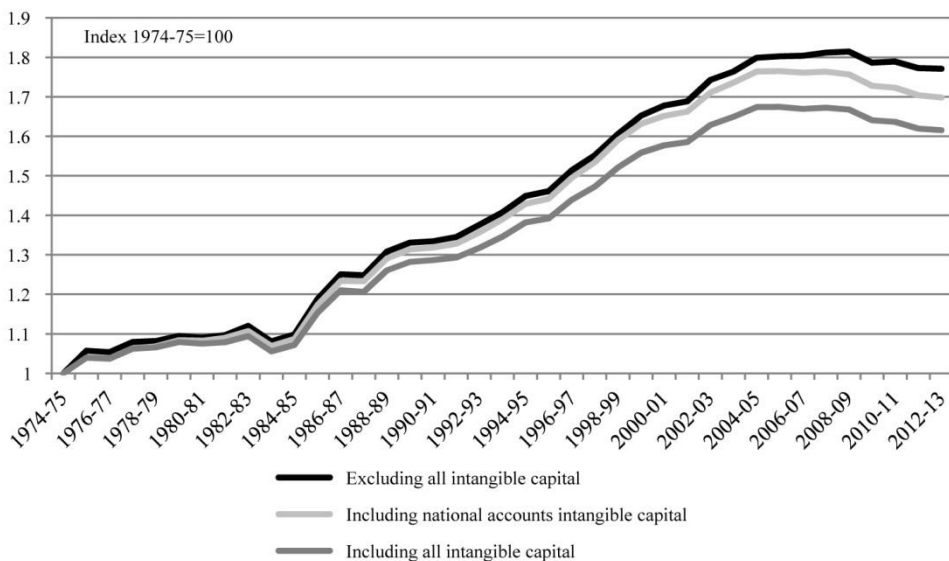


FIGURE 6. MULTIFACTOR PRODUCTIVITY, MARKET SECTOR, 1974-75 TO 2012-13

IV. Public Funding

Besides fulfilling public needs (such as improving the products and services offered or better delivery of functions), the economic rationale for governmental involvement in the area of research and innovation is the existence of market failure associated with research and innovation. This type of market failure is typically due to the diffusion of knowledge beyond the control of the innovator, which implies that the private rate of return to research and innovation is lower than its social return. Thus, governments intervene to eliminate this gap between private and social returns.

Another reason for the provision of public support is that governments want to stimulate research and innovation performed by the business sector. This is likely to be below the socially optimal level, as firms are often discouraged from engaging in research activities by the inherently high risk of research (Arrow 1962). Therefore, governments intervene to assist firms either by mitigating their private costs or by raising awareness of the technological opportunities that are available to reduce both the cost and uncertainty of research and innovation.

There are two main sources of data on public support for R&D and innovation in Australia: the Science, Research and Innovation Budget Tables (SRIBTs) and the ABS survey on R&D. With each federal budget, the Australian government publishes SRIBTs, which provide an overview of government support for science, research and innovation over a period of ten years. The SRIBTs summarise the total amount of Australian government support by sector of performance while also breaking down total expenditures by program and socioeconomic objectives. The ABS survey on public spending on R&D captures R&D expenditures when the R&D is performed.

The SRIBTs classify government support for research and innovation into four sectors of performance: Commonwealth research agencies, the higher education sector, the business enterprise sector, and a “multisector” category. Figure 7 presents public spending as estimated for the year 2012-13. The higher education sector is the recipient of the largest share of science and innovation funding from the Australian government, receiving around 32 percent of all public support, followed by the business enterprise sector and those in the multisector category, which respectively received 25 percent and 23 percent of all support. The research agency sector has received the smallest portion of support, equivalent to 20 percent of the total support.

The public funding devoted to each of these sectors is allocated to different areas. An analysis of the \$8.9 billion outlay by the Australian government for R&D and innovation in 2012-13 shows the following:

Higher Education Research: Performance-based block funding (PBBF) accounts for 67 percent of the total funding to the higher education sector. PBBF is provided through a number of ‘performance-based’ arrangements, such as the Research Training Scheme (RTS), the Institutional Grants Scheme (IGS), the Research Infrastructure Block Grants scheme (RIBG), and the Australian Postgraduate

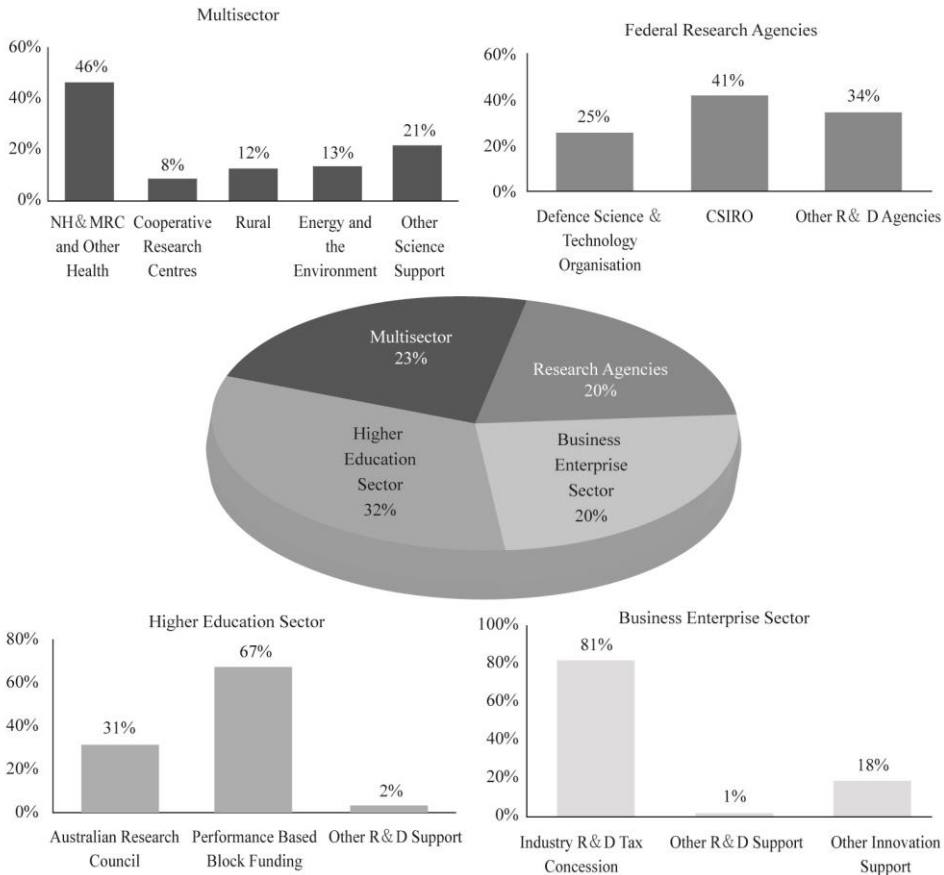


FIGURE 7. AUSTRALIAN GOVERNMENT SPENDING ON SCIENCE AND INNOVATION, 2012-13

Awards scheme (APA).¹³ Australian Research Council (ARC) funding accounts for 31 percent of all funding to higher education. Other R&D support accounts for 2 percent.

Business Enterprise Sector: Government support for business sector science and innovation activities is delivered through a range of programs. The main program is the R&D Tax Concession, which accounts for approximately 81 percent of the total amount of business support in 2012-13. The categories of Other Innovation Support and Other R&D Support account for 18 percent and 1 percent, respectively.

Research Agencies: Two main organisations – the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Defence Science and Technology Organisation (DSTO) – dominate the research funding allocated to public-sector research agencies. In 2012-13, the CSIRO accounted for 41 percent

¹³These arrangements are known as “performance-based” because allocations to each institution depend on its past performance as assessed by various formulae administered through the Department of Education, Employment and Workplace Relations.

of all public-sector research agency funding, while the DSTO accounted for 25 percent. Other public R&D agencies accounted for 34 percent.¹⁴

Multisector: Nearly 46 percent of multisector funding is devoted to the National Health and Medical Research Council (NHMRC) and to other health grants, which predominantly go to universities and private non-profit medical research institutes (MRIs). The Cooperative Research Centres (CRCs) and Rural Funds also have strong university components; they constitute around 8 percent and 12 percent of multisector outlays, respectively. The category entitled Energy and the Environment has a share of 13 percent, and Other Science Support is at 21 percent.

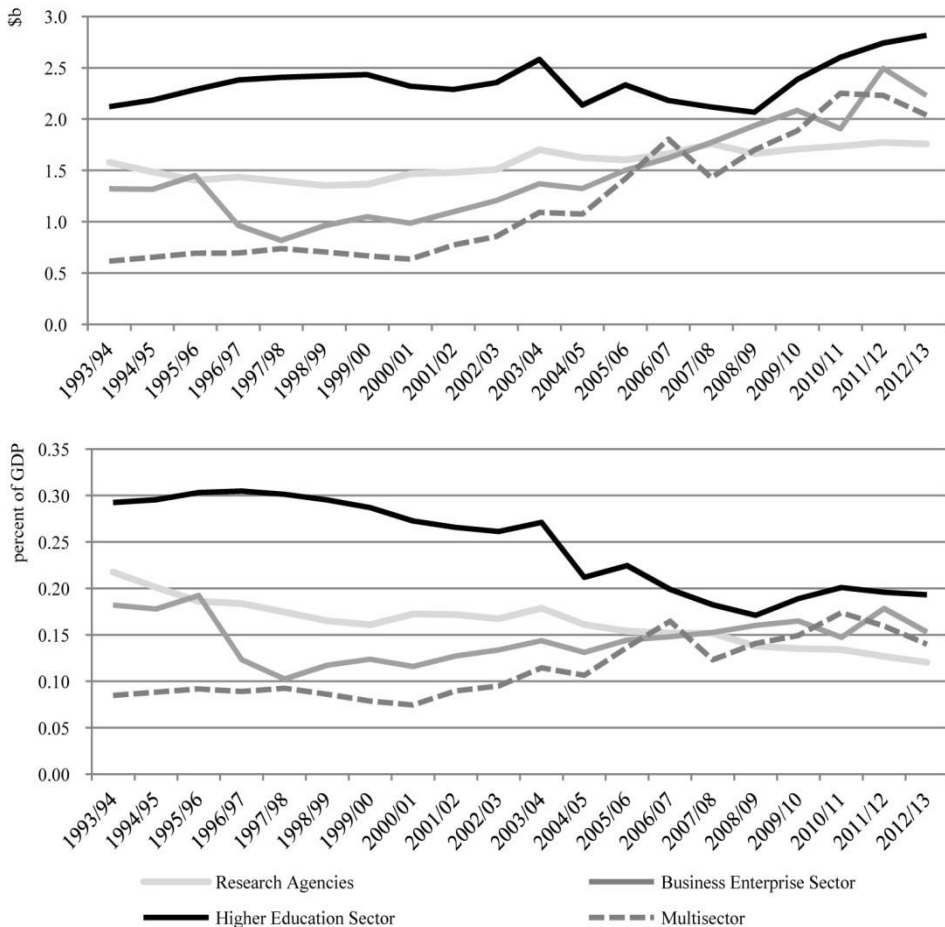


FIGURE 8. AUSTRALIAN GOVERNMENT SUPPORT FOR RESEARCH AND INNOVATION, 1993-94 TO 2012-13

¹⁴Other public R&D agencies include the Australian Nuclear Science and Technology Organisation (ANSTO), Geoscience Australia, Antarctic Division, Australian Institute of Marine Science (AIMS), Bureau of Meteorology Research Centre, Environmental Research Institute of the Supervising Scientist, Australian Animal Health Laboratory, Great Barrier Reef Marine Park Authority, and the Anglo-Australian Telescope.

Figure 8 plots the support for research and innovation and its components over time. From the top panel of the figure, total support has increased in real terms over the past two decades. However, as shown in the lower panel, it has fallen as a share of GDP. There have been noticeable changes in the role of the government support across its four components of funding. In particular, indirect public support for the business enterprise sector and for the multisector category has also grown in real terms during the past two decades. However, support to higher education and direct support to research agencies has barely grown. This has meant that the share of public support to the multisector category has roughly doubled between 1993-94 and 2012-13, while support to higher education has halved. A number of factors can account for this changing pattern in government investment, including an increased focus on collaboration in the multisector category and progressive increases in claims on the R&D tax concessions in the business enterprise sector.

ABS survey data can be used to explore how public R&D resources are allocated according to the intended purpose or outcome of the research. Figure 9 presents a comparison between 1992-93 and 2011-12, breaking down expenditures on R&D by the associated socioeconomic objective. As shown in the figure, the largest share of government R&D expenditure was directed towards economic activities, followed by defence and environment activities. However, social activities such as education and training and social development and community activities receive a small share of government R&D expenditure.

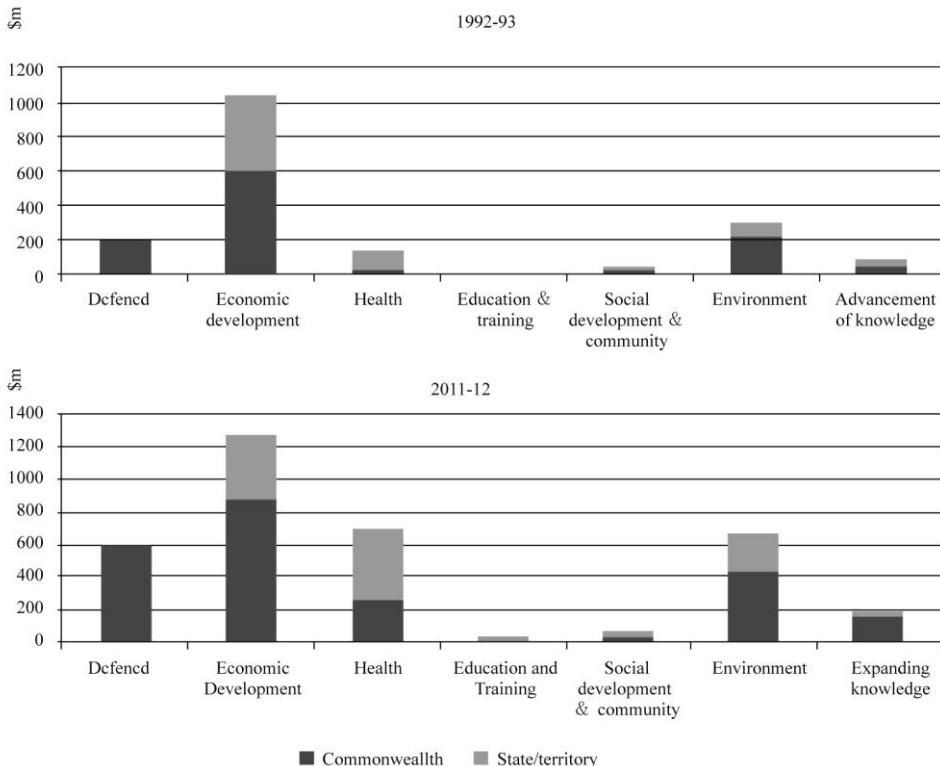


FIGURE 9. BREAKDOWN OF UNDERPINNING RESEARCH FUNDED BY THE COMMONWEALTH AND STATE/TERRITORY BY SOCIOECONOMIC OBJECTIVE, 1992-93 AND 2011-12

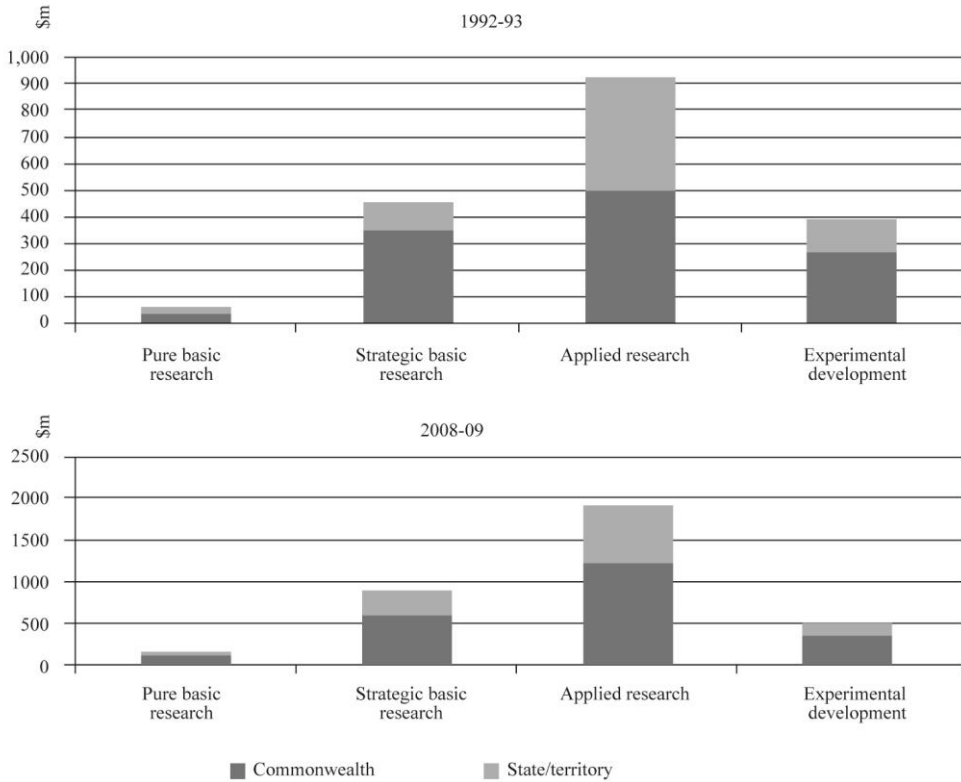


FIGURE 10. COMMONWEALTH SUPPORT FOR R&D, BY TYPE OF ACTIVITY, 1992-93 AND 2008-09

The ABS data also breaks down Commonwealth expenditures on R&D according to the types of activities, with the categories being basic research, applied research and experimental development. Basic research is broken down further into the two types of pure and strategic basic research. Applied research is a critical input to the innovation system and is often seen to be more immediately relevant and applicable for end users, specifically industry, than basic research. In Figure 10 it is shown that the Commonwealth and State governments focus more on applied research and strategic basic research at the expense of pure basic and experimental development research.

V. Public R&D Capital and Productivity Growth

Most of the literature that examined the relationship between R&D and economic or productivity growth have avoided the problem of obtaining an estimate of R&D capital stock by employing a measure of R&D intensity (i.e., a ratio of R&D expenditures to the value of production); see, e.g., Griliches (1998) and Haskel and Wallis (2013). However, this method implicitly assumes that the depreciation rate of R&D is zero, which is not a very realistic assumption. Hence, Elnasri and Fox (2014) use the stock of public-sector R&D as estimated with the

method of Corrado, Hulten and Sichel (2005, 2006).

Figure 10 plots multifactor productivity (MFP) growth, smoothed by a three-year centred moving average, against the Elnasri-Fox capital stock growth of public support for research agencies, higher education, and business enterprise. Productivity and public support for higher education activities move together throughout the period, which gives the appearance of a strong relationship. Similarly, with the exception of the early years, there is co-movement between productivity and research agencies' activities, again suggesting a positive correlation between them. Conversely, the divergent trends in productivity and the public support for the business enterprise sector suggest a negative relationship. However, this casual analysis presupposes a contemporaneous relationship between R&D and productivity; it is more likely that there are lagged effects of R&D expenditure on productivity given that knowledge typically takes time to disseminate. The correlations suggested by the bivariate plots may therefore represent an overly simplistic analysis. There may also be other potential influences on productivity which could be obscuring actual causal relationships. Therefore, to provide stronger evidence of the relationship between productivity and public knowledge, a detailed econometric analysis accounting for other influences is required.

Elnasri and Fox (2014) provide such a detailed analysis, isolating social returns from private returns while controlling for various factors that can affect Australia's productivity performance, such as the provision of public infrastructure, the business cycle, trade openness and the terms of trade. Although restricted by data availability to examine an aggregate of the twelve core market sectors over the period of 1993-94 to 2012-2013, they present extensive results from alternative models and conduct numerous robustness checks.¹⁵ Essentially, the results confirm the relationships apparent in Figure 9.

The conclusions from the Elnasri-Fox analysis can be summarized as follows. There is evidence that private-sector knowledge capital is a source of positive spillover to market-sector productivity. That is, not all benefits of research, innovation and other intangibles are captured privately, but there are "social" benefits which diffuse throughout the market sector.

There is strong evidence of productivity benefits from public spending on Commonwealth research agencies and higher education. However, the results show no evidence of social returns (in excess of private returns) from public support to the business enterprise sector, the multisector category, or defence R&D.

Several reasons can be postulated for this. Health research funding constitutes nearly 50 percent of public expenditures in the multisector category in 2012-13, as shown in Figure 7. Its output is not part of market-sector value added, and any productivity effects are likely to be very long term, through improvements in the health of the workforce and population more generally; hence, there is a bias against finding a positive significant result. Similarly, it is expected that while some select components of expenditures on defence may result in innovations with

¹⁵A longer time series would provide more confidence in the results, but given the lack of historical data this can only be remedied by the passage of time. The sample size is similar to that used in the related study of Haskel and Wallis (2013) for the U.K.

commercial value that appear in the market sector, defence services will not, again biasing the results against finding a positive relationship. The main public support for the research and innovation in the business enterprise sector is the industry R&D Tax Concession,¹⁶ comprising 81 percent of support to the sector in 2012-13. Unlike much of the funding to higher education and research agencies, the allocation of support is based on expenditures rather than on performance. Obviously, there are strong financial incentives for firms to maximise expenditures classified as being related to R&D, potentially biasing the results.¹⁷ In addition, there may be other policy goals of the R&D Tax Concession than raising productivity. Indeed, providing incentives for the establishment of small innovative firms may actually lower productivity, as new entrants often initially have lower productivity compared to incumbents; see, e.g., Baldwin (1995) and Aw, Chen and Roberts (2001).¹⁸

On the other hand, universities and research agencies are primary sources of knowledge and technology creation and diffusion. While the above analysis has focussed on the aggregate market sector, there is substantial international evidence of the positive impacts of universities and research agencies on firm productivity, through the development of skilled labour and positive externalities (Malecki 1997; Medda *et al.* 2005). Adams (2002) found evidence of academic spillover from U.S. R&D laboratories that induce the clustering of firms with universities and research agencies, while Anselin *et al.* (1997) and Woodward *et al.* (2006) found that R&D-intensive production tends to be located close to universities. After controlling for corporate R&D, Jaffe (1989) found that patented inventions at the state level in the U.S. depend significantly on university research.

Such evidence is not restricted to the U.S. For example, Yaşar and Morrison Paul (2012) found more patent activity in Chinese firms with university and research institution connections. In addition, they found that linkages with research institutions in particular raised firm productivity. The introduction of new products, processes, and new businesses was also positively associated with linkages with research institutions.

Hence, if the policy goal is to raise private-sector productivity, the evidence suggests that government research agencies and higher education are the areas with more potential gains from public funding support.

¹⁶Following a change in eligibility rules and allowances, the R&D tax concession was replaced by the “R&D tax incentive” from 1 July 2011: <http://www.ato.gov.au/Business/Research-and-development-tax-incentive/>.

¹⁷Thompson (2009, p. 3) notes the following: “However, some have argued that anecdotal evidence does not support the efficacy of R&D tax incentives. Regarding the US experience, a senior correspondent from Business Week describes his experience, speaking, off the record, with corporate executives (Gleckman 2006): ‘In 20 years, I’ve never had a single corporate executive from the pharmaceutical industry or the high-tech industry, or anyplace else tell me that they have done a dime’s worth of research that they otherwise wouldn’t have done as a result of the R&D credit. They spend lots of time and effort reallocating costs so they can take advantage of the credit, but they don’t actually do any more research.’ For Australia, survey evaluations of the Australian R&D tax concession (DITR 2005; DITR 2007a) found that approximately 30% of respondents admit that their R&D efforts would not have been smaller or completed at a slower rate in the absence of the concession.

¹⁸The evidence of the effectiveness of R&D tax concessions in only raising R&D intensity is mixed, without even considering the impact on productivity. In a study of nine OECD countries over a nineteen-year period, Bloom *et al.* (2000) found that tax incentives are effective in increasing R&D intensity. Yet, in a study of Australia using financial data on 500 large Australian firms between 1990 and 2005, Thomson (2009) finds that tax incentives are not an important determinant of a firm’s R&D investment decisions.

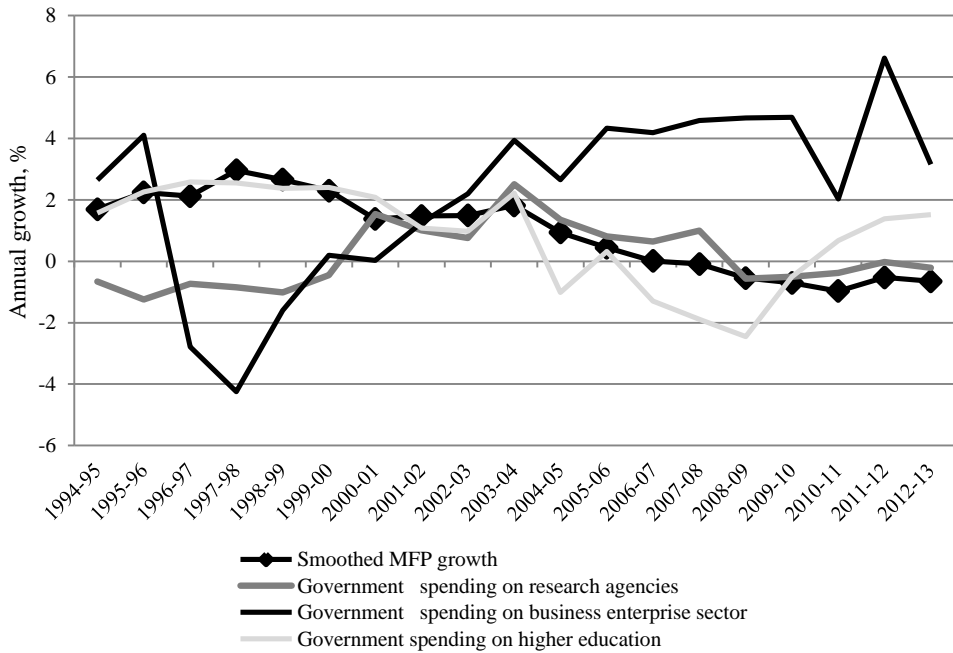


FIGURE 11. MARKET-SECTOR MFP GROWTH AND PUBLIC SUPPORT FOR RESEARCH AGENCIES, HIGHER EDUCATION AND THE BUSINESS SECTOR (1993/94-2012/13)

VI. Conclusions

Investments in research and innovation (such as information technology, R&D, skills development, design and organisational improvements and other types of intangible assets) are regarded as central drivers of productivity. They create more efficient services and production processes, more effective workplace organisation, and open up new markets. However, it is commonly argued that there are major market failures in the provision of a sufficient amount of such knowledge capital, as knowledge diffuses beyond the control of the innovator. This implies that the private rate of return for research and innovation is lower than its social return, resulting in underinvestment in knowledge capital than would be optimal if all returns were privately captured. Additionally, the high risks involved discourage firms from engaging in such activities.

For both reasons, the amounts invested by firms in research activities in a competitive framework are likely to be below the socially optimal level. This justifies intervention by governments directly to make their own investments in knowledge capital, or indirectly to support the private sector to reduce its costs. However, governments face the stumbling block of a large number of projects competing for tight budgets, raising questions about how available funds can be distributed most effectively to achieve policy goals, such as raising private-sector productivity. This paper makes reference to the international literature and draws on recent empirical research for Australia to provide some policy-relevant insights

related to the role of government in supporting productivity-enhancing research and innovation.

For a better understanding and to improve the functioning of the innovation systems of an economy, it is essential to track, or benchmark, performance. Developing robust and relevant measures of research and innovation is difficult. The intangible nature of research and innovation poses problems for the measurement of spending and the depreciation of spending in defining capital stocks. As such, research and innovation are largely ignored in the National Accounts and in the corporate financial reports of many countries, where they have been only treated as intermediate expenditures. However, excluding investments in these intangible assets means that investments are underestimated, which may distort measures of growth in capital services and, consequently, productivity. Hence, in addressing the role of government funding of research and innovation, this paper has paid significant attention to the fundamental issue of accounting for investments in knowledge capital.

Some key findings can be summarised as follows. First, in the case of Australia, measuring research and innovation by focusing only on the set of assets currently capitalised in the System of National Accounts seems unreliable. Total investment has been found to be under-reported, and this has distorted measures of the growth of capital services and, consequently, productivity. Different countries have capitalised intangibles to different degrees, making international comparisons complicated.

Also in the case of Australia, it was found that the partial capitalisation of intangible assets has lowered the estimates of productivity growth. As the Australian Bureau of Statistics is a leading agency in improving its National Accounts and productivity measurements in this way, it is likely that Australia's relative market-sector performance is better than currently thought.

Second, the accumulation of private-sector knowledge capital is a source of positive benefits (spillover) to market-sector productivity. This implies that innovative activity has broad benefits that diffuse through the economy.

Third, given the pressures on public finances, it is appealing to direct the innovation budget to areas with higher social benefits. Consistent with the findings of Haskel and Wallis (2010, 2013) for the U.K., the results presented in Section 6 and further findings of Elnasri and Fox (2014) for Australia suggest that government research agencies and higher education are areas with more potential gains compared to, e.g., providing firms with tax incentives for investment in R&D.

This remains a fertile field for further research. For example, the standard current approach to the capitalisation of intangibles is that of Corrado, Hulten and Sichel (2005, 2006), which effectively treats intangibles as if it treats tangibles. That is, it treats intangible capital (such as knowledge capital) as if it has similar characteristics to a truck, with a finite life during which it depreciates. This approach has benefits in terms of familiarity and, with some brave assumptions about deflators and depreciation rates, the relative ease of implementation. Unfortunately, it is not a very accurate description of what is going on with investments in intangibles; it is unlikely that, in general, an idea depreciates in the same way as a truck. By developing and expanding the approach proposed by Diewert and Fox (2014) in the context of amortizing goodwill (an intangible) for

commercial property, and taking into account the “sunk cost” aspect of investments, it seems possible to develop a significantly more realistic framework with which to address this important problem of appropriately accounting for intangibles.

An additional unresolved issue is the potential difference in the productivity impact from government support for different types of R&D, such as pure basic research versus applied research (see Figure 10). The unavailability of sufficient survey data prevented the further exploration of this important aspect of investment in knowledge capital for Australia.¹⁹

Finally, it is noted that the apparent persistence of the slowdown in productivity growth in industrialized countries, combined with recent budget concerns arising from less favourable economic conditions, will likely heighten the debate on the role of government innovation policies which raise productivity growth. While acknowledging the caveats in the existing literature (including the current paper) and the desirability of further analysis if appropriate data becomes available, there appears to be a role for government funding support; the evidence suggests that it is not through direct industry support through tax incentives but rather through support for government research agencies and higher education.

REFERENCES

- ABS.** 2007. “Experimental Estimates of Industry Multifactor Productivity.” Information paper, ABS Cat. No. 5260.0.55.001, Canberra, Australia.
- ABS.** 2013. “Estimates of Industry Multifactor Productivity, Australian Bureau of Statistics.” ABS Cat. No. 5260.0.55.002, Canberra, Australia.
- Bell, J., B. Frater, L. Butterfield, S. Cunningham, M. Dodgson, K. J. Fox, T. Spurling and E. Webster.** 2014. “The Role of Science, Research and Technology in Lifting Australian Productivity.” report for the Australian Academy of the Humanities, www.acola.org.au
- Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl.** 2009. “The Effects of Entry on Incumbent Innovation and Productivity.” *Review of Economics and Statistics* 91 (1): 20–32.
- Anselin, L, Varga, A and Acs, Z.** 1997, “Local Geographic Spillovers Between University Research and High Technology Innovations.” *Journal of Urban Economics* 42: 422–448.
- Arrow, K.** 1962. “The Economic Implications of Learning by Doing.” *The Review of Economic Studies* 29: 155–173.
- Aw, B. Y., X. Chen and M. J. Roberts.** 2001. “Firm Level Evidence on Productivity and Turnover in Taiwanese Manufacturing.” *Journal of Development Economics* 66: 51–86.
- Baldwin, J. R.** 1995. *The Dynamics of Industrial Competition: A North American perspective*, Cambridge University Press, Cambridge.
- Barnes, P. and A. McClure.** 2009. “Investments in Intangible Assets and Australia’s Productivity Growth.” Productivity Commission Staff Working Paper, March.
- Bloom, N., R. Griffith and J. Van Reenen.** 2002. “Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997.” *Journal of Public Economics* 85 (1): 1–31.
- Connolly, E. and K. J. Fox.** 2006. “The Impact of High-Tech Capital on Productivity: Evidence from Australia.” *Economic Inquiry* 44 (1): 50–68.
- Connolly, E. and L. Gustafsson.** 2013. “Australian Productivity Growth: Trends and Determinants.” *Australian Economic Review* 46 (4): 473–482.
- Corrado, C., C. Hulten and D. Sichel.** 2005. “Measuring Capital and Technology: An

¹⁹However, given the differences in industry structure across countries, it is unlikely that lessons from any one country using such a breakdown by R&D type will be easily transferable to other countries. However, if the data were available, the productivity impact of support for different types of R&D and innovation within these sectors could provide new insights for policymakers in any specific country.

- Expanded Framework.” In *Studies in Income and Wealth* Vol. 65, edited by C. Corrado, J. Haltiwanger and D. Sichel, University of Chicago Press.
- Corrado, C., C. Hulten and D. Sichel.** 2006. “Intangible Capital and Economic Growth.” NBER Working Paper No. 11948, National Bureau of Economic Research, Cambridge, Massachusetts.
- Crepon, B., E. Duguet, and J. Mairesse.** 1998. “Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level.” *Economics of Innovation and New Technology* 7: 115–156.
- Criscuolo, C., and J. E. Haskel.** 2003. “Innovation and Productivity Growth in the UK: Evidence from CIS2 and CIS3.” CeRiBA Working Paper, London School of Economics, London, UK.
- Diewert, W. E. and N. Huang.** 2011. “Capitalizing R&D Expenditures.” *Macroeconomic Dynamics* 15: 537–564.
- Diewert, W. E. and K. J. Fox.** 2014. “Sunk Costs and the Measurement of Commercial Property Depreciation.” University of British Columbia, Department of Economics Discussion Paper No.14-06.
- DITR.** 2007a. “How R&D Assistance Influences Company Behaviour.” Department of Industry, Tourism and Resources, Canberra.
- DITR.** 2007b. “High Variation in R&D Expenditure by Australian firms.” Department of Industry, Tourism and Resources, Canberra.
- Elnasri, A. and K. J. Fox.** 2014. “The Contribution of Research and Innovation to Productivity and Economic Growth.” School of Economics Discussion Paper UNSW.
- Gleckman, H.** 2006. Transcript of the 2006 Tax Analysts Conference Series, “Tax Incentives—Do they Work, and are they Worth the Cost?” Washington DC, as cited in Rashkin, M. D. (2007). *Practical Guide to Research and Development Tax Incentives*, Federal, State and Foreign, 2nd Ed, Chicago, Wolters Kluwer Business, p.30.
- Gordon RJ.** 2012. “Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds.” NBER Working Paper No 18315. <http://www.nber.org/papers/w18315>
- Gorodnichenko, Y., J. Svejnar, and K. Terrell.** 2010. “Globalization and Innovation in Emerging Markets.” *American Economic Journal Macroeconomics*: 194–226.
- Griffiths, W. and E. Webster.** 2010. “The Determinants of Research and Development and Intellectual Property Usage among Australian Companies, 1989 to 2002.” *Technovation* 30, 471481.
- Griliches, Z.** 1981. “Market Value, R&D and Patents.” *Economics Letters* 7: 183–187.
- Griliches, Z.** 1988. “Productivity Puzzles and R&D: Another Nonexplanation.” *Journal of Economic Perspectives* 2 (4): 9–21.
- Griliches, Z.** 1998. *R&D and Productivity: The Econometric Evidence*, University of Chicago Press: Chicago.
- Hall, B. H.** 2011. “Innovation and Productivity.” National Bureau of Economic Research Working Paper No. 17178.
- Hall, B. H. and N. Rosenberg.** 2010. *Handbook of the Economics of Innovation*, Vol. 1 & 2, North-Holland: Amsterdam.
- Haskel, J. and G. Wallis.** 2010. “Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector.” IZA Discussion Paper Series No. 4772.
- Haskel, J. and G. Wallis.** 2013. “Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector.” *Economics Letters* 119: 195–198.
- Isaksson, A.** 2007. “Determinants of Total Factor Productivity: A Literature Review.” Staff Working Paper No. 02/2007, United Nations Industrial Development Organization.
- Jaffe, A.** 1989. “Real Effects of Academic Research.” *American Economic Review* 79: 957–970.
- Janz, N., H. Loof, and B. Peters.** 2003. “Firm Level Innovation and Productivity—Is there a Common Story Across Countries?” Mannheim, Germany: ZEW Discussion Paper No. 03-26.
- Lichtenberg, F.** 1993. “R&D Investment and International Productivity Differences.” NBER Working Paper No. 4161, Cambridge, MA.
- Loof, H., and A. Heshmati.** 2006. “On the Relationship Between Innovation and Performance: A Sensitivity Analysis.” *Economics of Innovation and New Technology* 15: 317–344.

- Louca, J.** 2003. "Multifactor Productivity and Innovation in Australia and Its States." In *Productivity and Regional Economic Performance in Australia*, edited by C. Williams, M. Draca and C. Smith, Collection of Papers prepared by the Office of Economic and Statistical Research, Queensland Treasury.
- Mairesse, J., and S. Robin.** 2010. "Innovation and Productivity: a Firm-Level Analysis for French Manufacturing and Services Using CIS3 and CIS4 data (1998-2000 and 2002-2004)." Paris, France: CREST-ENSAE.
- Malecki, E. J.** 1997. *Technology and Economic Development: the Dynamics of Local, Regional and National Competitiveness*, Longman, London.
- Medda, G., C. Piga, and D. S. Siegel.** 2005. "University R&D and Firm Productivity: Evidence from Italy." *Journal of Technology Transfer* 30 (1/2): 199–205.
- Mohnen, P.** 2001. "International R&D Spillovers and Economic Growth." In *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*, pp.50–71, edited by M. Pohjola, Oxford University Press, London.
- Mowery, D. C. and B. N. Sampat.** 2010. "Universities in National Innovation Systems." unpublished manuscript, Haas School of Business, University of California, Berkeley, <http://innovate.ucsb.edu/wp-content/uploads/2010/04/Mowery-Sampat-Univ-National-Innovation-Systems.pdf>
- Nadiri, I.** 1993. "Innovations and Technological Spillovers." NBER Working Paper No. 4423, Cambridge, MA.
- OECD.** 2005. *Oslo Manual: The Measurement of Scientific and Technological Activities—Guidelines for Collecting and Interpreting Innovation Data*, 3rd edition, p.46, OECD, Paris.
- Oliner, S. D., D. E. Sichel and K. J. Stiroh.** 2007. "Explanation of a Productive Decade." *Brookings Papers on Economic Activity* 1: 81–137.
- Parham, D.** 2006. "Empirical Analysis of the Effects of R&D on Productivity: Implications for Productivity Measurement?" OECD Workshop on Productivity Measurement and Analysis, Bern, Switzerland, 16–18 October.
- Parham, D.** 2012. "Australia's Productivity Growth Slump: Signs of Crisis, Adjustment or Both?" Visiting Researcher Paper, Productivity Commission, Canberra.
- Phelps, E.** 2013. *Mass Flourishing: How Grassroots Innovation Created Jobs, Challenge, and Change*, Princeton University Press, Princeton.
- Productivity Commission.** 2006. "Potential Benefits of the National Reform Agenda." Productivity Commission Research Paper, Canberra.
- Productivity Commission.** 2007. "Public Support for Science and Innovation." Productivity Commission Research Report.
- Productivity Commission.** 2009. "Australia's Productivity Performance, Submission to the House of Representatives Standing Committee on Economics: Inquiry into Raising the Level of Productivity Growth in Australia." September.
- Rosenberg, N.** 1963. "Technological Change in the Machine Tool Industry, 1840-1910." *Journal of Economic History* 23: 414–443.
- Rosenberg, N.** 1981. "Why in America?" In *Yankee Enterprise and the Rise of the American System of Manufactures*, edited by O. Mayr and R. C. Post, Washington, DC: Smithsonian Institution Press; Reprinted in *Exploring the Black Box*, Cambridge: Cambridge University Press, 1995.
- See House of Representatives Standing Committee on Economics.** 2010. *Inquiry into Raising the Productivity Growth Rate in the Australian Economy*, The Parliament of the Commonwealth of Australia, Canberra, pp.31–57.
- Siedschlag, I., Z. Zhang, and B. Cahill.** 2010. "The effects of the Internationalisation of Firms on Innovation and Productivity." ESRI Working Paper No. 363, Economic and Social Research Institute, Dublin, Ireland.
- Schmookler, J.** 1966. *Invention and Economic Growth*, Cambridge, MA: Harvard University Press.
- Shanks, S. and S. Zheng.** 2006. "Econometric Modelling of R&D and Australia's Productivity." Productivity Commission Staff Working Paper.

- Soames, L., D. Bruncker and T. Talgaswatta.** 2011. "Competition, Innovation and Productivity in Australian Businesses." Methodology Research Papers, Cat. No. 1351.0.55.035, Australian Bureau of Statistics, Canberra.
- Syverson, C.** 2011. "What Determines Productivity?" *Journal of Economic Literature* 49 (2): 326–365.
- Thomson, R.** 2009. "Tax Policy and R&D Investment by Australian Firms." Intellectual Property Research Institute of Australia Working Paper No. 05/09, Melbourne Institute of Applied Economic and Social Research, University of Melbourne.
- Department of Innovation, Industry, Science and Research.** 2012. "Australian Innovation System Report." December.
- Webster, E. and P. H. Jensen.** 2006. "Investment in Intangible Capital: An Enterprise Perspective." *Economic Record* 82 (256): 82–96.
- Wong, M., D. Page, R. Abello and K. Pang.** 2007. "Explorations of Innovation and Business Performance Using Linked Firm-Level Data." Methodology Research Papers, cat. No. 1351.0.55.020, Australian Bureau of Statistics, Canberra.
- Woodward, D., O. Figueiredo, and P. Guimaraes.** 2006. "Beyond the Silicon Valley: University R&D and Hightechnology Location." *Journal of Urban Economics* 60: 15–32.
- Yaşar, M. and C. J. Morrison Paul.** 2012. "Firm Performance and Knowledge Spillovers from Academic, Industrial and Foreign Linkages: The Case of China." *Journal of Productivity Analysis* 38: 237–253.