National Collaborative Research Infrastructure (NCRIS) spending and economic growth

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LateralEconomics

CAPABLE, INNOVATIVE, RIGOROUS

Glossary

ALA	Atlas of Living Australia
ANFF	Australian National Fabrication Facility
ANSTO	Australian Nuclear Science and Technology Organisation
AURIN	Australian Urban Research Infrastructure Network
BCR	Benefit-cost ratio
CBA	Cost-benefit analysis
FTE	Full-time equivalent
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GVA	Gross Value Added
IO	Input Output
LE	Lateral Economics
IMOS	Integrated Marine Observing System
NCRIS	National Collaborative Research Infrastructure Strategy
NEESFF	National Earth & Environmental Science Facilities Forum
PHRN	Population Health Research Network
ROI	Return on investment
TERN	Terrestrial Ecosystem Research Network
TIA	Therapeutic Innovation Australia

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1. Executive Summary

The National Collaborative Research Infrastructure Strategy (NCRIS) is designed to enhance Australia's infrastructure for scientific research and its application and translation to outcomes. It does this by providing funding for 22 NCRIS facilities, which link over 200 institutions (e.g. universities, research institutes, etc.) employing over 1,900 highly skilled researchers and technical experts. Many of these experts are world leaders.[1]

As outlined in this report, NCRIS has provided multiple benefits to Australia since it was established in the mid-2000s. These have included:

- contributing to economic stimulus during the global financial crisis (GFC) and its aftermath; and
- enhancing Australia's physical and intangible capital for research and translation into outcomes for the benefit of the community, providing a large Return on Investment (ROI).[2]

In previous work, Lateral Economics has demonstrated very high benefit to cost ratios of two NCRIS facilities. With this in mind, in this report, Lateral Economics explores the extent to which investment in NCRIS facilities constitutes an economic stimulus over the period of economic recovery from the COVID pandemic. Reasons for believing that the funding planned for NCRIS in 2021-22 and 2022-23 will provide uncommonly cost-beneficial economic stimulus are as follows.

- Even without its contribution to stimulating additional activity, the benefit to cost ratio of investment in NCRIS facilities appears to be very high. For instance, if the average benefit cost ratio of investment in NCRIS were half of what we estimated it to be for two of the NCRIS facilities, it would still generate over $7 for every $1 invested. Such large ratios are a consequence of the vast range of ways that NCRIS activities lower the cost of knowledge creation and make the creation of new knowledge possible alongside the value of that knowledge when created.

- Unlike a cash stimulus to households, none of the additional government outlays would initially leak into savings (although

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[1] (2020a) *National Research Infrastructure*, Department of Education, Skills and Employment website: https://www.dese.gov.au/national-research-infrastructure.

[2] For example, see Lateral Economics' studies of the ROI of AuScope (Lateral Economics, 2016) and PHRN (Lateral Economics, 2017).

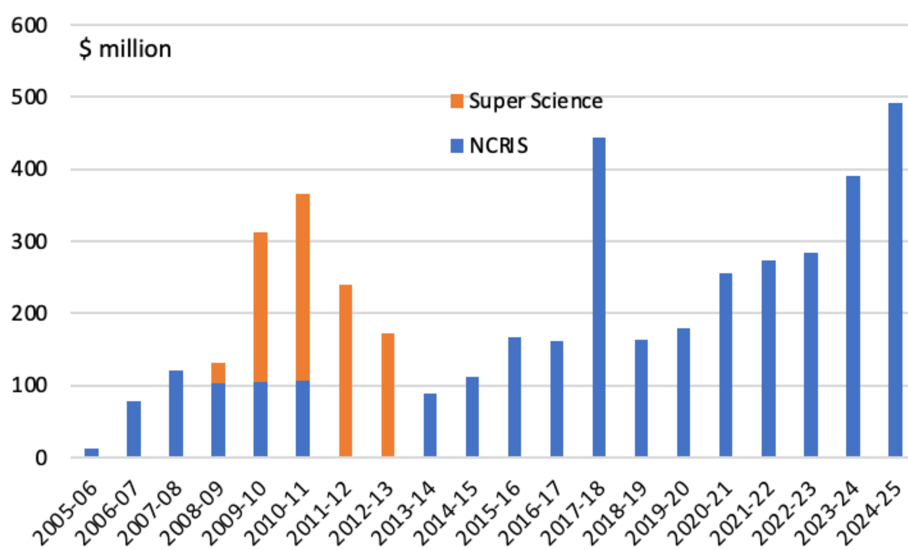
there would be leakages from wages paid to staff employed by NCRIS facilities).

- Every dollar spent on NCRIS facilities generates around $1.29 in additional contributions – in cash and in kind – from other parties including some from offshore.

1.1 Stimulus via NCRIS

The levels of NCRIS and Super Science funding over the late 2000s and early 2010s helped support Australia's economic recovery from the GFC (Figure 1). Both NCRIS and Super Science funding supported the expansion of Australia's national research infrastructure.[3] While small from a macroeconomic perspective, the funding did promote activity in a range of important scientific endeavours and contributed to the employment (and retention in Australia) of highly-skilled researchers.

Figure 1. Australian Government national research infrastructure funding



Source: Australian Government (2021) SRI Budget Tables, retrieved from, https://www.industry.gov.au/data-and-publications/science-research-and-innovation-sri-budget-tables. Super Science Initiative figures are from the 2009-10 Australian Government Budget (Budget Paper 2). Estimates from 2020-21 to 2024-25 are from the DESE Portfolio Budget Statement 2021-22.

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[3] The scope of this report is confined to NCRIS spending, and hence LE has not included Super Science funding in our economic impact and ROI estimates. However, in appropriate places, we note the potential enhancement of impacts estimated through the Super Science funding.

As shown in Figure 1 above, NCRIS funding is ramping up over the next few years, which is consistent with the economy's ongoing need for support during the recovery from the COVID-19 recession.[4]

Note that the funding amounts shown in Figure 1 amount to only a fraction of the total value of infrastructure created or made accessible to researchers via NCRIS. Consider that, while the total value of funding from 2005-06 to 2019-20 (in today's dollars) amounts to $2.00 billion (or $3.03 billion if Super Science funding is considered), according to the Department of Education, Skills and Employment (DESE):

- taking into account contributions from partners, NCRIS is "a $7.1 billion Australian Government initiative supported by universities, state and territory governments and research organisations nationwide"; and
- in 2017-18, "for every $1 of investment the government put into NCRIS, there was total of $1.29 of co-investment from other sources", a level of co-investment that appears to be more generally representative.[5]

Stimulus via NCRIS is expected to have a larger effect than cash transfers. For example, every dollar spent on NCRIS leads directly to economic activity and so lowers unemployment whereas a proportion of cash transfers may be saved. That said, to the extent the stimulus feeds into wages and salaries, the leakages are analogous to giving money to households, as there are still the same two sources of leakage: savings and imports. In net terms, stimulus via NCRIS would still be expected to have a larger impact than an equivalent amount of stimulus via cash transfers.

The effectiveness of government fiscal stimulus can be determined by the relative estimates of fiscal multipliers which express the extent to which an additional dollar of government expenditure (or loss of government revenue) raises total economic output through spill-over effects. For example, for each dollar's increased expenditure on an activity with a multiplier of 1.5 GDP is increased by $1.50 once its spill-over effects are taken into account. In this example, some government spending measure – for instance increased government expenditure on 'shovel ready' infrastructure – generates increased activity. The additional wages paid those who may otherwise be unemployed and the

[4] The funding spike in 2017-18 appears to be due to Research Infrastructure Investment Plan (RIIP) funding announced that financial year. See Australian Government (2018, p. 13).

[5] DESE (2020b) *How Australia's national research infrastructure is responding to COVID-19*: poster: https://www.education.gov.au/sites/default/files/covid-19_poster_ncris_comms_fa.pdf and DESE (2020a) *National Research Infrastructure*, website page: https://www.dese.gov.au/national-research-infrastructure.

additional income earned by capital that would otherwise be idle then finds its way back into the economy as some of it is, in turn, spent. Thus the consumption of newly employed workers will rise stimulating further demand in the economy and so on.

In recessions, additional spending in the economy generates substantial output effects with multipliers greater than one. Other things being equal, the greater the slack in the economy, the higher the multiplier. Further, where stimulus is pursued through higher government investment or spending, every additional dollar spent increases economic activity. By contrast, where fiscal expansion relies on putting money into people's pockets – via cash grants or tax cuts – some of that money will be saved and thereby 'dilutes' the extent of the immediate stimulus. Thus, other things being equal, expanding direct government expenditure is a more direct way of stimulating the economy.

From LE's consultations and review of the evidence, it appears that there is significant scope for stimulus via NCRIS. LE's estimates of the impact of expected NCRIS funding over the next few years are presented in Table 1. These estimates are reported in terms of Gross Value Added (GVA) and GDP.[6] The economic impact analysis has revealed that NCRIS stimulus has contributed to supporting the economy during the GFC and the current COVID-19 pandemic. That support is via direct expansion of NCRIS facilities, supply-chain impacts, and induced consumption impacts as households earning money as a result of the additional activity spend it in the economy.

By 2022-23, when NCRIS funding is expected to be nearly $300 million, it will potentially boost GDP by $446 million, relative to the baseline, generating an additional $127 million in taxation revenue (i.e. covering around 45% of the NCRIS funding injection that year).

While the total GDP impact is small relative to the total economy, representing around 0.02% boost to GDP, it would nonetheless boost employment of people in scientific disciplines and underpin longer-term benefits by augmenting Australia's scientific and knowledge capital. It could directly support the employment of an additional 300-350 full-time equivalent (FTE) scientific and technical staff, plus in the order of an additional 1,400 people across support staff, the supply-chain, and in other industries supported indirectly.

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[6] GVA measures the contributions of industries to the economy exclusive of the impacts of indirect taxes and subsidies, which are included in GDP, which measures total economic activity at market prices.

Table 1. Estimated macroeconomic and fiscal impacts of stimulus over 2020-21 to 2022-23

	2020-21 $m	2021-22 $m	2022-23 $m
1. NCRIS funding	256.4	273.6	283.9
2. Leveraged investment	76.9	82.1	85.2
3. Total investment	333.3	355.6	369.1
4. Additional GVA (direct)*	116.6	124.5	129.2
5. Additional GVA (indirect & induced)	259.9	277.4	287.9
6. Additional GVA (total)	376.6	401.9	417.1
7. Additional GDP (total)	402.9	430.0	446.3
8. Commonwealth Gov't revenue	94.1	100.5	104.3
9. State Gov't revenue	20.1	21.5	22.3

Source: LE estimates, 2021, based on desktop research and consultations detailed in the report. N.B. Direct refers to the impact on the specific sector impacted, assumed to be Professional, Scientific and Technical Services for OPEX and Non-residential Construction for CAPEX.
**Direct may also be referred to as "first round".*

1.2 Return on investment

Return on investment (ROI) is essentially the dollars of benefits returned for dollars invested. Based on LE's previous research and desktop research and consultations undertaken for this current study, we expect a ROI for NCRIS spending in the order of 7.5:1, as discussed below.

Part of the return on NCRIS investment is difficult to quantify in dollar terms and would represent additional ROI if it could be quantified. For example, difficult to quantify benefits include:

- enhancements of core scientific knowledge in a huge range of fields (e.g. plant phenomics, nuclear science, ecology, oceanography, among many); and
- 'soft power' benefits to Australia – i.e. international science diplomacy, as it enables Australia to participate in various international forums and to participate in and access the benefits of scientific infrastructure globally. This infrastructure is best thought of as investment in highly specialised fixed assets (e.g. the Giant Magellan Telescope) plus the complementary highly specialised skills needed to operate them effectively.

Based on desktop research and consultations with 15 facilities, a short summary of selected examples of major benefits arising from NCRIS facilities is provided in Figure 2.

Figure 2. Selected examples of major benefits of NCRIS-supported infrastructure to the Australian community

Bushfire preparedness. With a range of sensors across Australia supported by NCRIS facilities such as TERN and AURIN, Australia can be better prepared for bushfire threats in the future.

Cyclone warnings. IMOS is providing rich, high frequency data from Australia's surrounding oceans which can provide early warning signs of cyclones, not to mention ocean acidification and sea level rise associated with climate change.

Population health. A range of NCRIS facilities (e.g., PHRN, Phenomics Australia, Bioplatforms Australia, Therapeutic Innovation Australia) are helping to improve the health of Australia's population.

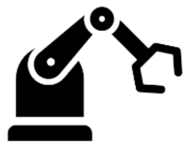
Understanding the building blocks of reality. NCRIS facilities such as Microscopy Australia, National Imaging Facility, ANSTO, and Astronomy Australia are contributing to world leading research on the building blocks of the universe and of life.

Monitoring biodiversity. Australia's unique biodiversity is being monitored, described and protected by the Atlas of Living Australia (ALA), BioPlatforms Australia, IMOS and TERN. In particular, ALA is our national biodiversity data infrastructure. It integrates and delivers fundamental data on Australia's plants, animals and fungi to support ecosystem assessment, monitoring and planning.

Boosting crop yields and resilience. The Australian Plant Phenomics Facility contributes fundamental services in the effort to improve crop yields and crop resilience with genomic and molecular characterisation performed through Bioplatforms Australia.

Deriving value from data. ARDC, Pawsey Supercomputing Centre and the National Computational Infrastructure enable data from many fields of research across a wide range of scales to be stored, curated, managed and analysed.

Understanding the earth. AuScope improves our understanding of fundamental earth science and enables a range of benefits including substantial reductions in the cost of and more effective resource exploration.



Advanced manufacturing. The Australian National Fabrication Facility (ANFF) and Therapeutic Innovation Australian (TIA) provide industry and the wider community with access to cutting-edge advanced manufacturing technologies. Furthermore, NCRIS organisations such as Astronomy Australia are involved in advanced manufacturing activities.

While it is challenging to value such a broad range of benefits, some of which will only be realised in decades to come (e.g. understanding of long-term climate change impacts), various studies, including previous LE studies have attempted to quantify the ROI of NCRIS supported activities, particularly those supported by the Population Health Research Network (PHRN) and AuScope. These studies reported ROIs of 16:1 and 15:1 respectively. These are unusually high numbers for a cost/benefit analysis. They are nevertheless not unusual for some infrastructure projects particularly intellectual infrastructure which can radiate spill-over benefits in numerous directions often as free, unpriced externalities. Indeed, benefit cost ratios of the kind LE found in these cases are common for other intellectual infrastructure which circulates as a free good and radiates new opportunities in numerous domains – for instance the services of Google and Wikipedia.

It was not possible to comprehensively assess the ROI of the NCRIS facilities collectively as part of this assignment. Nonetheless, we endeavour to provide an estimate of the magnitude of NCRIS's ROI to the Australian community based on aggregate funding data and an assumed ROI of 7.5:1, which is approximately half that found for AuScope and PHRN.

LE estimates that, in 2020-21, the total value of the physical and intangible capital stock produced by NCRIS funding since 2005-06 is $2.27 billion (or $3.09 billion if Super Science funding is also considered). Applying the expected ROI of 7.5:1 to this capital stock yields an expected benefit in PV terms of approximately $17.03 billion of community benefits of NCRIS activities (or $23.18 billion if Super Science funding is also considered).

Based on consultations and review of information from NCRIS groups, it is clear that planned increases in NCRIS funding will act as a stimulus over the next two financial years – a period of time during which a stimulus is likely to generate economic benefits. It seems clear that it will yield an ROI well in excess of most other potential targets for stimulus spending. This reasoning is likely to also extend to further spending above that which is planned, should governments wish to pursue it.

1.3 Conclusions

Based on economic theory and evidence from the time of the GFC to the present, the planned increase in NCRIS funding over the next two financial years will deliver uncommonly cost-effective stimulus. NCRIS-supported activities can deliver a double dividend of stimulus and long-term benefit or ROI. Furthermore, NCRIS's economic impact and ROI is amplified by induced co-investment from partners, including state governments—for example, the WA Government investing in Onslow Ocean Gliders sub-facility of the Integrated Marine Observing System (IMOS).

NCRIS also provides opportunities for international engagement and cooperation, which may be considered as "science diplomacy". Examples include:

- Atlas of Living Australia (ALA) acting as the Australian node of the Global Biodiversity Information Facility, and also ALA's establishment of the Living Atlases program in 2016, by which other nations (now 24) can establish their own biodiversity data systems;
- Australian Plant Phenomics Facility's cooperation with the European Plant Phenotyping Network (EPPN)on the EPPN2020 project, supported by the European Union's Horizon 2020 program, to provide access to state-of-the-art plant phenotyping facilities and methods, with the potential to having major benefits for crop improvements;
- IMOS, which is a Global Regional Alliance of the Global Ocean Observing System and a voluntary contribution to the UN Decade of Ocean Science for Sustainable Development; and
- Bioplatforms Australia's collaboration with EMBL and ELIXIR, a network of Europe's leading life science organisations, with mutual benefits in terms of the development of standards and the sharing of data and information.

Partly by acting as an economic stimulus, the benefits of the planned increase in spending will substantially outweigh its costs. Based on previous research and research conducted for this study, it is expected it would yield an ROI at least half of what LE has estimated for AuScope and PHRN, meaning at least $7.50 for every dollar of spending. The economic impact means that it is likely to generate considerable tax revenue, indeed likely more than the additional outlays will cost the budget over the long-term.

To illustrate, assuming an ROI of 7.5 and that the estimated benefits associated with NCRIS take the form of increased GDP, the $814 million of NCRIS funding over 2020-21 to 2022-23, would ultimately result in an additional $1.53 billion of tax revenue over the long-term, or nearly twice the amount of funding.[7]

The NCRIS facilities are great Australian success stories and allow Australia to engage proudly and productively in international scientific circles. They are providing massive value for money for the Australian community. This success story of Australian science and organisation should be widely proclaimed and further supported, particularly as our economy recovers from the pandemic induced recession of 2020.

[7] $814 million x 7.5 (i.e. ROI) x 25% (i.e. Commonwealth tax take) = $1.53 billion.

2. Introduction to the study

2.1 Scope of work

The NCRIS facilities, via the Population Health Research Network (PHRN), have engaged Lateral Economics to undertake an economic analysis of the potential effectiveness of stimulus delivered via NCRIS organisations, including:

- Economic and fiscal impact estimates
- Cost-benefit analysis of additional NCRIS activities

The proposition that has motivated this study is that NCRIS expenditure would provide more efficient stimulus than a lot of traditional infrastructure. This is for numerous reasons. First, traditional infrastructure spending takes a long time to plan, gain approval for and implement. Second, as will be demonstrated, the investment in NCRIS is likely to be far more cost-beneficial than almost all investment in infrastructure.

Third, the amount of investment in human capital (and intangible capital more broadly) in the Australian economy is even greater than the investment in physical capital. The World Bank estimated that, in 2005, Australia's intangible capital stock was $12.1 trillion compared with produced capital of $3.5 billion and natural capital of $1.3 billion.[8] In a narrower study, which considered human capital rather than the broader concept of intangible capital, the ABS estimated that Australia's human capital stock in 2001 was valued at $7.0 trillion.[9]

Human (and intangible or knowledge) capital offers a broad base over which to expand the expenditure, and its impact will be assessed along with that of investments in physical capital (e.g. supercomputers and microscopes).

2.2 Approach to the study

The scope of work specified that, in undertaking the analysis, Lateral Economics would study the effectiveness of additional NCRIS spending

[8] Lateral Economics (2011) *The Herald/Age - Lateral Economics Index of Australia's Wellbeing*, p. 33, based on World Bank (2011) *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium*, p. 27.

[9] ABS (2008) *Measuring Human Capital Flows for Australia: A Lifetime Labour Income Approach*, p. 36.

that was undertaken around the time of the stimulus package in response to the GFC. It would use methodologies refined in its previous work including:

- Analysis of the effectiveness of education building projects funded as part of the 2009 stimulus package;
- Previous studies of the impact and net benefits of NCRIS organisations including AuScope and Population Health Research Network (PHRN);
- Other studies on the benefit of research infrastructure (e.g. Social & Economic Impact of the Daresbury Synchrotron Radiation Source); and
- Study of the economic value of the Australian Census for the Australian Bureau of Statistics (ABS).[10]

The ROI analysis would rely on LE's previous findings of ROIs of investment in NCRIS organisations of 15:1 for AuScope and over 16:1 for PHRN. It is expected that LE could use these ROI estimates along with desktop research to develop a defensible ROI estimate for the whole NCRIS program and quantify its economic benefit in dollar and percentage of GDP terms.

2.3 Limitations of the study

Within the scope, timeframe, and budget of the study, LE has had to rely largely on existing information supplemented by consultations with NCRIS organisations (see Appendix A). Given the complexity and far reach of NCRIS activities, LE has necessarily been constrained in the comprehensiveness of the analysis. Hence, estimates in this report should be treated as indicative of the magnitude of impacts and benefits rather than as definitive estimates or forecasts.

Furthermore, after reviewing information and engaging in consultations regarding NCRIS activities, it is apparent that a large part of the benefits of NCRIS will accrue over the long-term, over a timescale of several decades, and are likely unquantifiable. NCRIS is making a large contribution to supporting research efforts in a wide range of fields, but not all this research is translatable to outcomes in the short-term. For example, IMOS supported research enables the Royal Australian Navy to better predict the movement of torpedoes through the water, a benefit which is important from a national defence perspective, but challenging to quantity in dollar terms.

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[10] Lateral Economics (2016, 2017 and 2019).

3. Overview of NCRIS

3.1 Introduction to NCRIS

NCRIS is a network of world-class research infrastructure facilities which aims to drive greater innovation in the Australian research sector and the economy more broadly. The projects encourage collaboration between the research sector, industry, and Australian governments to conduct world-class research. NCRIS supports strategically important research enabling Australian researchers and international partners to address national and global challenges.

NCRIS was established in 2004 and the network currently supports national research capability through 22 active projects comprising over 200 institutions employing well over 1,900 highly skilled technical experts, researchers, and facility managers.

The Australian Government invested nearly $1.8 billion in NCRIS over 2005-06 to 2019-20, and total funding over 2020-21 to 2022-23 is budgeted at nearly $900 million (Figure 1 above). One of the advantages of the NCRIS model, which requires co-investment, is that it leverages funding from other organisations including state governments and research organisations. Evidence of this leverage includes:

- The 2017-18 NCRIS Census found "for every $1 of investment the government put into NCRIS, there was total of $1.29 of co-investment from other sources", comprising $0.30 in cash and $0.99 in-kind; and
- KPMG reported in 2014 that each Australian government dollar invested in NCRIS projects has seen an additional $1.06 co-investment from co-investors including industry, NGOs, state governments and foreign governments (e.g., On Giant Magellan Telescope via Astronomy Australia).[11]

Taking into account $1.9 billion of NCRIS funding announced in 2016 as part of the Australian Government's 2016 National Research Infrastructure Roadmap:

> *Since 2004, the Australian Government has invested nearly $3.3 billion to deliver world-class research infrastructure. This has attracted more than $1 billion in co-investment from state and*

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[11] DESE (2020b),based on Wallis Market and Social Research (2019) *National Research Infrastructure Census Report (2017-18)*, p. 3, and KPMG. (2014) *NCRIS Strategy Project Reviews Overarching Report*.

territory governments, universities, research facilities and industry.[12]

In summary, NCRIS has proven highly successful in augmenting and increasing access to Australia's national research infrastructure in a wide range of scientific fields, and it has leveraged substantial co-contributions from a range of partners. The findings from a 2014 review by KPMG for the Department of Education and Training suggest that the key factors contributing to the success of the program have been the strategic allocation of resources and addressing market failures. In this sense the government invests in NCRIS as a public good as it would not otherwise be funded privately.[13]

3.2 NCRIS activities

NCRIS facilities span a wide range of scientific endeavours which are important to our understanding of the building blocks of our physical and biological environment (Table 2). Note these are selected examples only. A full list of NCRIS facilities is provided in Appendix B. [14]

Table 2. Summary of NCRIS activities (selected examples)

Fields	Facilities
Physics and chemistry	ANSTO, Astronomy Australia
Molecular bioscience	Bioplatforms Australia, National Imaging Facility
Big data and computer science	Pawsey Supercomputing Centre, National Computational Infrastructure, ARDC
Environment and biosphere	Atlas of Living Australia, AuScope, IMOS, TERN, AURIN
Agriculture and biosecurity	Australian Plant Phenomics Facility
Advanced manufacturing	ANFF
Human health and medical science	PHRN, Phenomics Australia, Therapeutic Innovation Australia, Microscopy Australia, Bioplatforms Australia

Source: LE, 2020.

[12] DESE (2020c) *National Collaborative Research Infrastructure Strategy (NCRIS)*, https://www.education.gov.au/national-collaborative-research-infrastructure-strategy-ncris.

[13] KPMG (2014).

[14] Also see the diagram aligning facilities with National Research priorities.

The range of NCRIS facilities and their activities is so broad and varied it is impossible to do justice to them in the confines of this report.

For example, NCRIS supports physicists and other scientists in understanding the fundamental laws of the universe. For instance, NCRIS provides support to ANSTO, which has a synchrotron and particle accelerators, and Astronomy Australia, which provides astronomical research in Australia and is also heavily engaged in international projects (e.g. the Giant Magellan Telescope). (See also Box 1).

Box 1. NCRIS as an enabler of international collaborations and science diplomacy

NCRIS also provides opportunities for international engagement and cooperation. These offer benefits not just as "science diplomacy". They increase the extent to which foreign researchers include Australia in their research. This generates better knowledge about Australia, including where it ensures Australia is included in cross-country analyses. It also unlocks flows of foreign investment in and collaboration with Australian research infrastructure. Examples include the following.

- Atlas of Living Australia (ALA) acting as the Australian node of the Global Biodiversity Information Facility, and also ALA's establishment of the Living Atlases program in 2016, by which other nations (now 24) can establish their own biodiversity data systems.
- Australian Plant Phenomics Facility's cooperation with the European Plant Phenotyping Network (EPPN) on the EPPN2020 project, supported by the European Union's Horizon 2020 program, to provide access to state-of-the-art plant phenotyping facilities and methods, with the potential to have major benefits for crop improvements.
- Bioplatforms Australia's collaboration with ELIXIR and EMBL, networks of Europe's leading life science organisations, with mutual benefits in terms of the development of standards and the sharing of data and information.
- Phenomics Australia's active membership of the International Mouse Phenotyping Consortium, a world-wide alliance of 21 research institutions and organisations collaborating to fully describe mammalian gene function, with mutual benefits through harmonising experimental protocols and open sharing of highly-curated data.
- PHRN is part of the International Population Data Linkage Network (IPDLN), which is the peak international organisation for data linkage agencies and researchers. Australia's leadership in data linkage has been recognised by the IPDLN, with the IPDLN Director position held by Australians twice in the last 10 years. The PHRN hosted the 2020 IPDLN conference with more than 600 attendees from around the world. The PHRN infrastructure also continues to support international collaboration with 80 peer-reviewed publications involving international collaborations using the infrastructure in 2019-20.
- National Computational Infrastructure (NCI) is part of a global

network of federated data centres allowing access to internationally produced climate model outputs allowing researchers to contribute to international decision-making on climate change. Through NCI, researchers can access and contribute to internationally significant data collections.

- IMOS is a Global Regional Alliance of the Global Ocean Observing System and a voluntary contribution to the UN Decade of Ocean Science for Sustainable Development.

Australia's involvement in the Square Kilometre Array (SKA) Pathfinder project is another example, although the bulk of the funding has come from non-NCRIS sources. Australia's contribution to the SKA Pathfinder project has been in the order of $300 million, with several hundred million dollars of contributions from partner countries.[15]

Source: Consultations with NCRIS organisations.

The NCRIS infrastructure in molecular bioscience gives researchers the ability to analyse genes, cells, genomes, and proteins—driving innovation in health, immunology, and medicine industries. Organisations funded include Bioplatforms Australia (BPA), Microscopy Australia, Phenomics Australia, and the National Imaging Facility, among others.

NCRIS infrastructure supports research into the environment and biosphere assisting with better understanding the earth, ecosystems and natural resources. AuScope helps analyse the earth and geological systems. The Integrated Marine Observing System (IMOS) monitors oceans and sea life. The Groundwater Infrastructure program monitors groundwater resources and the Atlas of Living Australia pulls together national biodiversity data making it accessible. Finally, the Terrestrial Ecosystem Research Network (TERN) helps researchers detect and interpret changes in ecosystems.

NCRIS organisations help develop knowledge surrounding Australian agriculture and its challenges. The NCRIS infrastructure includes the Australian Plant Phenomics Facility (APPF), the Australian Animal Health Laboratory and the Australian Biosecurity Intelligence Network.

Additionally, NCRIS infrastructure is helping develop new cures for diseases and to identify epidemiological trends, through organisations such as Phenomics Australia, Population Health Research Network, and Therapeutic Innovation Australia.

[15] Wild, S. (2020) "World's largest radio telescope needs to hit US$1-billion target", vol. 577, p. 305.

NCRIS facilities have strong interactions with industry, providing them with cutting-edge equipment via facilities such as ANFF, for example. ANFF provides the means to make materials and devices that are the bedrock of many technological innovations, including diagnostics, sensors, electronics, optical systems, photonics, and quantum technologies. This directly supports the development and commercialisation of new technologies by industry, and particularly by start ups and small to medium-sized enterprises (SMEs). ANFF helps companies partly de-risk early-stage innovation by providing access to its advanced tools. Through the availability of its experts, ANFF can short cut development and iteration times when developing new processes or implementing new schemes. Furthermore, ANFF is aligned with an important objective of NCRIS: the leveraging of a national-level network of strategic investments to ensure Australia has access to the research facilities it needs without mass duplication.

From the above discussion, it is clear that NCRIS facilities have overlapping, interdisciplinary research interests and that collaboration can be beneficial. Hence, NCRIS organisations have established their own forums and networks, including with non-NCRIS facilities. A good example of this is the National Earth & Environmental Science Facilities Forum (NEESFF). According to NEESFF's Terms of Reference:

This forum was established following a meeting between the Atlas of Living Australia (ALA), Australian Urban Research Infrastructure Network (AURIN), AuScope, Australian National Data Service (ANDS), GeoScience Australia, Integrated Marine Observation System (IMOS), National Research Data Cloud and the Terrestrial Ecology Research Network (TERN) to discuss and investigate strategic initiatives to enhance coordination between National Collaborative Research Infrastructure Strategy (NCRIS) facilities and government entities for the enhancement of Australian research and society. Common to all the participants is the importance of spatial and environmental data in their work, whether as data users, producers, or providers.[16]

3.3 Key challenges facing NCRIS facilities

Based on LE's review of information provided by NCRIS facilities and consultations with those operating the facilities, a range of NCRIS assets such as ICT infrastructure and capital are at risk of obsolescence within 2-4 years. For example, Bioplatforms Australia Genomics has significant technology flux with renewal required every 3 years.

Another challenge, perhaps better considered as an opportunity, is that some equipment is heavily under-utilised due to underinvestment in

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[16] NEESFF Terms of Reference provided to LE, May 2021.

complementary assets. Additional scientists and technical staff are arguably required to get full value for money from the world-leading scientific equipment at NCRIS facilities.

4. Fiscal stimulus via NCRIS

4.1 Estimates of NCRIS fiscal stimulus

LE has analysed the potential impacts of fiscal stimulus delivered via NCRIS. This is based on:

- historical funding for NCRIS;
- observed leverage of contributions from partners; and
- multipliers based on the literature and the Australian Input Output (IO) tables produced by the ABS.[17]

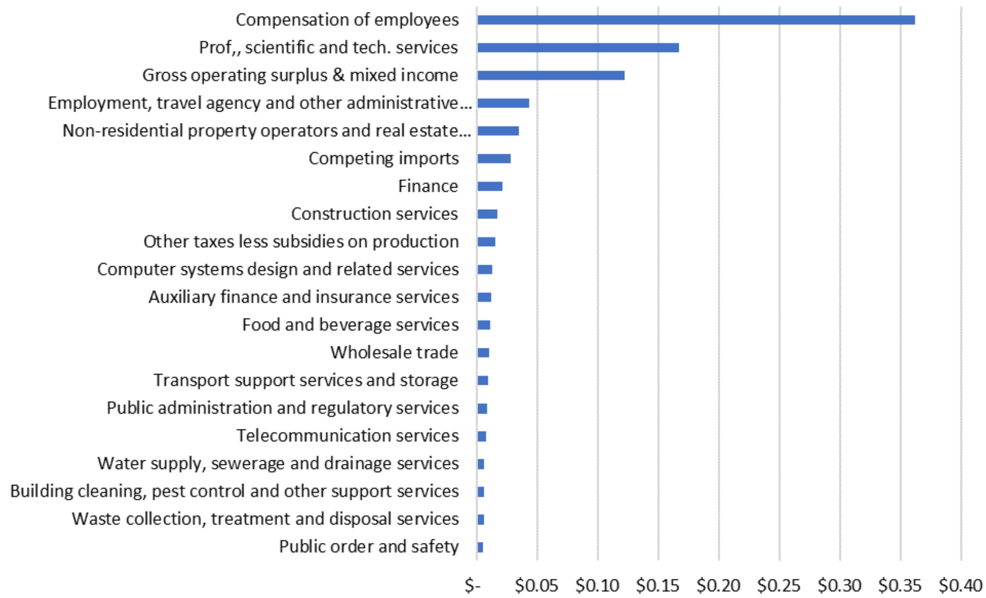
LE has used multiplier estimates equal to the Type II multipliers derived from the Australian supply-use table (the key IO table), which details the make-up of production by sector across the Australian economy, distinguishing intermediate goods, value added, indirect taxes, and imports. The Type II multiplier captures the impacts of purchases from the sector induced by NCRIS funding via supply-chain impacts and induced consumption spending resulting from higher incomes. In an economy well below its potential output (e.g. as in 2009-10 and currently in 2020-21), there is considerable slack or spare capacity in firms and, hence, great potential for the domestic supply chain to expand alongside the stimulated sector—i.e. there is limited crowding out.

The Type II multipliers used are similar in magnitude to the estimates of government expenditure multipliers for times when an economy operates substantially below potential. That is, one dollar of additional government spending translates into more than one dollar of GDP.

As a proxy for NCRIS facilities, the Professional, scientific and technical services industry sector is used. Contributions to the total value of production ($ contribution per $ of total production) by components is presented in Figure 3. This shows the largest contribution to production value comes from compensation of employees ($0.36 per $1.00), followed by purchases within Australia that firms make of other types of professional, scientific and technical services ($0.17). This is illustrative of the importance of human capital and technical knowledge in the sector.

[17] For an overview of the theory and evidence on fiscal stimulus, see Appendix C.

Figure 3. Contributions to Australian production value of Professional, scientific and technical services, 2017-18



Source: LE analysis based on ABS cat. no. 5209.0.55.001 Australian National Accounts: Input-Output Tables, 2017-18.

First, we provide indicative estimates of the macroeconomic and fiscal impacts of stimulus via NCRIS over the 2008-09 to 2010-11 period (Table 3). The calculations (which are described in Appendix D) assumed additional cash contributions which are fully spent in NCRIS-supported activities of $0.30 per dollar of NCRIS funding, consistent with the evidence on leverage discussed above.[18] That is, it is assumed that each dollar of NCRIS funding brings forth an additional $0.30 from partners (e.g. state governments or research institutions) which would not otherwise have been spent. We have been conservative in only counting cash contributions as leveraged investment. It is possible that in-kind contributions from other organisations do not represent new spending in the economy.

[18] Wallis Market and Social Research (2019, p. 3).

Table 3. Estimated macroeconomic and fiscal impacts of stimulus over 2008-09 to 2010-11

	2008-09 $m	2009-10 $m	2010-11 $m
1. NCRIS funding	102.8	104.1	107.1
2. Leveraged investment	30.8	31.2	32.1
3. Total investment	133.6	135.3	139.2
4. Additional GVA (direct)*	46.8	47.4	48.7
5. Additional GVA (indirect & induced)	104.2	105.6	108.6
6. Additional GVA (total)	151.0	152.9	157.3
7. Additional GDP (total)	161.6	163.6	168.3
8. Commonwealth Gov't revenue	40.4	40.9	42.1
9. State Gov't revenue	8.1	8.2	8.4

Source: LE estimates, 2021, based on desktop research and consultations detailed in the report. N.B. Direct refers to the impact on the specific sector impacted, assumed to be Professional, Scientific and Technical Services for OPEX and Non-residential Construction for CAPEX.
**Direct may also be referred to as "first round".*

The estimates show additional yearly GDP of $160-170 million, resulting in additional tax revenue of $40-50 million, arising from NCRIS spending of $100-110 million in each of the financial years 2008-09 to 2010-11.

These estimates are based on NCRIS funding only, and do not include $495 million of Super Science funding from the Education Investment Fund (EIF) for national research infrastructure over the three-year period. It is likely Super Science funding would have similar multiplier impacts to NCRIS funding, particularly as a substantial proportion of it went to NCRIS facilities.

For example, if we include Super Science funding, in 2009-10 there was total Australian Government funding for national research infrastructure of $312 million, implying a boost to yearly GDP from investments in national research infrastructure of $491 million.

We do the same thing for budgeted expenditures for NCRIS over 2020-21 to 2022-23 (Table 4).

Table 4. Estimated macroeconomic and fiscal impacts of stimulus over 2020-21 to 2022-23

	2020-21 $m	2021-22 $m	2022-23 $m
1. NCRIS funding	256.4	273.6	283.9
2. Leveraged investment	76.9	82.1	85.2
3. Total investment	333.3	355.6	369.1
4. Additional GVA (direct)*	116.6	124.5	129.2
5. Additional GVA (indirect)	259.9	277.4	287.9
6. Additional GVA (total)	376.6	401.9	417.1
7. Additional GDP (total)	402.9	430.0	446.3
8. Commonwealth Gov't revenue	94.1	100.5	104.3
9. State Gov't revenue	20.1	21.5	22.3

Source: LE estimates, 2021, based on desktop research and consultations detailed in the report. N.B. Direct refers to the impact on the specific sector impacted, assumed to be Professional, Scientific and Technical Services for OPEX and Non-residential Construction for CAPEX.
**Direct may also be referred to as "first round".*

The economic impact analysis has revealed that NCRIS stimulus has contributed to supporting the economy during the GFC and the current COVID-19 pandemic. That support is via direct expansion of NCRIS facilities, supply-chain impacts (a Type I multiplier impact), and induced consumption impacts as households earning money as a result of the additional activity spend it in the economy (a Type II multiplier impact). By 2022-23, when NCRIS funding is expected to be nearly $300 million, it will potentially boost GDP by $446 million, relative to the baseline, generating an additional $127 million in taxation revenue (i.e. covering around 45% of the NCRIS funding injection that year).

While the total GDP impact is small relative to the total economy, representing around 0.02% boost to GDP, it would nonetheless boost employment of people in scientific disciplines and contribute to long-term benefits through building up Australia's scientific and knowledge capital. It could directly support the employment of an additional 300-350 full-time equivalent (FTE) scientific and technical staff, plus in the order of an additional 1,400 people across support staff, the supply-chain, and in other industries supported indirectly.

4.2 Assumptions

The assumptions in the modelling of economic impacts are set out in Table 5. An implicit assumption is that the economy was substantially below its potential in the wake of the GFC and will remain substantially below its potential over 2020-21 to 2022-23. This is a reasonable assumption in early 2021, given the uncertain economic outlook. When an economy is well below its potential, multipliers such as those used in this analysis apply, and the implicit assumptions of impact analysis using IO tables (e.g. no supply constraints, no price responses) are reasonable.[19]

Table 5. Assumptions underlying economic modelling

Parameter	Value	Justification
Leveraged investment	30%	Based on Wallis (2019)
Investment split OPEX v CAPEX	50%	Desktop review & consultations
Direct GVA share (OPEX)	45%	IO tables for 2009-10
Direct GVA share (CAPEX)	25%	IO tables for 2009-10
OPEX GVA effect	1.17	LE analysis of IO tables for 2009-10
CAPEX GVA effect	1.09	LE analysis of IO tables for 2009-10
Commonwealth Gov't share	0.25	Budget and GDP data
State Gov't share	0.05	Budget and GDP data

Source: LE, 2021 based on a range of sources outlined in the table.

As an economy approaches its potential output, the amount of crowding out or satisfaction of domestic demands via imports increases. As one sector expands, others may need to contract. In these circumstances, analysis such as that presented in this report is inappropriate and a Computable General Equilibrium modelling exercise would be required.

[19] The estimates of indirect impacts from this study should be taken as upper bounds of potential economic impacts - cautious interpretation of indirect/multiplier effects is required when these are generated by IO models (Gretton, 2013).

4.3 Summary of economic impact analysis

In summary, LE's economic impact analysis reveals the potential for NCRIS funding to provide stimulus to the economy when it needs it and, at the same time, to enhance Australia's human and knowledge capital stocks at the same time. The ROI to the community of such investment is considered in the next section.

5. Return on Investment in NCRIS

5.1 Introduction to ROI

ROI can be measured in several ways, all attempting to gauge how successful a project has been in terms of recovering both the initial investment and earning a return on it. Sometimes it is expressed as percentage project yield, or internal rate of return, and sometimes it is expressed as a ratio of benefits to costs over the lifecycle of the investment. Occasionally it is net benefits (i.e. benefits less costs) that is used as the numerator. Benefits and costs need to be expressed in dollar terms in CBA or ROI analysis.

For our purposes, we define the ROI as equivalent to what is known in cost-benefit analysis (CBA) as the benefit-cost ratio (BCR):

(2) $ROI = BCR = \{ \sum_i (Benefits_i / (1+r)^i \} / \{ \sum_i (Costs_i / (1+r)^i \}$

In equation 2, *i* stands for year and begins at zero, and increases by one for each year for the lifetime of the project. *r* stands for the discount rate by which future benefits and costs and converted into present value (PV) terms. It is important to do this in an ROI or CBA, to account for the time value of money. (A dollar today is worth more than a dollar in the future, because it can be invested to increase its future value). Applying a discount rate amounts to unwinding the process of compound interest.

In Australia, the discount rate recommended by the Office of Best Practice Regulation is 7%, although as some scholars have argued, [20] this discount seems very high with long and short-term interest rates on government bonds being as low as they are today. The higher the discount rate the more future benefits and costs are discounted. At higher discount rates, projects which have high up-front costs and benefits continuing into the future can be disadvantaged in project assessments.

Critical to the concept is the ability to estimate relevant benefits and costs in dollar terms. Conceptually, there are at least four broad types of benefits which can be valued:

- technological spill-overs;
- human capital benefits;
- public good benefits from research; and

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[20] See Department of Prime Minister and Cabinet (2020) *Guidance Note: Cost-benefit analysis* and Terrill, M. and Batrouney, H. (2018) *Unfreezing discount rates: Transport infrastructure for tomorrow*, Grattan Institute.

- cultural benefits.[21]

Also, the uncertainty with which future benefits will be realised would ideally be accounted for in the analysis.

As this discussion suggests, and as noted in section 2.3 above, quantifying costs and benefits can be challenging for NCRIS activities, but as demonstrated in the next section, several economic studies have attempted to estimate BCRs and ROIs for scientific endeavours based on available data and plausible assumptions.

5.2 Evidence on ROI of scientific research

Overall, growing living standards require productivity growth via technological change. Science and its translation into new practices and technologies is a major contributor to technological change. Science generates spill-overs across organisations and sectors, lifting growth.

Hence, investment in research can produce a return on investment by increasing productivity among other benefits. It is evident that the knowledge generated from research has positive spill-over effects across organisations and sectors consequently improving economic growth. For example, see the summaries of selected studies in Table 6. This is just a sample of the range of studies which highlight high returns to investments in science and the generation of new knowledge. For example, a review of the socio-economic benefits of weather and climate services in Europe surveys 13 studies which estimate benefit-cost ratios for weather services, with ratios ranging from 2:1 to 10:1.[22]

Empirical studies show that returns on R&D vary widely, but a characteristic finding is that returns are high, often in the region of 20% to 60%. This is because of the high potential for knowledge spill-overs across the economy from R&D. Further as the Productivity Commission has argued more basic ‘pre-commercial’ research is likely to generate higher returns because of the greater likely breadth and magnitude of spill-overs. The research fostered by NCRIS is predominantly, though not exclusively of this kind.

The potentially high ROI of scientific research is evident from a range of studies including two previous studies of NCRIS facilities by Lateral Economics (2016, 2017). ROIs/BCRs can exceed 10:1 where the funding leverages other investments and provides a platform for a wide

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[21] Florio, M. (2019) *Investing in Science: Social Cost Benefit Analysis of Research Infrastructures*, MIT Press, p. 297.

[22] Perrels, A. et al. (2013) “Socio-economic benefits of weather and climate services in Europe”, *Advances in Science and Research*, vol. 10, p. 69.

variety of highly cost-beneficial additional activities—e.g. investments in improving the accessibility of essential data for research by agencies including AURIN, IMOS, and PHRN.

Table 6. Summaries of ROI studies

Study	Findings
PHRN ROI (Lateral Economics, 2017)	Strong net benefits. Scenario A suggests a benefit of over $7 billion $16 in value for every $1 in cost
AuScope study (Lateral Economics, 2016)	A net benefit of $3.7 billion $15 of benefit for every $1 in economic cost
European research infrastructure projects (Florio, 2019)	Economic rate of return of 19.4% per annum and expected NPV of €124 million from €104 million of investment in 24 research infrastructure projects in 9 EU countries over 2008 to 2013
European health care research infrastructure (Battistoni et al. 2016)	Estimated benefits of €2,059 million compared with costs of €466 million over thirty years—i.e. a benefit-cost ratio of 4.42
High luminosity upgrade of Large Hadron Collider (Florio, 2020)	Benefit-cost ratio of upgrade equal to 1.7:1
Open Data G20 (Lateral Economics, 2014)	A 5% improvement in efficiency of new infrastructure expenditure Potential benefit 0.10% of Australian GDP or $1.5 billion
Research Impact Study OSCE (Robertson, 2020)	Well over 100x NSW government funding (> the typical 5x-8x total), because other funding leveraged Annual return to the NSW economy is estimated to be over $600M
Estimating potential benefits of IMOS (Zhang and Wang, 2011)	Total potential benefits are estimated to be $35 million pa (through improved fishery management and efficiency)
Estimating the Economic Benefits of Regional Ocean Observing Systems (Kite-Powell et al, 2005)	Annual benefits are likely to run in the multiple $100s of millions of dollars per year

Study	Findings
UK Synchrotron study (Science & Technology Facilities Council, 2010)	Creation of jobs and construction operation represents a direct financial impact of £600 million. Due to multiplier effects, initial investment created a total financial impact of nearly £1 billion
US weather forecast valuation survey (Lazo et al, 2009)	US public receives US$31.5 billion in benefits compared with US$5.1 costs of producing weather forecasts

Source: various studies reviewed by LE, 2021.

5.3 Estimates of NCRIS ROI

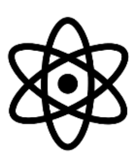
Based on previous research and consultations with NCRIS facilities, it appears that the broad range of NCRIS activities are at least as beneficial dollar-for-dollar as those facilities LE has already undertaken comprehensive ROI assessments of—i.e. AuScope and PHRN. These studies suggested an ROI or BCR of 15-16 to 1. An indication of the wide range of applications beneficial to the community as a result of NCRIS activities is presented in Figure 4.

Figure 4. Selected examples of major benefits of NCRIS-supported infrastructure to the Australian community

Bushfire preparedness. With a range of sensors across Australia supported by NCRIS facilities such as TERN and AURIN, Australia can be better prepared for bushfire threats in the future.

Cyclone warnings. IMOS is providing rich, high frequency data from Australia's surrounding oceans which can provide early warning signs of cyclones, not to mention ocean acidification and sea level rise associated with climate change.

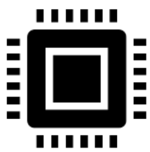
Population health. A range of NCRIS facilities (e.g., PHRN, Phenomics Australia, Bioplatforms Australia, Therapeutic Innovation Australia) are helping to improve the health of Australia's population.



Understanding the building blocks of reality. NCRIS facilities such as Microscopy Australia, National Imaging Facility, ANSTO, and Astronomy Australia are contributing to world leading research on the building blocks of the universe and life.

Monitoring biodiversity. Australia's unique biodiversity are being monitored, described and protected by the Atlas of Living Australia (ALA), BioPlatforms Australia, IMOS, and TERN. In particular, ALA is our national biodiversity data infrastructure. It integrates and delivers fundamental data on Australia's plants, animals and fungi to support ecosystem assessment, monitoring and planning.

Boosting crop yields and resilience. The Australian Plant Phenomics Facility contributes fundamental services to the effort to improve crop yields and crop resilience with genomic and molecular characterisation performed through Bioplatforms Australia.



Deriving value from data. ARDC, Pawsey Supercomputing Centre and the National Computational Infrastructure enable data from many fields of research across a wide range of scales to be stored, curated, managed and analysed.

Understanding the earth. AuScope improves our understanding of fundamental earth science and enables a range of benefits, including substantial reductions in the cost of and more effective resource exploration.

Advanced manufacturing. The Australian National Fabrication Facility (ANFF) and Therapeutic Innovation Australia (TIA) provide industry and the wider community with access to cutting-edge advanced manufacturing technologies. Furthermore, NCRIS organisations such as Astronomy Australia are involved in advanced manufacturing activities.

Source: Lateral Economics research and consultations, 2021.

It was not possible to comprehensively assess the ROI of the NCRIS facilities collectively as part of this assignment. Nonetheless, we endeavour to provide an estimate of the magnitude of NCRIS's ROI to the Australian community based on aggregate funding data and an assumed ROI of 7.5:1, which is approximately half that found for AuScope and PHRN.

It is obvious that the net benefits of research supported by NCRIS could be large, given the many areas of life and industry for which NCIRS-supported research is relevant. For example, AuScope-supported research, which includes world-leading techniques for finding new mineral deposits, could unlock huge amounts of value.[23] Consider that Australia's currently known or proved mineral reserves were estimated to be worth $386 billion in 2017-18 by the ABS.[24] Increasing that by just one percent through world-leading mineral exploration techniques could unlock nearly $4 billion of value, though this is an overestimate of the net benefits available as it abstracts from the cost of extraction.

LE estimates that, in 2020-21, the total value of the physical and intangible capital stock produced by NCRIS funding since 2005-06 is $2.27 billion (or $3.09 billion if Super Science funding is also considered). This estimate of the capital stock was made by inflating historical funding data (see Figure 1 above) to current dollar values based on the implicit price deflator for GDP and accumulating them over time, with an assumed depreciation rate of 5 percent per annum to allow for some depreciation of physical and intangible capital over time. It is also assumed NCRIS funding is augmented by 30 percent, as per the Wallis Market and Social Research (2019) finding there is 30 percent cash co-contributions by partners, to derive the total capital stock.

Applying the expected ROI of 7.5:1 to this capital stock yields an expected benefit in PV terms of approximately $17.03 billion of community benefits of current NCRIS facilities (or $23.18 billion if Super Science funding is also considered). An ROI of this magnitude is entirely plausible given the wide range of NCRIS-supported activities which have relevance to important sectors (e.g. resources, agriculture, and biotechnology), our environment, and our preparedness for natural disasters (Box 2).

Box 2. NCRIS and minimising natural disaster costs

Lateral Economics is currently undertaking a comprehensive ROI analysis of the NCRIS facility IMOS (i.e. Integrated Marine Observing System). One of the activities supported by IMOS and the WA Government is the deployment of Ocean Gliders at various locations in the Indian and Pacific Oceans around Australia. Ocean Gliders can collect detailed temperature data from the ocean and, hence, can contribute to much more accurate forecasts of the trajectories of cyclones, including of locations where they cross the coast. This is important for both natural disaster preparedness and for the avoidance of unnecessary shutdowns of important bulk ports (e.g. WA iron ore export terminals).

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[23] Regarding the Australian Lithospheric Architecture Magnetotellurics Project (AusLAMP) in which AuScope is collaborating with the Geological Survey of South Australia, the University of Adelaide, and Geosciences Australia, see https://www.auscope.org.au/posts/auslamp-milestone?rq=auslamp

[24] ABS cat. no. 4655.0 - Australian Environmental-Economic Accounts, 2019.

According to information gathered in consultations, an unnecessary shutdown could cost a bulk port in the order of $10 million per hour, and hence minerals exporters would highly value having more accurate forecasts of the path of cyclones. It is relatively straightforward to see that if NCRIS-supported activities such as ocean gliders could avoid an unnecessary half-day or full-day shutdown of bulk port operations through improved forecasts, then the benefit to the community would be in the tens of millions and many multiples of the costs of purchasing and operating the gilders (which cost up to $250,000 each).

Source: based on LE consultation with Professor Charitha Pattiaratchi, Oceans Graduate School, University of Western Australia in March 2021.

This could be considered a conservative estimate because it is likely we are under-estimating the total capital stock (physical and intangible) supported by NCRIS facilities, as we have not been able to include estimated values for all the equipment and data that NCRIS facilities allow researchers access to across Australia.

Consultations revealed that NCRIS facilities such as Microscopy Australia have been proactive and savvy in reaching agreements with a range of university and private sector labs across Australia to bring them into their network so their instruments are widely available to researchers. It is likely that small strategic investments by NCRIS facilities can yield large gains to the community by expanding the range of NCRIS partners providing access to equipment and data.

Such an exercise to provide a comprehensive accounting of the value of all equipment and data NCRIS facilities allow access to would form a much larger assignment than the current assignment LE has undertaken. We would also need to comprehensively consider the full range of international collaborations undertaken by NCRIS facilities, such as the international collaboration on heavy-ion-accelerator-enabled research (Box 3).

Box 3. Access to international infrastructure case study: Heavy Ion Accelerators (HIA)

The discovery of new chemical elements has been an important goal in science for centuries. The heaviest naturally occurring elements on Earth are uranium and plutonium, with atomic numbers 92 and 94 (corresponding to the number of protons in their atomic nuclei). Through nuclear fusion reactions at large accelerator facilities, all elements up to 118 (called oganesson) have now been synthesized, atom-by atom, during years of bombardment of heavy target nuclei using intense beams of rare calcium-48 nuclei.

Now efforts are being made to create elements 119 and 120. Due to current lack of even heavier target elements, beams of Ca-48 cannot be used, so bombardments with heavier elements on lighter targets must be used. However, it is not yet known which projectile element heavier than Ca will give the highest yield of the new elements, or which beam energies are best. This could make the difference between discovering a new element on one year, or in 1000 years!

The NCRIS Heavy Ion Accelerators (HIA) project is now making a contribution. HIA has enhanced the capabilities of the Australian National University Heavy Ion Accelerator Facility (HIAF) through the Super Science initiative, and now supports operations of HIAF. Together with ANU and ARC investment, scientists at HIAF have developed the best capability in the world to evaluate which reactions will be the most effective to synthesise new elements.

This has resulted in the invitation to join the international nSHE collaboration, based in Japan, who are leaders in efforts to synthesise elements 119 and 120. The team uses the billion dollar world-class RIKEN heavy ion accelerator, and ultra-sensitive electromagnetic separators and detectors. The ANU team is now planning measurements in Australia on candidate reactions using targets of rare materials, prepared and shipped from Japan. The new collaboration thus provides access to Australian researchers to target materials and expertise unavailable in Australia, and also to the RIKEN Accelerator Facility in Japan, and the world-leading separators and detector systems.

This is the first Australian contribution to efforts to discover new synthetic elements.

Source: Provided by the Australian National University Heavy Ion Accelerator Facility.

Regarding the fiscal impacts of NCRIS funding, the economic impact means it is likely to generate comparable tax revenue and potentially more tax revenue than it will cost over the long-term. To illustrate, assuming an ROI of 7.5 and that the estimated benefits associated with NCRIS take the form of increased GDP, the additional $814 million of NCRIS funding over 2020-21 to 2022-23, would ultimately result in an additional $1.53 billion of tax revenue over the long-term, or nearly twice the amount of funding.[25]

Finally, it should be noted there is large potential to achieve net benefits to the Australian community with relatively small increases in scientific and research staff at some under-utilised facilities. This is because it

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[25] $814 million x 7.5 (ROI) x 25% (i.e. Commonwealth tax take) = $1.53 billion.

appears there is significant under-utilisation of some world-class scientific equipment. Given the existence of the sunk costs invested in the facility's assets, greater use of them represents a 'free lunch' by which we could expand their output at well below their current average unit cost. In addition to the cost effectiveness of NCRIS facilities and the likelihood of continuing slack in the economy, funding the marginal cost of greater use of such facilities is likely to be even more cost effective as a stimulus than our analysis suggests the planned increase in NCRIS spending in 2021-22 and 2022-23 will be.

6. Conclusions

Based on economic theory and evidence from the time of the GFC to present, we can think of few approaches to providing additional stimulus to the Australian economy that are more cost effective than increasing investment in NCRIS.

NCRIS supported activities can deliver a double dividend of stimulus and long-term benefit or ROI. Furthermore, NCRIS's economic impact and ROI is amplified by induced co-investment from partners, including state governments—for example, the WA Government investing in Onslow Ocean Gliders sub-facility of IMOS and even some investors from offshore, such as investments by foreign governments in the Square Kilometre Array which has been partly supported by NCRIS. It also helps stimulate private sector investment. For example, Bioplatforms Australia is part of the ReFuGe 2020 Consortium (short for Reef Future Genomics) along with organisations such as the Great Barrier Reef Foundation and James Cook University, with one of the sponsors being global mining giant Rio Tinto.[26]

From LE's consultations and research, it is clear that NCRIS has added many billions of dollars of value to the Australian community for an outlay many billions less than this. The potential for unexpected spin-off benefits—for example, just as wi-fi was a spin-off of CSIRO's work—is large.

There are several areas for potential future research extending on the analysis in this report. These include:

- comprehensive accounting of the value of assets (physical and intangible) for which NCRIS facilities provide access to, an exercise which could be coordinated with the preparation of future National Research Infrastructure reports; and
- more in-depth ROI studies of specific NCRIS facilities, as LE has previously conducted for AuScope and PHRN, and is currently conducting for IMOS.

The NCRIS facilities are great Australian success stories and allow Australia to engage proudly and productively in international scientific circles. They are providing massive value for money for the Australian community. Indeed, the benefit to cost ratio for expenditure on NCRIS facilities is so large that, given sufficient time to recoup its return on investment, every dollar invested in NCRIS is likely to generate nearly

[26] See https://www.scimex.org/newsfeed/coral-dna-first-a-giant-leap-in-search-for-super-coral-secrets

two dollars in benefits simply in the form of increased tax revenue from the economic uplift it produces. This success story of Australian science and organisation should be widely proclaimed and further supported, particularly as our economy recovers from the pandemic induced recession of 2020.

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Appendix A – NCRIS facilities consulted

In developing this report, Lateral Economics engaged with multiple NCRIS facilities, including:

- ANTSO
- ARDC
- Astronomy Australia
- Atlas of Living Australia
- AuScope
- Australian Plant Phenomics Facility
- Bioplatforms Australia
- IMOS
- Microscopy Australia
- National Imaging Facility
- Pawsey Supercomputing Centre
- Phenomics Australia
- PHRN
- TERN
- Therapeutic Innovation Australia

Appendix B – Full list of NCRIS facilities

- Australian Centre for Neutron Scattering
- Centre for Accelerator Science
- National Deuteration Facility
- Heavy Ion Accelerators
- Astronomy Australia
- AuScope
- Integrated Marine Observing System (IMOS)
- Atlas of Living Australia (ALA)
- Terrestrial Ecosystem Research Network (TERN)
- Australian Plant Phenomics Facility (APPF)
- Australian Centre for Disease Preparedness
- Phenomics Australia
- Population Health Research Network (PHRN)
- Therapeutics Innovation Australia (TIA)
- Australian Urban Research Infrastructure Network (AURIN)
- Bioplatforms Australia
- Microscopy Australia
- National Imaging Facility (NIF)
- Australian Research Data Commons (ARDC)
- Australian National Fabrication Facility (ANFF)
- National Computational Infrastructure (NCI)
- Pawsey Supercomputing Centre (Pawsey)

Source: https://www.dese.gov.au/national-research-infrastructure/funded-research-infrastructure-projects

Appendix C – Fiscal stimulus

Logic of fiscal stimulus

The word "fiscal" derives from the Latin noun fiscus meaning basket or treasury. Fiscal stimulus can stimulate the macroeconomy by increasing expenditure and/or decreasing taxes. While the objectives behind government expenditure and taxation are many and varied, government seeks to set the *fiscal stance* – the relationship of outlays to revenue or the budget deficit or surplus – with a view to stabilising economic growth at the highest sustainable rate possible. In this it is complemented by monetary policy which addresses interest rates and the supply of money and is managed by a central bank.

Fiscal policy can be implemented through a wide range of measures. These measures include cash handouts. For example, the Rudd governments gave cash payments to Australians during the GFC. Other forms of stimulus include tax cuts, rebates of taxes and charges, spending on infrastructure, and government grants. In October 2008, the Rudd Government provided a $10.4 billion dollar stimulus package targeted towards pensioners and low-income families in the form of cash bonuses, spending to support housing construction and new training places.[27] As the economic downturn from the GFC intensified, large scale infrastructure spending was brought forward. An additional $42 billion stimulus package, the *Nation Building and Jobs Plan*, was announced in February 2009.

Throughout the COVID-19 crisis and recession, the Australian Government has implemented expansionary fiscal policy in the form of JobKeeper and JobSeeker payments. The JobKeeper Payment is the largest peacetime fiscal and labour market intervention in Australia's history, with the total cost estimated at $101 billion.[28] JobKeeper was designed to prioritise macroeconomic support and is targeted at those who are already employees. The stimulus package was designed to staunch the decline in job loss and provide a confidence boost to both employers and employees.

Discretionary fiscal stimulus such as JobKeeper and the JobSeeker Coronavirus Supplement—as distinct from the automatic stabilisers that

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[27] Australian Treasury. (2009) *Australia's response to the global financial crisis*, https://treasury.gov.au/speech/australias-response-to-the-global-financial-crisis.

[28] Australian Government (2020) *COVID-19 Response Supporting Australians through the crisis*, https://budget.gov.au/2020-21/content/covid-19.htm.

kick in as economy goes into recession via lower tax receipts and higher unemployment and social security benefits spending—is appropriate when there is idle labour and/or capital in the economy (now because of the COVID-19 pandemic). Stimulus can involve new fiscal measures or bringing forward existing ones, and arguably there is a big opportunity to do this with NCRIS funding.

The Gross Domestic Product (GDP) of a country is the final value of goods and services produced in the economy in a given time period (quarter or year). The National Accounts provide regular estimates of GDP which indicates the economy's performance and describe the relationship between output, income and spending. The national income accounting equation shows government spending (G), is one element of aggregate demand, which determines aggregate income and output (Y) in the short-term:

(1) $Y = C + I + G + X - M$

The other components of equation 1 are C for consumption spending, I for capital investment (i.e. not financial investments in stocks or bonds or purchases of existing non-financial assets), and X for exports, and M for imports. Fiscal policy can boost Y directly in the short-term if it does not result in crowding out of I or net export (X-M) due to a lack of available slack in the economy. When such slack is available, an expansion of G can be subject to a multiplier effect as it can directly boost Y and boost it indirectly through stimulating C as additional spending boosts disposable incomes and consumption spending.

However, fiscal policy does have some limitations such as timing lags and the crowding out effect, noted above. There are three types of timing lags. Firstly, the *recognition lag* refers to the time it takes policy makers to ascertain there is a problem to be addressed. Secondly, the *legislative lag* refers to the time it takes to have the policy approved by both Houses in Federal Parliament. Finally, the *implementation lag* refers to the time it takes to implement the policy and for the policy to take effect.

There is also the possibility of crowding out which occurs where private expenditures fall as a result of an increase in government purchases. This can occur where labour markets are tight as increasing government purchases of some things are likely to bid resources away from the provision of others. To finance expenditures, the government will need to borrow funds which can increase interest rates, reducing private investment and consumption spending.

Fiscal policy can be expansionary or contractionary. Expansionary fiscal policy involves increasing government expenditure and/ or decreasing taxes and is appropriate when unemployment is high or during a recession. Contractionary fiscal policy involves decreasing government expenditure and/ or increasing taxes which is appropriate when the economy is above the full employment equilibrium and inflation is beyond its target band.

Evidence on fiscal stimulus

The effectiveness of fiscal stimulus can be determined by the relative estimates of fiscal multipliers which refer to how much governments can expect in terms of increased economic output per dollar of stimulus. Additional increases in the demand for goods and services in the circular flow of income stimulate further rounds of spending which will result in larger effects on employment and economic output.

The value of economic multipliers can be affected by several factors:

- An increase in the propensity to consume increases the multiplier effect and conversely savings diminish it;
- With a given propensity to consume, the greater the proportion of that consumption is spent on domestic goods and services, the higher the multiplier, and conversely the more that consumption leaks into imported goods and services, the lower the multiplier.
- Where activity is stimulated, the greater its connections or linkages with other activity either up or downstream, the greater the multiplier.

Regarding the latter point, this is why government stimulus programs are often focussed on the construction sector (e.g. the Rudd Government's education infrastructure spending or the current Australian Government's building industry stimulus package). Construction is a sector which purchases large quantities of inputs from its supply chain, including timber, cement, pipes, tiles, plumbing services, engineering services, and architectural services, among other inputs.

Inter-industry linkages such as these are detailed in Input Output tables produced by statistical agencies such as the ABS. We can distinguish between the direct, indirect and induced effects of increasing demand for some industry's output. Where demand expands for an industry's output – for instance because of a fiscal stimulus firms directly producing that output increase supply. In turn they fuel an indirect expansion as they increase purchasing from their suppliers. This indirect effect is captured in Type I multipliers. Where there is slack in the economy, this draws previously idle resources into the economy. The additional income thus produced generates additional induced demand, with this effect producing its own (smaller) round of induced demand and so on. The net effect of this diminishing increments to activity is captured in the Type II multiplier.[29]

Where there is full employment the boost of fiscal stimulus will be offset either partially or fully by crowding out affects. As the economy transforms to expand production in one area, resources are bid from others. The mechanism by which this happens in an open economy is typically that interest rates will rise and the exchange rate will appreciate. Other things being equal, the former typically reduces household spending and investment while the latter reduces net exports.[30]

To summarise, macroeconomic theory suggests several factors will influence the size of the government spending multiplier, including, importantly for our purposes, the state of the economy and the type of spending. Studies of the effectiveness of fiscal stimulus indicate that multipliers for government investment and consumption spending are relatively similar in size, but somewhat larger for government investment.[31] It is apparent that, during times of economic weakness, fiscal stimulus can have sizable output multipliers, particularly for spending and targeted transfers. The most cost-effective multiplier appears to be investment in productive assets such as infrastructure. According to the IMF, evidence suggests that multipliers for government investment are between 1.2x and 1.4x.[32] Summaries of noteworthy studies of fiscal multipliers are presented in Table 8.

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[29] Input Output tables and Type I and II multipliers are well explained on this site: https://www.gov.scot/publications/about-supply-use-input-output-tables/pages/user-guide-multipliers/

[30] Comley, B. et al. (2002) "The effectiveness of fiscal policy in Australia", *Treasury Economic Roundup, Winter 2002*. In the long-run, higher interest rates reduce capital accumulation and adversely affect growth. For example, according to the Mundell-Fleming (IS-LM-BP) model, expansionary fiscal policy in IS-LM with fixed exchange rates results in an increase in government spending, increase in income, rise in interest rates resulting in the crowding out effect reducing net exports and private investment. Griffith University Professor Tony Makin argues this is what happened during the GFC but this has been contested by the Australian Treasury. See Makin (2014) and Australian Treasury (2014).

[31] Coenen G. et al. (2012) "Effect of Fiscal Stimulus in structural models", *American Journal: Macroeconomics*, vol 4, no. 1, pp. 22-68.

[32] IMF (2009). Fiscal multipliers, http://www.imf.org/external/pubs/ft/spn/2009/spn0911.pdf

Table 7. Summaries of multiplier studies

Study	Findings
Baum et al (2012)	Government spending multipliers range between 0 and 2.1, with a mean of 0.8 during the first year after fiscal measures are taken.
	Government revenue multipliers range from about –1.5 to 1.4, with a mean of 0.3.
Perotti (2005)	For Australia, the spending multiplier falls within a range spanning from -0.1 to 0.4 at the one-year horizon and from 0.7 to 1.4 at the three-year horizon.
IMF (2009)	The fiscal multiplier for temporary discretionary fiscal expenditure in Australia is 0.5 for transfers to liquidity constrained consumers.
	Between 1.2 and 1.4 for government investment.
OECD (2009)	Australian multiplier for the first two years is between 0.9 and 1.3 for public investment.
	Between 0.4 and 0.8 for transfers to households.
Carmigniani (2014)	Impulse response functions (IRF) indicate that an increase in government consumption increases GDP and the cumulative long-term multiplier is greater than one.

Source: various studies reviewed by LE, 2021.

Cash grants tend to be the most efficient means of fiscal expansion where the need for stimulus is urgent because of the speed with which they can be paid and start injecting spending into the economy. However over somewhat longer periods of time, fiscal stimulus aimed at boosting research and the infrastructure for research is likely to be more effective for at least two reasons. First none of it leaks into savings. Second the research has long term benefits. According to Leigh (2012) approximately 40% of households increased their consumption as a result of additional cash they received from the 2008-09 fiscal stimulus, with an estimated marginal propensity to consume of 0.41-0.42.[33] Further, to the extent that this consumption was on imported goods and

[33] Leigh, A. (2012) "How Much Did the 2009 Australian Fiscal Stimulus Boost Demand? Evidence from Household-Reported Spending Effects", *The B.E Journal of Macroeconomics*, vol. 12, no. 1. Note that Leigh (2012, p.1) did note that "Since this estimate is based largely on first-quarter spending, it may understate the longer-run impact of the package on consumer expenditure."

services it would further lower the multipliers that would be expected from the cash stimulus. Further, cash transfers or tax cuts can 'leak' into savings, a particular risk where consumption opportunities have been reduced by COVID-19 with a substantial portion of the current stimulus being saved.

By contrast, as discussed, boosting scientific research is more likely to optimise short and long-term benefits.

Appendix D – Fiscal stimulus calculations

The following points step through the logic of the calculations in Table 3, using 2009-10 values to illustrate.

- In row 2, the NCRIS funding amount of $104.1 million in 2009-10 (in row 1) is multiplied by 30% to reflect the additional $0.30 of investment per $1.00 of NCRIS funding, giving $31.2 million of additional investment, and this amount is added to $104.1 million to give total investment of $135.3 million.
- In row 4, the direct impact on Gross Value Added (GVA) is calculated by assuming that half the increased funding is capital investment and half is operational spending and applying the ratios of GVA to output for Non-residential construction (21.5%) and for professional, scientific and technical services (50.7%) to the respective amounts. So, in 2009-10, 50% x 25% x 135.3 + 50% x 45% x 135.3 = $47.4 million of additional GVA directly stimulated. This could be considered a "first round" spending impact, before the impacts on the supply-chain (Type I impact) or induced consumption (Type II Impact) occur.
- Jumping to row 6, we apply Type II GVA effects estimated from the IO table to the investment amounts for capital expenditure and OPEX to yield the total GVA increase.[34] Using the Type II GVA effect estimates of 1.06 for Non-residential Construction and 1.25 for Professional, Scientific and Technical Services to yield total additional GVA of 1.09 x 50% x 135.3 + 1.17 x 50% x 135.3 = 152.9.
- Row 5 captures the indirect boost to GVA as the total boost recorded in row 6 the direct impact on GVA recorded in row 4. Thus the row 5 indirect value for 2010-11 is 152.9 – 47.4 = 105.5 (with the discrepancy with the figure due to rounding).
- The additional GVA is converted into additional dollars of GDP by inflating it by 7%, reflecting the approximate contribution that indirect taxes (less subsidies) inflate GDP relative to GVA. This gives 1.07 x 152.9 = 163.6 for the 2010-11 value in row 7.
- In row 8, this is converted into Commonwealth tax revenue by multiplying the additional GDP by 25%, reflecting the approximate

[34] The GVA effect shows the ultimate increase in total GVA from a one dollar increase in output of a sector. It is related to a multiplier, which measures how much output or GVA changes for a unit increase in output or GVA, respectively.

Commonwealth tax take as a proportion of GDP—i.e. 25% x 163.6 = 40.9.

- In row 9, a similar calculation is performed for state government taxes, assuming a tax share of GDP of 5% (8.2 = 5% x 163.6).