Deloitte Access Economics

Minerals Research Institute of Western Australia

Economic Impact Assessment

August 2015

Deloitte.

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Mark Woffenden
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28 August 2015

Dear Mark

RE: Economic Impact of the Minerals Research Institute of Western Australia

Thank you for the opportunity to work with the Minerals Research Institute of Western Australia (MRIWA) and your stakeholders to develop this report. This represents our final report on the economic impact of MRIWA.

Deloitte Access Economics have undertaken an economic impact assessment on selected research projects funded by MRIWA in recent years. This analysis has been based on various data supplied by MRIWA, its stakeholders and our own research.

Overall, we have estimated that five selected projects funded by MRIWA will contribute up to $90.4 million more in net present value (NPV) terms to WA gross state product by 2020, in addition to 75 full time equivalent jobs and $7.8 million in NPV terms to State Government revenues.

These estimated economic impacts represent a significant net return to the State Government on the cost of funding the five selected research programs, and indeed on the total cost of all projects funded by MRIWA / MERIWA for all mineral related research projects since the 1990s.

Should you have any questions, please do not hesitate to contact me on (08) 9365 8095.

Yours sincerely,

Matt Judkins
Director
Deloitte Access Economics Pty Ltd

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Executive Summary

Study objective

The objective of this study is to measure the economic impact to Western Australia of funding for research and development activities provided by the Minerals and Energy Research Institute of Western Australia (MRIWA). The study quantifies the value to the Western Australian economy of a selected list of research projects funded by MRIWA.

The role of the Minerals and Energy Research Institute of WA

MRIWA is a statutory body established by the Western Australian Government Minerals and Energy Research Act 1987 to encourage development of the minerals and energy industries within the State. MRIWA's primary aim is to encourage and stimulate minerals related research specifically, by granting funds for research required by the State's minerals industry to ensure it continues to be an engine of economic growth.

MRIWA is a new body which replaces the previous Minerals and Energy Research Institute of Western Australia (MERIWA), which had a similar mandate, although one that included energy related research also.

MRIWA invests funds from the State Government in research projects especially designed to develop solutions that address opportunities and challenges that face Western Australia's minerals sector. MRIWA invests within Australia and globally, through competitive grants made to research organisations that leverage multi-partner co-funding from industry and /or other government sources.

Supporting the State's powerhouse industry sector

Western Australia's resources industry is a fundamental driver of the state's economic development and prosperity. The industry is the largest contributor to the Western Australian economy, contributing $78 billion (or approximately a third) to WA's total industry output in 2013-14.

By value, Western Australia's mineral and petroleum industry grossed over $114 billion in sales in 2014, up by 66 per cent over the past 10 years. Mineral extraction is a critical component of the state's resources wealth, accounting for 44 per cent of sales in 2014.

The study finds that five selected research projects funded by MRIWA / MERIWA are estimated to have had positive effects on output, employment and State Government revenues in Western Australia.

The project selection process

The five selected projects represent only a small proportion of the total number of research projects funded by MRIWA and its predecessor MERIWA (which have together funded 163 resource related research projects in Western Australia since the late 1980s).

The five projects were chosen according to a selection criteria, which included the age of the project (very recent or very old projects were not considered), the nature of the sponsored research (oil and gas, safety, environment and mediation related research were not considered) and the availability of information (projects with information on commercial application and impacts, and accessibility to industry stakeholders and researchers were prioritised).

Projects for which credible information was available and / or industry stakeholders were available to discuss and verify impacts formed the basis of the economic impact analysis. This information provided sufficient confidence and credibility to establish that the research funded by MRIWA resulted in verifiable commercial impacts to the mining sector.

The focus of this project selection process on picking projects with appropriate and credible data sources means that the economic impacts calculated, while robust, only represent a portion of the total impacts generated by MRIWA / MERIWA's support for mining related research in WA. The five research projects included in the economic impact assessment were:

- Project 1: Advancing the strategic use of seismic data in mines – this project focussed on improved data use to better understand seismic activity and risks. The greater confidence around seismic risks results in reduced mine down-time following blasting and consequent cost savings for the operator
- Project 2: Improving thickener technology – this study built on thickener technology concepts, identifying key factors affecting thickener performance and modifying design and operating conditions to realise operational improvements. This included increased thickener throughput, greater operational stability, and reduced flocculent consumption
- Project 3: Gold processing technology – this project was undertaken to conduct a process and operation review of leaching and gold recovery, aiming to minimise reagent costs and maximise gold recovery
- Project 4: Mine waste rock dump design – this research developed a mathematical model to support and optimise waste rock placement; minimising haulage costs and the potential for environmental harm
- Project 5: Greenfields geochemical exploration – This project aimed to reduce discovery costs through the application of landform models.

Estimated economic impacts: low cost to government, significant benefit to WA

The estimate of economic impact consists of both direct commercial benefits and indirect (flow-on) economic benefits generated by the selected research projects funded by MRIWA. The total economic impacts are defined according to the effects of the four modelled scenarios – encompassing impacts to Gross State Product (GSP, or aggregate economic output in Western Australia), employment, and State Government revenues.

An overview of the four modelled scenarios is provided below:

- Scenario 1 – This scenario models a 0% inducement[1], with extrapolation[2] of benefits to all industry sponsors
- Scenario 2 – This scenario includes a 50% inducement factor (excluding some projects which were 0% across all scenarios[3]), with industry sponsor extrapolation. This scenario is the least conservative and represents the upper-bound of the benefits

[1] Inducement refers to the extent to which MRIWA's role in supporting research funding for a particular project had the effect of inducing industry co-funding for the project.

[2] An extrapolation scenario estimates the benefits to all sponsors involved in a research project, with the benefits of those not directly engaged estimated according to metrics provided by those sponsors who were directly engaged in the study.

[3] Not a MRIWA-led project, therefore no inducement effects; and hence no industry costs are modelled

- Scenario 3 – The underlying assumption for this scenario is a 0% inducement factor, with no extrapolation of benefits across sponsors. This scenario is the most conservative and represents the lower-bound of the benefits
- Scenario 4 - This scenario includes a 50% inducement factor (excluding some projects which were 0% across all scenarios), with no industry sponsor extrapolation. This scenario is adopted as the baseline outcome for the study.

Cumulatively, the analysis demonstrates that the research projects funded by MRIWA have positive effects on output in Western Australia (Table 1).

Table 1: Summary of cumulative impacts to output, employment and State Government revenue (deviation from the base case)

Economic indicator	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GSP increase, NPV (2014-15 $m)	59.5	120.8	48.0	90.4
Employment (average FTEs)	2.7	7.8	2.1	6.2
WA Government revenue, NPV (2014-15 $m)	4.9	10.5	3.9	7.8

Source: Deloitte Access Economics analysis; Industry sponsor input

Between 2008-09 and 2019-20, under the baseline scenario (Scenario 4),[4] Western Australia's GSP is cumulatively estimated to be $90.4 million higher than under the base case scenario in NPV terms (2015 dollars).

The incremental impacts on State tax and royalty revenue follow a similar pattern to GSP impacts. Under the baseline Scenario 4, between 2008-09 and 2019-20, State Government revenue is cumulatively estimated to be almost $7.8 million higher than under the base case scenario in NPV terms.

On average, job creation between 2008-09 and 2019-20 in the baseline Scenario 4 is estimated to be approximately 6.2 FTEs. Estimated job creation is highest under Scenario 2,[5] reaching an average of 7.8 FTEs across the same time period.

The estimated economic impacts represent a significant net return to the State Government on the cost of funding the five selected research programs. The aggregated benefit ($90.4 million in NPV terms) significantly outweighs not only the funding cost of the five selected projects, but also the entire funding across all MRIWA / MERIWA projects since 1990 ($25.7 million in NPV terms across all projects).[6]

Beyond dollars and cents

Along with the quantitative economic benefits resulting from MRIWA-funded research, this study also seeks to highlight the less quantifiable but nonetheless important outcomes MRIWA has achieved in relation to innovation, education and capacity development in WA.

[4] Scenario 4 models 50% inducement

[5] Scenario 2 models 50% inducement; with extrapolation. This is the least conservative scenario.

[6] This excludes the cost of operational funding provided to MRIWA / MERIWA. Operational funding to the organisation is small in any case compared to the funds provided to support research. In nominal terms, the value of this aggregate funding contribution by MRIWA / MERIWA is $7.8 million.

A key example of MRIWA's contribution to education and capacity development in WA is encompassed in its new tertiary scholarship program. MRIWA recently established the new scholarship program to succeed the previous tertiary scholarship scheme, which was operated for many years by the former MERIWA.

The purpose of the MRIWA Scholarship Program is to support graduate research training in disciplines underpinning the minerals industry in WA by enabling students of exceptional research promise to undertake higher degrees by research at the participating universities in WA.

The scholarships are typically awarded to PhD students enrolled in the Faculties of Engineering, Computing and Mathematics and Science. The MRIWA Scholarship Program (MSP) is expected to total approximately $0.9 million over the three years from 2013-14 to 2015-16 (inclusive).

In addition to the MSP, two other examples of how MRIWA's support for research and development in WA has allowed innovation to occur on a global scale are also considered.

The project, Improving Solvent Extraction Technology, saw interactions between the WA-based researchers and one of the project's global sponsors in the USA, a major gold miner. Based on the techniques developed in the project, the sponsor company implemented a new design to existing mixer settlers. This new approach eliminated a range of previous challenges relating to the operation of the settlers and effectively allowed a smoother production and lower associated costs.

The sponsor company confirmed that knowledge derived directly from this research will also be applied to future projects undertaken by the firm. The sponsor company also indicated that the commercial outcomes of the research were well received within the organisation. Visibility and appreciation of the research being conducted in WA was generated among the company's executive leadership team.

Another project, Hydrothermal Footprints of Magmatic Nickel Sulfide Deposits, saw global reach achieved when three of the WA-based researchers involved initiated a training program with the head office of one sponsor company; a major European-based miner of multiple base metals.

The training provided an opportunity for the company geologists to get more involved in the research and teaching program by providing access to the expertise of the WA-based researchers. The research also utilised novel instruments not available in Europe at the time which enabled knowledge transfer to occur from WA-developed research findings and to the firm's European operations.

The case studies developed in the project continue to act as a template and guide the company's scale of exploration conducted in a specific area. This template is facilitating the evaluation of potential investment or acquisition of existing exploration and mining projects by the sponsor with more confidence and at lower cost.

1 Introduction

1.1 Background

1.1.1 The Resources industry in Western Australia

Western Australia's resources industry is a fundamental driver of the state's economic development and prosperity. The industry is the largest contributor to the Western Australian economy, with the resources sector contributing $78 billion (or approximately a third) to WA's total industry output in 2013-14.[7]

The resources sector also accounted for approximately 90 per cent of the state's total merchandise exports in 2014 (and approximately 48 per cent of national exports).[8] By value, Western Australia's mineral and petroleum industry grosses just over $114 billion in sales in 2014, up by 66 per cent over the past 10 years.

Mineral extraction is a critical component of the state's resources wealth, accounting for 44 per cent of sales in 2014. Iron ore is the State's highest value commodity, accounting for 75 per cent (or $65 billion) of total mineral sales in 2014.[9]

After a period of strong growth, the Western Australian resources industry is undergoing a period of transition as it moves from a construction phase to a production phase. This is occurring against a backdrop of falling global commodity prices.[10] The decline is reflected in the non-rural component of the benchmark Reserve Bank of Australia Price Index, which dropped by 18 per cent over the past year in Special Drawing Rights (SDR) terms (9% in Australian dollar terms)[11] – reaching its lowest point since January 2007.

There is currently a concerted effort among participants in the sector to reduce operating costs and maintain profitability. Additionally, one of the most concerning aspects of the current downturn is the steady decline in mineral exploration expenditure, which has fallen by almost 40 per cent over the past four years. A healthy pipeline of exploration spending is critical to ensuring future growth and activity in the sector from new developments.

Research and development is a key aspect of reducing operating and exploration costs and increasing the probability of new finds and profitability. It is important that both industry and government work to facilitate research and development activity that helps to secure the ongoing prosperity of the mineral resources sector in Western Australia. Organisations like the Minerals Research Institute of Western Australia (MRIWA) play an important role in this regard by assisting the minerals industry fund key research and development activities, which focus on long term, sustainable production and exploration activity in the minerals sector.

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[7] Chamber of Commerce and Industry of Western Australia, 2015
[8] Department of Mines and Petroleum, 2014
[9] Department of Mines and Petroleum, 2014
[10] Chamber of Minerals and Energy Economic Brief, 2015
[11] Reserve Bank of Australia, 2015

1.1.2 MRIWA's role in the Mineral Resources sector in Western Australia

MRIWA commenced its operations on 1 February 2014, after the Minerals Research Institute of Western Australia Bill 2013 received royal assent on 18 December 2013. The Minerals Research Institute of Western Australia Act 2013 (the Act) established MRIWA as a statutory body to encourage and foster minerals research for the benefit the State. The new body replaces the previous Minerals and Energy Research Institute of Western Australia (MERIWA).

MRIWA's primary aim is to encourage and stimulate minerals related research specifically, by granting funds for research required by the State's minerals industry to ensure it continues to be an engine of economic growth.

MRIWA invests funds from the State Government in research projects especially designed to develop solutions that address opportunities and challenges that face Western Australia's minerals sector.

MRIWA invests within Australia and globally, through competitive grants made to research organisations that leverage multi-partner co-funding from industry and/or other government sources. In addition to investing State Government funds in minerals research, MRIWA also awards annual scholarships for post-graduate research.

1.1.3 MRIWA's fundamental aims

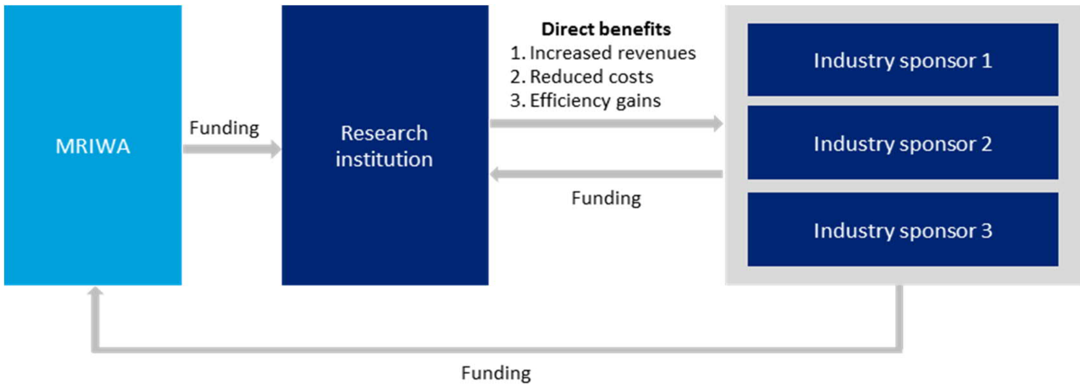
In the period from February 2014 to June 2015, MRIWA achieved a number of key aims:

- Investment in a number of new research projects, with $4.9 million committed to new research projects. Notable amongst these are:
  - $2.58 million grant to the Distal Footprint project (a $16 million, 3-year initiative focused on the Capricorn region of Western Australia, being conducted with CSIRO, Curtin University and The University of Western Australia), which seeks to develop a new way of discovering mineral deposits in the area;
  - $0.6 million to the bid by the CRC for Optimising of Resource Extraction for a second term (this comprised some $30 million of industry cash and requested $35 million in new Commonwealth funds).
- Establishment of a strong 'pipeline' of potential applications for further MRIWA investments in research.
- Commencement of a new Tertiary Scholarships Program. Over the first three years of MRIWA operation, this program will offer two Director's PhD scholarships, with a total value of $240,000, a further 8 PhD scholarships, total value of $560,000, and the 'Odwyn Jones Awards', which will annually provide up to 6 scholarships of $5,000 each, for students to progress their fourth year research project.
- Positioning the Institute as an influential member of the local and national innovation system for the minerals industry.

1.1.4 Objectives of MRIWA-funded projects

MRIWA's primary function is to provide and administer financial grants for minerals research to support and encourage the on-going development of the minerals industry in Western Australia. Figure 1-1 illustrates the typical grant structure, with MRIWA providing funding directly to a research institution for a specific research project. Industry sponsors provide funding through MRIWA to the institution for the same project and often work closely with the institution in developing and testing the body of work (for the majority of research projects, industry funding goes through MRIWA in the first instance). The research programs may generate three benefits for sponsors in the form of increased revenues, reduced costs and / or efficiency gains.

Figure 1-1: MRIWA funding



Source: Deloitte Access Economics

MRIWA's investment decisions are guides by the Research Priority Plan (the Plan), which outlines the minerals research priorities for the State. The Plan defines five priority research themes, which will form the basis for measuring the economic impact of projects administered under its funding:

i. Find more resources – develop methods and tools to meet the challenging exploration environments in Western Australia;

ii. Expand the mining envelope – allow deeper mining of more geo-technically challenging ore bodies;

iii. Increase recovered value – develop advanced modelling for processing circuits to efficiently recover minerals from increasingly low grade and complex mineralisation;

iv. Improve productivity – reduce the operating and capital costs of mining in Western Australia;

v. Develop new products and markets – develop processes that lead to new mineral products and markets for Western Australia.

1.2 Purpose of this study

The purpose of this study is to undertake an Economic Impact Assessment (EIA) of MRIWA's funding of research and development to the state of Western Australia. The EIA quantifies the value to the Western Australian economy (to direct industry participants, the minerals resource industry and economy as a whole) of a selected list of projects funded by MRIWA. The results of the EIA will form a key input into MRIWA's submission to secure further funding from the Government of Western Australia to continue its support of research and development activities in WA.

1.3 Structure of the report

The report is set out as follows:

- Chapter 1 is an introductory chapter that presents the project background and objectives
- Chapter 2 outlines the methodology utilised for the EIA. The methodology includes several key elements. These are:
  - Project selection
  - Data collection and analysis
  - Measurement of direct economic benefits
  - Measurement of indirect economic impacts
- Chapter 3 assesses the economic impact of the selected MRIWA funded projects, and details the direct and indirect economic impacts of the selected projects
- Chapter 4 presents the qualitative impacts of some of the research and education support provided by MRIWA. It is recognised that not all of MRIWA's contributions to the economy can be measured quantitatively. This chapter presents a series of case studies that catalogue key contributions in a qualitative manner.

2 Methodology

2.1 Project selection

MRIWA and its predecessor entity, MERIWA, have together co-invested in over 300 research projects for the minerals and energy industries in Western Australia since the late 1980s. Consequently, determining the benefits for all (or even a moderate proportion of) MRIWA and MERIWA funded projects was not feasible within the given scope.

Therefore, the first step in the project selection process was to determine how a smaller, credible sample of research projects ought to be selected. This led to a filtering process (Figure 2-1) to exclude those projects that did not meet the scope of the study and the related objectives. These were:

- Projects that were very recent – recently completed projects (i.e. less than 2 years old) were unlikely to have a credible track record of commercial outcomes to accurately measure economic benefits. Although future expected benefits could be estimated with stakeholder input, future estimations are less robust and was therefore avoided where possible
- Projects that funded research relating to oil and gas – the scope of this study is limited to measuring the impact of minerals related research funding. This reflects MRIWA's new mandate (as of 2014) to focus on the minerals sector specifically
- Projects that funded research relating to safety, environment and mediation – these projects were excluded as these fields are not included in the remit for MRIWA, and the likelihood of measuring credible, quantifiable economic impacts from such projects were considered low
- Projects that were very old – although older projects were more likely to have a track record of commercial application and outcomes, very old projects were considered less likely to have stakeholders available to discuss and verify impacts to ensure credibility around the estimates. Projects greater than 15 years since completion were excluded as a result

The research projects included in the initial assessment list following this process of filtering comprised projects sponsored by MRIWA and MERIWA that are relevant to the organisation's current minerals-focused mandate. [12]

As there is no requirement for recipients of MRIWA funding to record and report on the commercial outcomes of funded research, the assessment of each MRIWA project required a bespoke approach to estimate benefits, and as a result, significant stakeholder consultation (with related researchers and industry sponsors) was required to understand the nature of benefits attached to each project.

This initial list of research projects became the focus of industry / researcher consultation to determine commercial application and impacts. However, given the volatility in the WA

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[12] The Minerals and Energy Research Institute of Western Australia (MERIWA) was succeeded by the Minerals Research Institute of Western Australia (MRIWA) on 1 February 2014 which limited its focus to the minerals industry, excluding previous subjects of research including energy, environment and health & safety.

resources sector at the time of the study, the initial consultation process revealed that some industry stakeholders involved with the selected MRIWA research projects were no longer in the employment of the related firm, or if they remained with the firm, were unable to engage due to other, more pressing priorities.

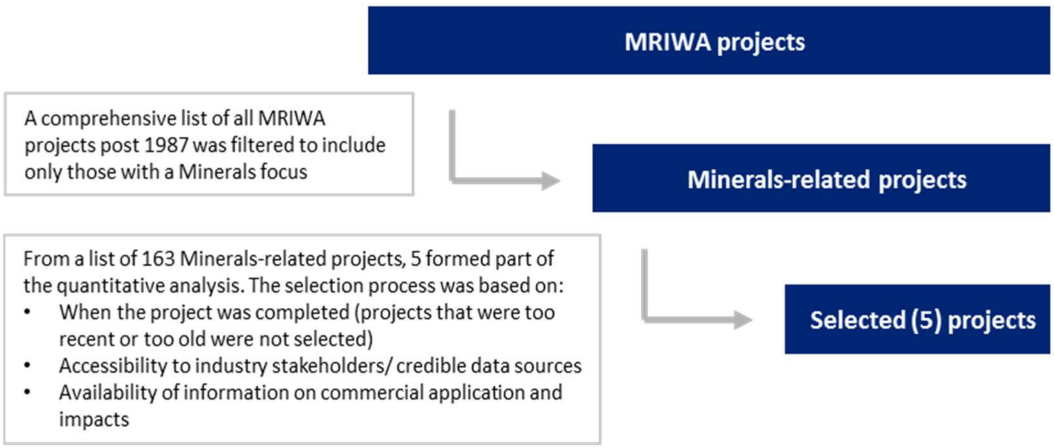
Therefore, projects were further prioritised if information on commercial application and impacts was readily available and / or if industry stakeholders were available and willing to engage. Projects for which credible information was available and / or industry stakeholders were available to discuss and verify impacts formed the basis of the analysis. This information provided sufficient confidence and credibility to establish that the research funded by MRIWA resulted in verifiable commercial impacts to the mining sector.

The focus of this project selection process on picking projects with appropriate and credible data sources means that the economic impacts calculated, while robust, only represent a portion of the total impacts generated by MRIWA's support for research.

It is possible that the filtering process employed (particularly the prioritisation of those projects with good information sources and available industry stakeholders) may have influenced the final project sample towards 'winners' – that is, highly successful projects may be more likely to have more information available and stakeholders that are more willing to talk about the outcomes.

Although this may be the case, MRIWA's funding contribution to other projects rarely, if ever, results in value destruction to the economy. That is, the State's loss in a scenario where the research proves unsuccessful is limited to the cost of the MRIWA funding contribution.[13]

Figure 2-1: Project selection process



Source: Deloitte Access Economics

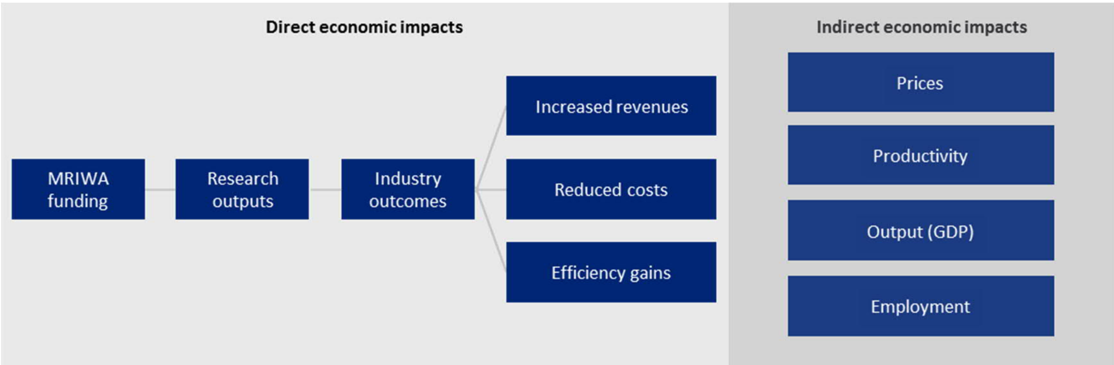
[13] This cost can be greater to the extent that MRIWA's funding is considered to have induced additional funding for the project from industry sponsors than would otherwise be the case. The inducement effect is considered in chapter 2.3.3. For example, if MRIWA's contribution is assumed to have induced funding from sponsors, then the aggregate cost to the economy from an unsuccessful project would be higher than MRIWA's funding contribution alone and would also include that proportion of sponsor funding that MRIWA's support for the project is considered to have induced from industry.

2.2 Direct economic benefits

2.2.1 Definition

Direct economic benefits relate to the value of economic activity directly generated for industry sponsors through the application of MRIWA funded research. In essence, these direct benefits are the positive commercial outcomes for sponsors, and can take the form of increased revenue, improved efficiency, and / or reduced operating costs. Figure 2-2 illustrates how MRIWA's funding for research activities flow through to direct impacts for industry sponsors (and ultimately indirect impacts through the economy).

Figure 2-2: Industry Impacts



Source: Deloitte Access Economics

2.2.2 Approach to quantification

DAE undertook an extensive consultation and data collection process to assess and quantify the commercial outcomes for industry sponsors of MRIWA funded research projects. This included engaging with respective researchers, as well as industry sponsors to obtain information to credibly estimate the commercial outcome for a given company. These estimates formed the baseline scenario for valuing the direct benefits to industry of MRIWA-funded research. However, a process of extrapolation was also employed to gauge the potential benefits for industry sponsors beyond those directly engaged in the study.

The baseline scenario for estimating direct benefits focussed upon quantifying the commercial value to individual industry sponsors that were engaged as part of the consultation process (or where publically available information allowed these impacts to be measured without direct engagement with firms). [14]

However, commercial benefits were not limited to industry sponsors who were engaged as part of the study. For the majority of projects included in the analysis only one or two industry sponsors were directly engaged during the study, however in most cases the project involved many more sponsors. During discussions with individual sponsors that were directly engaged, evidence was also collected regarding the likelihood and nature of commercial outcomes experienced by other sponsors in the research group that were not

[14] For example, two projects did not involve direct stakeholder consultation but rather independent reports regarding the commercial benefits to sponsor companies were available and were used as the basis for benefit estimation in this study

able to be engaged for the study (as noted above, for reasons of staff turnover and or lack of availability).

From this process, anecdotal evidence emerged that the application of research had possibly benefitted other companies in the sponsor group that were not directly engaged in our study (or in one case had permeated the entire WA mining industry). Therefore, to capture some of the benefits to industry participants who were not directly engaged, the study employed a simplified extrapolation methodology. This provided an upper-bound estimate of the measured benefits. The extrapolation process was not applied across the entire WA mining sector. Extrapolating benefits to the entire mining industry would have been problematic, as it was unclear where the research was implemented (and would have led to a gross overestimation of the commercial benefits).

Rather, extrapolation was limited to the sample of companies who directly sponsored the given research project. This restricted the upper-bound estimate to companies with direct knowledge of (and involvement in) the project. These firms were considered likely to adopt the research project's outcomes in their own operations, even if the firm evidence to confirm this was not available. Therefore, quantification of direct benefits consists of two scenarios:

- a baseline (more conservative) scenario whereby only the benefits to sponsors who were directly engaged in the study are included
- an extrapolation (less conservative) scenario whereby the benefits to all sponsors involved in a research project are estimated, with the benefits of those not directly engaged estimated according to metrics provided by those sponsors who were directly engaged in the study.

Figure 2-3 provides an example of the extrapolation process followed. In the illustrated example, three industry sponsors were involved in the MRIWA research. However, only one ("Industry sponsor 1") was engaged directly through our consultation process – identifying a quantifiable commercial benefit (10% cost decrease).

Under a scenario where extrapolation was not modelled, the 10% cost decrease is applied exclusively to Industry Sponsor 1 when calculating the direct benefits of the research. However, under the extrapolation scenario, this cost decrease is also applied to Industry Sponsor 2 and Industry Sponsor 3.

Figure 2-3: Example of extrapolation

Project sponsor	Identified commercial benefit	No extrapolation scenario	With extrapolation scenario
Industry sponsor 1	N/A - sponsor not engaged	Not modelled	10% cost decrease modelled
Industry sponsor 2	10% cost decrease	10% cost decrease modelled	10% cost decrease modelled
Industry sponsor 3	N/A - sponsor not engaged	Not modelled	10% cost decrease modelled

Source: Deloitte Access Economics

2.3 Direct economic costs

2.3.1 Definition

Measuring and modelling the direct commercial benefits of MRIWA funded research does not capture the whole picture. In the case of an EIA, it is critical that the counterfactual scenario is clearly defined. In this case, the direct economic costs of providing the research funding must be considered in the counterfactual scenario to capture how those research funds might have been otherwise employed. The counterfactual refers to the scenario that is expected to have emerged in the absence of the investment case – in this case, a scenario where MRIWA funding is not provided. The economic impacts are expressed as deviations from this counterfactual scenario.

2.3.2 Approach to quantification

The treatment of these costs in the modelling process ensured that the counterfactual scenario was considered, that is, that the measured benefits were offset against the real and opportunity costs of the research from which it stemmed. Two costs were measured and modelled in the economic impact analysis – the cost to government of funding the research and the cost to industry sponsors.

A cost to government exists (this is ultimately a cost to taxpayers) of raising the revenue required to fund research via MRIWA. This reflects both the opportunity cost (equal to the cost of the research) of putting these funds to productive use in other parts of the economy, and also a 'Dead Weight Loss' (DWL). DWL captures the loss of economic well-being, associated with increased taxation within the economy to fund the spending on research.

The modelled scenarios also incorporate a cost to industry sponsors involved in the research, as an increase in company expenditure was required to support the research project. However, the extent to which these industry costs are modelled is dependent upon the inducement effect employed. This is discussed in further detail in chapter 2.3.3 below.

2.3.3 The inducement effect

Inducement refers to the extent to which MRIWA's role in supporting research funding for a particular project had the effect of inducing industry co-funding for the project. While this point was tested in consultations with industry sponsors, few were able to provide credible views on the role that MRIWA co-funding played in securing the involvement of their firm, or how industry funding might have been otherwise deployed if MRIWA funding had not been provided.

A number of assumptions can be made regarding the inducement effect that can influence the extent of the economic impacts derived from MRIWA's funding support. In general, a lower inducement assumption yields a lower economic benefit by attributing a smaller role to MRIWA in inducing industry co-funding for the project.

2.3.3.1 100% inducement effect

At the other extreme of a low inducement scenario is a wholly attributable assumption, that is, that the existence of MRIWA (and the role it plays) has the effect of inducing all research funding from project sponsors (a 100% inducement factor). This implies that, in a counterfactual scenario, these funds from industry would not have otherwise been spent on research. The impact of this assumption on the modelling is to attribute all of the benefit derived from the research to MRIWA's role. This is an unrealistic assumption; an issue that has been explored in-depth with respect to the economic impacts of Cooperative Research Centres (CRC) in Australia (see Box 1).

Box 1: Inducement effects

The treatment of industry sponsorship in determining the economic impacts of government-funded research has been explored extensively; relating to Cooperative Research Centres in Australia. In an Insight Economics (2006) report, it was assumed that the CRC program was responsible for inducing 100% of industry funding. However, in a critique of this methodology, the Productivity Commission (2006) stated that this method for apportioning benefits was "dubious," and it is "highly improbable that industry sponsors would have produced research of zero value in the absence of the program." To adjust the benefits measured in the Insight Economics study, the Productivity Commission assumed the opposite – that the CRC program was responsible for no (0%) of industry funding. A subsequent report by Allen Consulting Group (2012) attempted to reach a compromise between the two above approaches. It noted that "consultations undertaken with CRC participants throughout this study indicate that the real story is perhaps, somewhere in between…" This analysis took a moderate position; assuming a 50% inducement effect. Crucially, in measuring benefits under this assumption, the study included a sensitivity analysis, which considered the 0% and 100% alternatives.

2.3.3.2 Towards a conservative inducement scenario

For this analysis, two inducement scenarios were examined: one at 0% and one at 50%. [15] A 100% inducement factor was not modelled due to the inherent risks in overestimating benefits by attributing the full value of commercial outcomes to MRIWA.

Rather, a 50% inducement factor was adopted for the baseline scenario, which is in line with similar analysis undertaken for other studies. [16] This effectively attributes only half of the derived benefit to MRIWA's role, with the underlying assumption that half of the industry co-funding for the research would have been channelled into research causes by sponsors in the absence of MRIWA.

A 0% inducement factor implies that, in the absence of MRIWA projects, industry sponsors would have channelled all co-funding to research activities in any case, which is assumed to have similar economic benefits to the MRIWA-funded research outcomes. In this case, the incremental benefits of MRIWA funded projects are directly proportional to MRIWA's share of the research funding (i.e. if MRIWA contribute 10% of the total research cost, only 10% of the derived commercial benefit is attributed to MRIWA).

Figure 2-4 illustrates the effect of the three different inducement scenarios on the modelling methodology in a hypothetical example. The example entails a research project with a total estimated benefit of $200 million, and a total research funding cost of $100 million, where industry funded 90% of the cost ($90 million) and MRIWA funds 10% ($10 million).

[15] For some research projects, MRIWA was not the primary source of non-industry funding; therefore, in this instance, the inducement factor was assumed to be 0% under these scenarios.
[16] See Box 1.

In the 50% inducement scenario, it is assumed that 50% of industry expenditure on research would be spent on similar activities in the absence of MRIWA. Therefore, the commercial benefit of the research project attributable to MRIWA is equal to $110 million. This is calculated as follows:

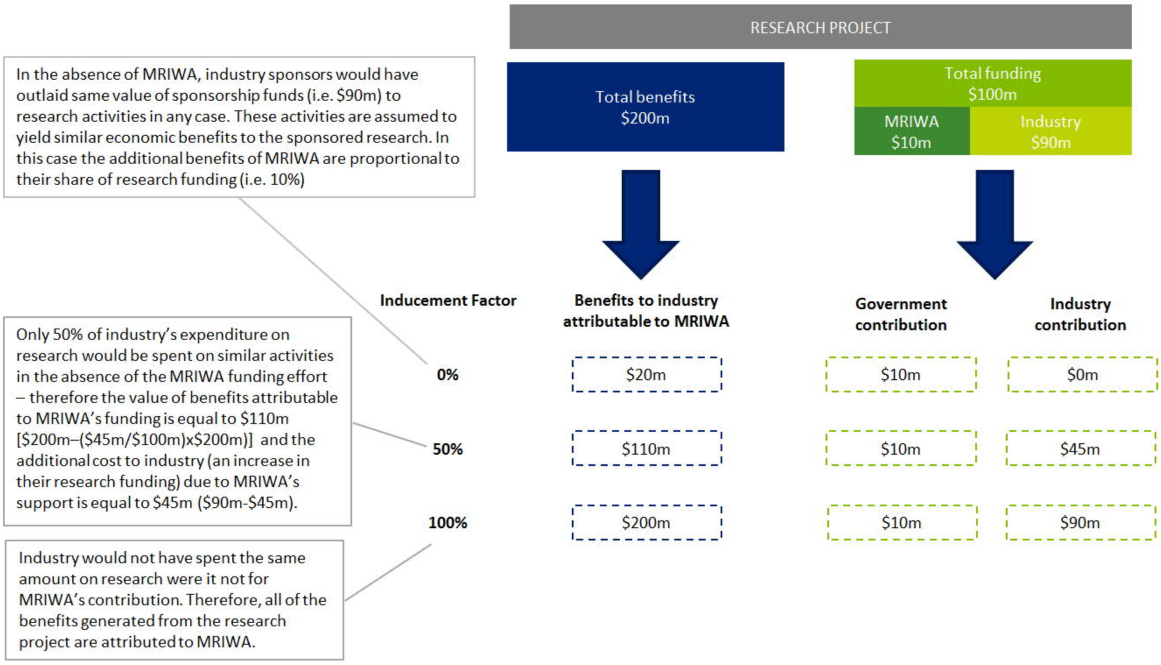
$$[\ \$200m \times \frac{(\$45m\ +\ \$10m)}{\$100m}]$$

The additional cost to industry (an increase in their research spending) of the MRIWA research is equal to $45m [$\$90m - \$45m$][17].

The impact of the inducement assumption on the value of commercial benefits attributable to MRIWA is significant, as portrayed in Figure 2-4. A 100% inducement assumption yields a benefit attributable to MRIWA of $200 million, while a 0% inducement assumption yields a benefit attributable to MRIWA of just $20 million. It is for this reason that the study provides estimates of the economic impact based on two scenarios - a 50% scenario and a 0% scenario.

The cost to government (both the opportunity cost and the DWL) is modelled identically under all scenarios.

Figure 2-4: Hypothetical inducement scenarios



Source: Deloitte Access Economics

[17] This scenario considers an inducement factor of 50%, therefore the additional cost to industry is equal to $90m – (50% x $90m) i.e. $45 million.

2.4 Scenario analysis

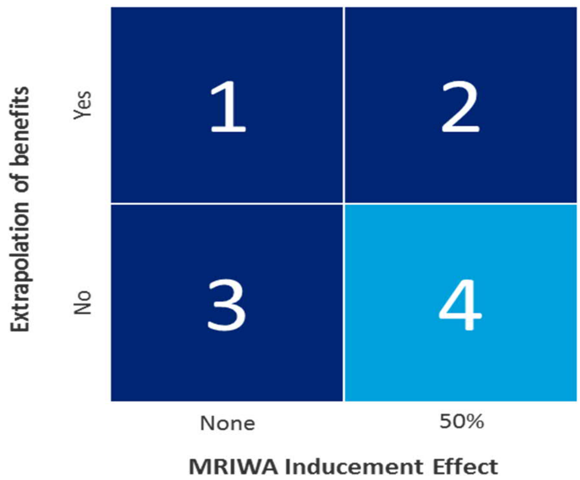
Economic impacts were estimated across four scenarios in the study in order to incorporate the different assumptions relating to the two inducement factors, together with the extrapolation and non-extrapolation of benefits across sponsors. These scenarios are illustrated in Figure 2-5.

Scenario 3 is the most conservative scenario modelled as it only measures the benefits directly indicated through our consultation process (i.e. no extrapolation of benefits) and assumes that no additional industry research funding was induced by MRIWA (i.e. a 0% inducement factor).

Scenario 4 is adopted as the baseline scenario (light blue highlight in Figure 2-5) as it provides a defendable, yet conservative estimate of the benefits of MRIWA-funded research. The scenario is conservative as it does not include the extrapolation of benefits to other industry sponsors. The fact that only verified benefits are included for sponsored engaged in the study provides credibility to the outcomes, as does the fact that the 50% inducement factor adopted is also consistent with similar studies undertaken (see Box 1). An overview of the four modelled scenarios is provided below:

- Scenario 1 – This scenario models a 0% inducement, with extrapolation of benefits to all industry sponsors
- Scenario 2 – This scenario includes a 50% inducement factor (excluding some projects which were 0% across all scenarios[18]), with industry sponsor extrapolation. This scenario is the least conservative and represents the upper-bound of the benefits
- Scenario 3 – The underlying assumption for this scenario is a 0% inducement factor, with no extrapolation of benefits across sponsors. This scenario is the most conservative and represents the lower-bound of the benefits
- Scenario 4 - This scenario includes a 50% inducement factor (excluding some projects which were 0% across all scenarios[18]), with no industry sponsor extrapolation. This scenario is adopted as the baseline outcome for the study.

Figure 2-5: Scenarios modelled in the study



[18] Not a MRIWA-led project, therefore no inducement effects; and hence no industry costs are modelled

2.5 Indirect economic impact

2.5.1 Definition

Indirect economic impacts constitute the flow-on effects of the direct economic impacts through the economy. These include impacts on prices, productivity, output (Gross State Product), and employment (jobs and wages) from the initial direct impacts.

The indirect impacts of the selected MRIWA funded projects have been estimated using Deloitte's Computable General Equilibrium (CGE) model of the Australian economy: the Deloitte Access Economics' Regional General Equilibrium Model (DAE-RGEM).

2.5.2 Model background

The DAE-RGEM model is based upon a set of key underlying relationships between the various components of the model, each which represent a different group of agents in the economy. These relationships are solved simultaneously, and so there is no logical start or end point for describing how the model actually works (further information on the model structure is provided in Appendix B).

The key components of the model include a representative household, producers, investors and international (or linkages with the other regions in the model, including other Australian States and foreign regions). A CGE model employs more sophisticated modelling techniques than a traditional Input-Output (IO) model in that it models the economy simultaneously through thousands of mathematical equations. The additional sophistication is driven by five key aspects:

- Explicit treatment of prices – the values of transactions is disaggregated into prices and quantities, allowing for behavioural responses to price changes to be modelled.
- Constraints in factor markets – a range of possible assumptions around the availability of the primary factors of production. In the case of Deloitte Access Economics' in-house CGE model - the DAE-RGEM model - all capital must be funded by savings (that is, a choice must be made between consumption and investment), and the available labour stock is a function of demographic forecasts and participation rates (which is driven by wage movements).
- Sophisticated equation structure – detailed equation structures including, for example, the formation of prices and behavioural responses. This provides a significant body of variables that may be used to model policy "shocks".
- Detailed treatment of direct and indirect impacts - Industries and consumers are more detailed, allowing for intra and inter-regional trade, consumer choice between saving and consumption and the possibility for substitution between different intermediate inputs.
- Time dynamics – many CGE models (including the DAE-RGEM model) explicitly include the treatment of time, allowing for year-on-year time profiles of, for example, investment and consumption activity, and producing corresponding year-on-year outcome profiles for a wide range of indicators including GDP, employment, wages, industry output etc.

Box 2 below provides more detailed background regarding the DAE-RGEM model. Chapter 3 outlines the quantified direct and indirect economic impacts of the selected MRIWA-funded projects.

Box 2: Deloitte's CGE Model (DAE-RGEM)

The DAE-RGEM is Deloitte Access Economics in-house CGE model.

This model is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the economy. It allows analysis in a single, robust, integrated economic framework, and has enjoyed regular application to questions of large scale investment.

The model captures changes in macroeconomic aggregates including GDP, employment export volumes, investment and private consumption. At an industry level, detailed results such as output, trade flows and employment are also produced.

A global model with flexible regional aggregation

The DAE-RGEM model has a highly flexible regional specification based on an underlying database that includes 129 sectors and a large number of statistical regions. The model allows for the disaggregation of an economy into sub-regions that operate together as a single entity, while also engaging in interregional trade.

Flexibility in sectoral aggregation

The DAE-RGEM model is highly flexible in its sectoral specification. We have extensive experience in providing custom sectoral breakdowns to suit each individual analysis, allowing for targeted analysis of sectors of interest — decreasing modelling risk while maximising modelling value.

Flexibility in model specification

Deloitte Access Economics has an active in-house model development team which, alongside customisation of the model database, also customise the model itself and actively ensure that the model specification is appropriate for the analysis at hand.

3 Economic impact assessment

3.1 Direct economic impact

3.1.1 Introduction

Perhaps the most critical set of assumptions for the modelling of the expected economic impacts to WA from MRIWA funded research relates to the value of the direct economic impacts or 'shocks'. That is, determining the value of commercial benefits that directly accrued to industry sponsors in WA, the timing of that benefit and the nature of it (i.e. a cost saving, revenue increase and / or efficiency gain).

These assumptions were developed by Deloitte Access Economics through consultation with industry sponsors and literature review. Five projects were ultimately selected for inclusion in the economic impact analysis based on the selection criteria and considerations outlined in chapter 2.1.

Below, a summary of each of the five modelled projects is provided along with a discussion about the nature of the commercial impacts to sponsors, and the estimated value of those impacts.

3.1.2 Project 1 – Advancing the strategic use of seismic data in mines (M406)

3.1.2.1 Project summary

This study[19] focused on improved data use to better understand seismic activity and risks. Five key areas were included in the research: the relation of in-situ stress fluctuation to occurrence of large events; seismicity associated with caving processes; assessment of long term seismic risk; and the process of rock mass degradation through seismic processes.

This project was the latest in a number of research items relating to mine seismicity. Five other related studies[20] were included in this analysis to reflect the entire cost of the research stream.

These research projects led to the development of a software package, mXrap. In some cases, the software decreases the exclusion times required following rock blasting to ensure seismic risks are sufficiently stable to recommence mine operations. The greater confidence around seismic risks results in reduced mine down-time and consequent cost savings for the operator.

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[19] POTVIN, Y. and WESSELOO J. 2012. "Advancing the strategic use of seismic data in mines" (M406)

[20] POTVIN, Y., NEDIN, P., SANDY, M and ROSENGREN, K., 2001. "Toward the elimination of rockfall fatalities in Australian mines" (M341); NEDIN, P and POTVIN, Y, 2005. "Australian Rockfall Research – Phase II" (M360); HEAL, D.; HUDYMA, M.; OWEN, M. and POTVIN, Y., 2006. "Mine seismicity and rockburst risk management – phase II" (M355); WESSELOO, J.; DIGHT, P., and POTVIN, Y., 2009. "High resolution seismic monitoring in open pit mines" (M366); HEAL, D.; HUDYMA, M.; MIKULA, P.; OWEN, M.; POTVIN, Y. and WESSELOO, J., 2009. "Broadening the application of seismic monitoring in underground mines" (M386)

3.1.2.2 Information driving direct impacts

Project sponsors provided estimates of the percentage of sites and the workforce typically affected by seismological exclusion zones, the prevalence of exclusion zones to protect against seismological risks at these sites (number of occurrences per year) and the typical reduction in exclusion times already experienced as a result of the deployment of the mXrap software.

The value of this benefit is calculated as a labour productivity benefit, with labour cost used as a proxy for the value of the productivity dividend. This stems from the additional labour output derived by sponsors as a result of less idle time due to exclusion zones being in force.

Productivity benefits related to the avoidance of idle machinery and equipment is not captured due to the lack of available data on these costs. As such, the benefit is a conservative estimate of the total likely benefit construed to project sponsors. The labour productivity benefit was calculated by using industry feedback together with publicly available information on headcount at the relevant sponsor sites and estimates of average mining wages to generate an indication of the value of output per worker. [21]

Table 2 summarises for scenario 4 (baseline impacts) the value of industry benefits, industry costs (value of research funding provided by industry) and government costs (value of research funding provided by MRIWA[22]) related to project 1. The value of the direct impacts illustrated in Table 2 utilise a 7% real discount rate over 15 years from 2005. A further 20% discount is applied to benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows. Appendix A contains more detail on the assumptions adopted for estimating benefits related to this research project.

Table 2: Project 1 benefits and contributions

Baseline (Scenario 4) impacts modelled	NPV 2015 dollars (millions)
Industry benefits	$15.6
Industry contribution	$3.6
Government contribution	$1.5

Source: Deloitte Access Economics analysis; Industry sponsor input

[21] Employment estimates were sourced from the Department of Mines and Petroleum and wage estimates from the Australian Bureau of Statistics)
[22] The government costs modelled in Table 2 exclude the DWL; however this is included in the CGE model.

3.1.3 Project 2 – Improving thickener technology (M279)

3.1.3.1 Project summary

Thickeners are used by the minerals industry for large-scale separation of fine particles related to the mining process, from process liquids. Efficient performance of thickeners is crucial to most mineral processing, hydrometallurgical and water treatment operations. This project[23] built on thickener technology concepts developed by CSIRO in a preceding project, using two high rate thickeners, operating in parallel at the site of one sponsor.

This research formed a part of a wider Australian Mineral Industries Research Association Limited (AMIRA)[24] project concerning improving thickener technologies (amounting to $10m in total funding). The research was conducted by the AJ Parker Co-operative Research Centre. All these costs were accounted for in the analysis.

The AMIRA series of projects has advanced the understanding of the processes occurring within gravity thickeners. This has been achieved through a combination of various processes, including fluid dynamics and physical modelling, experiments, performance testing and extensive on-site measurements. As a consequence of long-term industry support, the research team now leads the world in identifying the key factors affecting full-scale thickener performance and in modifying design and operating conditions to realise improvements.[25]

Commercial benefits relating to these projects were identified and measured in a report developed by Strategic Technology Evaluation and Management (STEM) for AJ Parker Co-operative Research Centre.[26] The research yielded five key operational benefits with related commercial outcomes. These were increased thickener throughput, overflow clarity, underflow density, greater operational stability, and reduced flocculent consumption.

3.1.3.2 Information driving direct impacts

Commercial benefits stemming from these operational improvements were adapted from the STEM report. The benefits estimated in the STEM report were predominantly operating cost savings generated from the application of the research, which in turn were calculated from surveys completed by 22 of the 27 sponsoring companies involved in the projects.

Given that the MRIWA funded project formed part of the wider AMIRA project, the benefits derived were adjusted to reflect the proportion of the total project funding accounted for by MRIWA. This was achieved by assuming a 0% inducement assumption for this project under all scenarios (i.e. a 50% inducement assumption is not applied under any circumstance to this project).

The most commonly stated benefits that were obtained from the completed surveys included reduced flocculant consumption, increased underflow density, improved overflow clarity, plant throughput increases and increased fundamental knowledge of thickeners.

Three companies identified CAPEX savings that were directly attributed to the research program. These included savings associated with reduced size and/ or number of

[23] JOHNSTON, R. R. M., SWIFT, J. D., NGUYEN, T., SIMIC, K. and FARROW J. B., 1997. "Improving thickener technology."
[24] The organisation is now titled 'AMIRA International'
[25] https://www.p266project.com/. Accessed 15 July 2015
[26] Strategic Technology Evaluation and Management (STEM), "Evaluation of benefits from AMIRA Project P266", Report submitted to AJ Parker Cooperative Research Centre, 19 April 2004

thickeners, savings resulting from reducing downstream processing, and reductions in the need for future tailings dams.

Additionally, seven companies identified OPEX benefits – five of which attributed the reduction to greater process stability and control; and the remaining to reduced flocculant costs. Reduced maintenance costs and tailings management were also identified as benefits.

Table 3 summarises for scenario 4 (baseline impacts) the value of industry benefits, industry contributions (value of research funding provided by industry) and government costs (value of research funding provided by MRIWA [27]) related to project 2. The value of the direct impacts illustrated below are derived by using a 7% real discount rate over 15 years from 2005. A further 20% discount is applied to benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows. Appendix A contains more detail on the assumptions adopted for estimating benefits related to this research project.

Table 3: Project 2 benefits and contributions

Baseline (Scenario 4) impacts modelled	NPV 2015 dollars (millions)
Industry benefits	$1.9
Industry contribution	N/A[28]
Government contribution	$0.2

Source: Deloitte Access Economics analysis; Industry sponsor input

3.1.4 Project 3 – Gold processing technology (M238)

3.1.4.1 Project summary

Similar to Project 2, this study was part of a wider AMIRA project, [29] with research again conducted by the AJ Parker Co-operative Research Centre. All these costs were accounted for in the analysis.

The broader project was undertaken to conduct a process and operation review of current leaching and gold recovery practices; and to develop a methodology to allow plant operators to minimise reagent costs, while maximising gold recovery. [30]

To sustain profitability, gold mining companies have an objective to reduce costs associated with processing and maximising gold recovery, as gold ores are often mined at lower grades. To minimise processing costs, reagents must be used effectively, operating reagent set points must be realistic and safe, and reagent addition should be automated where possible.

[27] The government costs modelled in Table 3 exclude the DWL; however this is included in the CGE modelling.
[28] This is not a MRIWA-led project; rather it was led by AMIRA, with a portion of funding attributable to MRIWA. As a result, an inducement effect was not modelled.. The effect of this assumption is to generate benefits attributable to MRIWA that are in proportion to its share of the total project funding.
[29] LABROOY, S. and BAX, A. C., 1997. "Gold Processing Technology."
[30] MERIWA Annual Report, 2001-2002

The MRIWA component focussed specifically on decreasing cyanide plant operating costs, while simultaneously maintaining or increasing gold recovery. Cyanide, in the form of a very dilute sodium cyanide solution, is used to dissolve and separate gold from ore. [31]

Benefits relating to the stream of AMIRA projects were also identified and measured in a report by the STEM Partnership.[32] Companies identified 12 areas of operational benefit, with associated commercial outcomes. The predominant benefits pertaining to this research (identified by the greatest number of companies) included maintaining a core expertise available for the industry; training and educating of technical staff; improvement in the gravity gold process, and in the maintenance of yield and quality.

3.1.4.2 Information driving direct impacts

Commercial benefits were taken from the STEM report. These were calculated based on surveys undertaken by seven of the 20 companies that sponsored the project.

Again, given that the MRIWA funded project formed part of the wider AMIRA project, the benefits derived were adjusted to reflect the proportion of the total project funding accounted for by MRIWA. This was again achieved by assuming a 0% inducement assumption for this project under all scenarios (i.e. a 50% inducement assumption is not applied under any circumstance to this project).

Table 4 summarises for scenario 4 (baseline impacts) the value of industry benefits, industry contributions (value of research funding provided by industry) and government costs (value of research funding provided by MRIWA[33]) related to project 3. The value of the direct impacts illustrated in Table 4 are derived by using a 7% real discount rate over 15 years from 2005. A further 20% discount is applied to benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows. Appendix A contains more detail on the assumptions adopted for estimating benefits related to this research project.

Table 4: Project 3 benefits and contributions

Baseline (Scenario 4) impacts modelled	NPV 2015 dollars
Industry benefits	$16.0
Industry contribution	N/A[34]
Government contribution	$1.4

Source: Deloitte Access Economics analysis; Industry sponsor input

[31] MERIWA Published Reports - Mineral Processing, http://meriwa.wa.gov.au/sites/default/files/Mineral%20Processing%20Website%2016062015.pdf. Accessed 10 July 2015

[32] Strategic Technology Evaluation and Management (STEM), "Evaluation of the AMIRA P420B Project." Report submitted to AJ Parker Cooperative Research Centre for Hydrometallurgy, 17 September 2004.

[33] The government costs modelled in Table 4 exclude the DWL; however this is included in the CGE modelling.

[34] This is not a MRIWA-led project; rather it was led by AMIRA, with a portion of funding attributable to MRIWA. As a result, an inducement effect was not modelled. The effect of this assumption is to generate benefits attributable to MRIWA that are in proportion to its share of the total project funding.

3.1.5 Project 4 – Mine waste rock dump design (M415)

3.1.5.1 Project summary

This research[35] developed a mathematical optimisation model, which supports and optimises waste rock placement. The model seeks to minimise haulage costs and the potential for environmental harm through selective placement and encapsulation of reactive waste rock.

Three mathematical programming models with potential to handle real-world problems were developed as part of this research to generate an optimum waste rock placement and dump schedule.

The first, a Location Optimisation model supports the reduction in overall haulage distance and volume of re-handling; and minimises associated costs over the life of the mine. The second, a Truck Balance model aims to minimise opportunity costs incurred as a result of over or under-budgeting track capacity. Finally, a Combination (Combo) model combines the objectives of the previous two models, therefore optimising operations by generating a 'balanced' rock placement schedule, which considers both the haulage distance and the deviation in truck budgeting. The use of the three mathematical models generated through this research optimised the design and scheduling of waste rock dumps and haul, reducing associated costs as a result.

3.1.5.2 Information driving direct impacts

Cost savings identified in the project report [35], were used to estimate the cost savings to industry sponsors. Haulage estimates of the "Combo" model provided in the report were used to calculate the baseline benefits. The project report identified the Combo model as the recommended option for generating an optimal waste rock placement and dump schedule. Therefore, this was selected as the 'base case' against which the commercial benefits of this research were estimated.

Savings in haulage costs were calculated as the average ratio of the Net Present Cost (NPC) savings between the "Combo 1" and "Combo 2" models, and the Manual Method. The Combo 1 model presented a solution for a 'lift-by-lift' dump construction sequence, and the Combo 2 model for a 'multi-lift' dump construction sequence.

A cost factor of one cent per billion cubic metres (BCM) per flat metre hauled was used as the cost savings benchmark (this benchmark was given in the report itself).

Table 5 summarises the value of industry benefits for scenario 4 (baseline impacts), industry contributions (value of research funding provided by industry) and government costs (value of research funding provided by MRIWA[36]) related to project 4. The value of the direct impacts illustrated below are derived by using a 7% real discount rate over 15 years from 2005. A further 20% discount is applied to benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows. Appendix A contains more detail on the assumptions adopted for estimating benefits related to this research project.

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[35] TOPAL, E., LI, YU and ZHAO, FU. "Mine Waste Rock Dump Design using Mixed Integer Programming (MIP)"

[36] The government costs modelled in Table 5 exclude the DWL; however this is included in the CGE modelling.

Table 5: Project 4 benefits and contributions

Baseline (Scenario 4) impacts modelled	NPV 2015 dollars (millions)
Industry benefits	$1.1
Industry contribution	$0.097
Government contribution	$0.066

Source: Deloitte Access Economics analysis; Industry sponsor input

3.1.6 Project 5 – Greenfields geochemical exploration (M411)

3.1.6.1 Project summary

This research[37] aims to reduce exploration discovery costs through the application of various landform models. This approach has enabled researchers to more easily distinguish between and characterise different types of mineralogy. This provides greater confidence in identifying and targeting potential resources, resulting in lower exploration costs.

This project is the latest in a related stream of five research projects aimed at optimising gold exploration techniques. As a result, the research funding costs related to the five other research projects were also included in this analysis to properly reflect the entire cost of the research leading to the commercial benefits [38].

3.1.6.2 Information driving direct impacts

Project sponsors provided estimates of exploration cost savings resulting directly from this research stream. Two industry sponsors were directly engaged and provided feedback on the commercial outcomes experienced. Both participants attributed a 10% reduction in their exploration expenditure directly to this research, with evidence of this benefit first emerging in 2010.

To estimate the overall benefits of the 10% discovery cost saving to these firms, exploration expenditures for each (and other industry sponsors) were extracted for the period between 2010 and 2014.[39] Because company exploration budgets are highly volatile from year to year, the forward projection of exploration spend beyond 2014 for the sponsor group was highly conservative to avoid overestimating expected benefits from future application of the research by sponsors. The lowest point of aggregate exploration spending among the industry sponsors in the four years to 2014 (plus inflation) was utilised to estimate 2015

[37] GONZALEZ-ALVAREZ, I. & CO-WORKERS 2014. “Greenfields Geochemical Exploration in a Regolith-dominated Terrain: the Albany-Fraser Orogen/Yilgarn Craton Margin.”

[38] WALSHE, J., BATH, A., CLOUTIER, J. & HOUGH, R. 2014. “High Grade Gold Deposits: Processes to Prediction” (M410); ROACHE, T.J., WALSHE, J.L. and HUNTINGTON, J.F., 2010. “On-site validation and implementation of new Hy-logging technologies – technology transfer and re-skilling” (M400); WALSHE, J L, and NEUMAYR, P, 2009. “Scale-integrated, architecturally, geodynamically and geochemically constrained targeting models for gold deposits in the eastern goldfields province, Yilgarn Craton” (M377); and WALSHE, J., NEUMAYR, P., and PETERSEN K, 2006. “Scale-integrated, architectural and geodynamic controls on alteration and geochemistry of gold systems in the Eastern Goldfields Province, Yilgarn Craton” (M358).

[39] SNL Financial (a database that includes financial data and analysis on a range of business sectors) was used to extract exploration spend.

exploration expenditure. Future benefits were subsequently projected through to 2020 by inflating the 2015 estimate on an annual basis.

Table 6 summarises the value of industry benefits for scenario 4 (baseline impacts), industry contributions (value of research funding provided by industry) and government costs (value of research funding provided by MRIWA[40]) related to project 5. The value of the direct impacts illustrated below are derived by using a 7% real discount rate over 15 years from 2005. A further 20% discount is applied to benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows. Appendix A contains more detail on the assumptions adopted for estimating benefits related to this research project.

Table 6: Project 5 benefits and contributions

Baseline (Scenario 4) impacts modelled	NPV 2015 dollars (millions)
Industry benefits	$32.3
Industry contribution	$2.5
Government contribution	$1.7

Source: Deloitte Access Economics analysis; Industry sponsor input

The benefits related to this project account for just under half of the combined estimated NPV of benefits from all five projects examined in this study. Therefore, the economic impacts modelled are sensitive to the direct benefits generated from this body of research specifically. While this is a risk in that a large proportion of total economic impacts are generated by this project, feedback from industry sponsors involved in this project also suggested that this research had achieved seminal status among industry. The anecdotal feedback suggested that the approach and techniques developed are now industry standard practice.

3.1.7 Overall direct economic impact

In aggregate, under the baseline scenario (scenario 4), the direct economic benefits estimated for the five projects included in this study sum to $66.9 million in 2015 dollar NPV terms for the 15 year period from 2005 to 2020. This is considered a conservative estimate given that conservative assumptions have been adopted as far as possible in estimating the value of direct impacts of the research funding under the baseline scenario 4 (as discussed in the above chapters).

Figure 3-1 illustrates the profile of nominal benefits estimated under each scenario adopted in this study. The baseline scenario 4 provides the second largest benefits. The tapering in benefits post 2014 is driven by the 20% discount applied to future benefits to reflect the uncertainty of future cash flows. It also reflects the conservative assumption adopted for project 5 with regard to basing future expected exploration outlays on the lowest value of actual outlays over the previous 4 year period (see Appendix A for more detail).

[40] The government costs modelled in Table 6 exclude the DWL; however this is included in the CGE modelling.

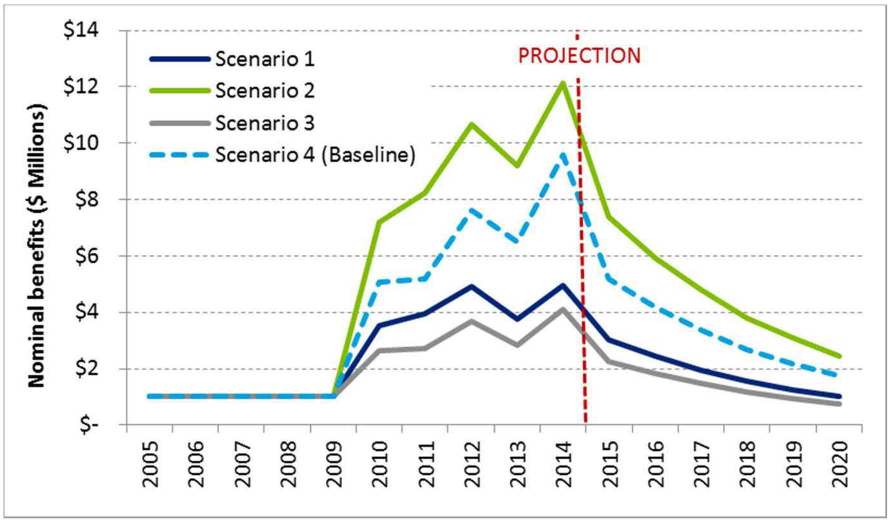
In comparison to the estimated benefits for scenario 4, industry contributed $6.3 million of funding towards these research projects in NPV terms over the same time period. MRIWA provided total funding worth $4.8 million in NPV terms to the five projects.

This represents a significant net return to project sponsors from their own research funding and that provided by MRIWA. Even in extending the MRIWA portion of funding costs beyond the five projects alone to include the cost of all projects funded by MRIWA / MERIWA for all mineral related research projects since 1990, a large net benefit remains. In total, MRIWA has funded $25.7 million worth of research in 2015 dollar NPV terms since 1990.[41] These five projects alone have yielded $66.9 million worth of benefits in comparison to the total research funding costs for government.

Sensitivity tests undertaken as part of the study examined how the total estimated benefit would change if projected benefits for the five projects between 2015 and 2020 were reduced further (projected benefits were already reduced by 20% to account for the uncertainty of future cash flows). A total 50 per cent discount applied to the projected benefits yielded a total benefit of $56.1 million in NPV terms (under the baseline, scenario 4) – still well above the total value of funding provided by MRIWA / MERIWA since 1990.

Table 7 below outlines the value of industry benefits, industry contributions, and government costs related to all five projects under each of the four scenarios modelled in this study.[42] Chapter 3.2 utilises these estimated direct impacts to generate estimates of indirect (flow on) impacts to the WA economy using CGE modelling.

Figure 3-1: Profile of nominal commercial benefits, by scenario



Source: Deloitte Access Economics analysis; Industry sponsor input

[41] This excludes the cost of operational funding provided to MRIWA / MERIWA. Operational funding to the organisation is small in any case compared to the funds provided to support research. In nominal terms, the value of this aggregate funding contribution by MRIWA / MERIWA is $7.8 million.

[42] See Appendix A: Indirect impact assumptions.

Table 7: Summary of direct economic impacts, 2005 to 2020 (NPV 2015 $ millions)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Project 1				
Industry benefits	$6.1	$21.8	$4.4	$15.6
Industry contribution	-	$3.6	-	$3.6
Government contribution	$1.5	$1.5	$1.5	$1.5
Project 2				
Industry benefits	$1.9	$1.9	$1.9	$1.9
Industry contribution	-	-	-	-
Government contribution	$0.21	$0.21	$0.21	$0.21
Project 3				
Industry benefits	$16.0	$16.0	$16.0	$16.0
Industry contribution	-	-	-	-
Government contribution	$1.4	$1.4	$1.4	$1.4
Project 4				
Industry benefits	$0.57	$1.4	$0.45	$1.1
Industry contribution	-	$0.097	-	$0.097
Government contribution	$0.066	$0.066	$0.066	$0.066
Project 5				
Industry benefits	$19.9	$49.5	$11.3	$32.3
Industry contribution	-	$2.5	-	$2.5
Government contribution	$1.7	$1.7	$1.7	$1.7
Total				
Industry benefits	$44.6	$90.7	$35.8	$66.9
Industry contribution	-	$6.3	-	$6.3
Government contribution	$4.8	$4.8	$4.8	$4.8

Source: Deloitte Access Economics analysis; Industry sponsor input

Note:

Scenario 1 – 0% inducement, with extrapolation
Scenario 2 – 50% inducement (excluding Projects 2 and 3 which are always 0%), with extrapolation
Scenario 3 – 0% inducement, with no extrapolation
Scenario 4 – 50% inducement (excluding Projects 2 and 3 which are always 0%), with no extrapolation (baseline)

3.2 Total economic impact

The total economic impacts are defined according to the effects of the four modelled scenarios upon:

- Gross state product (GSP, or aggregate economic output in Western Australia) [43]
- Employment
- State Government revenues.

The impacts to these economic parameters reported in this chapter include both direct and indirect effects.

The indirect or economy-wide contribution of MRIWA's ongoing research program refers to the flow-on economic activity generated by the direct economic impacts estimated in chapter 3.1. The total (direct and indirect) impacts are determined by applying the direct impacts in Deloitte Access Economics' in-house regional CGE model, DAE-RGEM (see chapter 2.5.2 for more information about the model and Appendix B for more detailed information on the model structure).

The economy-wide impacts generated by the MRIWA research activity is estimated in the CGE model as a function of three factors:

1. Cost savings to the mining industry – a positive productivity shock to mining operations in WA as a result of the commercial outcomes achieved by the five research projects
2. Initial research activity – an increase in the amount of tertiary education and research occurring in WA from the research funding
3. Government and industry costs of funding – resulting an increased State tax burden in the years of government outlay.

The incremental effects of these factors on output, employment and State Government revenue are estimated by comparing against levels likely under a base case scenario – the absence of MRIWA funding and research.

3.2.1 Gross State Product

GSP is the primary variable that encompasses the change in economic activity from increased mineral related research and resultant productivity gains. The cumulative impacts prior to 2010 are presented together, given the limitations in the modelling process to easily back-cast incremental activity form the current snapshot of economic activity. This initial impact prior to 2010 is due to increased research activity, along with the early productivity gains flowing to the mining sector from the relevant MRIWA research projects.

The productivity impacts build to 2013-14, reaching a peak of $11.8 million under the baseline Scenario 4[44] – meaning Western Australia's GSP is estimated to be $11.8m higher

[43] GSP is adopted here being a commonly understood economic metric. However, it should be noted that as GSP is an estimate of the overall output of an economy, it can be regarded as a less than ideal measure of the overall economic welfare of residents within an economy.

in that year due to the research and outcomes of the five MRIWA research projects modelled.

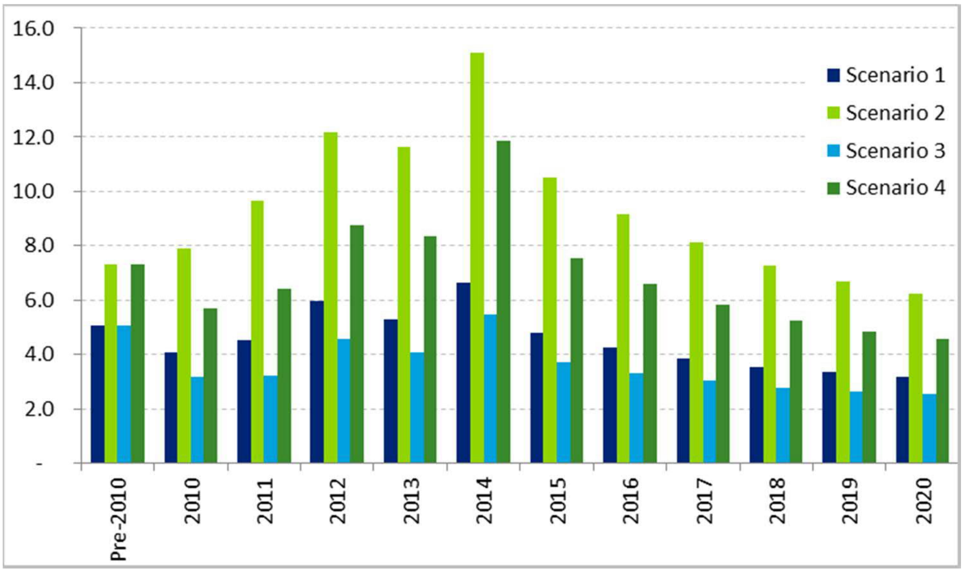
Despite the economic shocks subsiding from 2015 to 2020, the built up capital stock – drawn into WA as a result of the productivity gains – maintains GSP at a higher level than under the base case scenario.

Cumulatively, the analysis demonstrates that the research projects funded by MRIWA have positive effects on output in Western Australia.

Between 2008-09 and 2019-20, under the baseline Scenario 4, Western Australia's GSP is cumulatively estimated to be almost $83 million higher than under the base case scenario in real terms. In NPV terms (2015 dollars), over the same period to 2019-20, the increase in GSP under Scenario 4 is cumulatively $90.4 million. [45]

Table 8 below outlines the total GSP effects (in real terms) of MRIWA's funding of the five projects to 2019-20 (as a deviation from the base case). Figure 3-2 illustrates the profile of impact to Western Australia's GSP under each of the four modelled scenarios.

Figure 3-2: WA – Gross State Product, deviation from the base case ($m)



Source: Deloitte Access Economics analysis; Industry sponsor input

It is evident that the largest total GSP impact is generated from Scenario 2, which entails the highest direct impact as a result of the underlying assumption of 50% inducement and extrapolation of industry benefits to the industry sponsor population.

[44] Scenario 4 models 50% inducement; with no extrapolation; Scenario 1 models 0% inducement; with extrapolation; Scenario 2 models 50% inducement; with extrapolation; Scenario 3 models 0% inducement; with no extrapolation

[45] The discount factor for 2008-09 was applied to the aggregated value of impacts prior to this date due to limitations in the CGE model. This is expected to have a more conservative impact on the NPV numbers expressed.

3.2.2 Employment

The impact of the five MRIWA research projects on full time equivalent (FTE) employment in WA is distinct from the GSP increments. These highlight the relatively labour-intensive activities of research, most of which (by value) occurred prior to 2010. The increased employment associated with on-going improvements in mining activity are relatively modest, given mining is a capital-intensive sector.

On average, job creation between 2008-09 and 2019-20 in the baseline Scenario 4 is estimated to be approximately 6.2 FTEs. Estimated job creation is highest under Scenario 2, reaching an average of 7.8 FTEs over the same time period.

The employment impacts of the four scenarios (as a deviation from the base case) are summarised in Table 8 below.

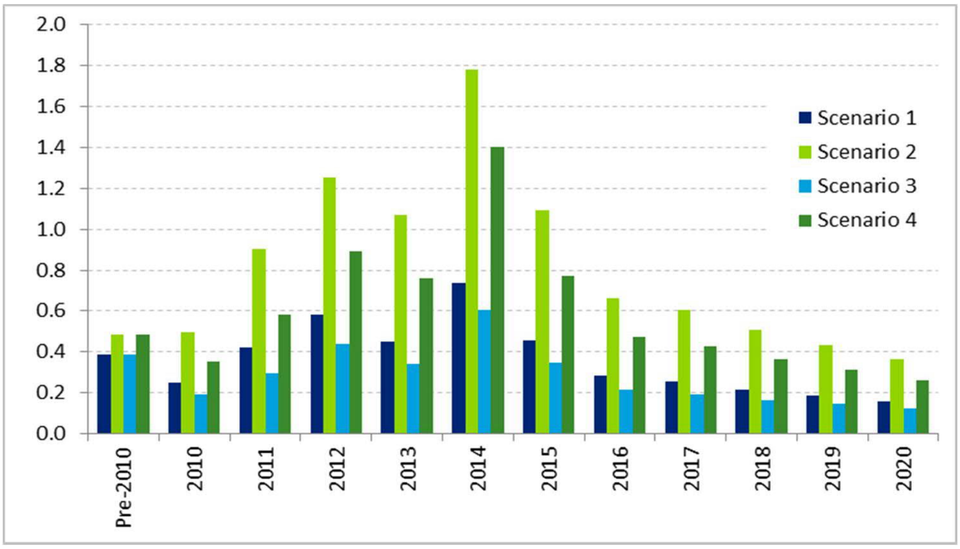
3.2.3 State Government revenue

The incremental impacts on State tax and royalty revenue follow a similar pattern to GSP impacts. The primary channel for this enhancement in revenue is through royalties paid, rather than typical State taxes (such as payroll tax or stamp duties) given royalties are directly linked to mining output.

Between 2008-09 and 2019-20, under the baseline Scenario 4, State Government revenue is cumulatively estimated to be almost $7.1 million higher than under the base case scenario in real terms. In NPV terms (2015 dollars), over the same period to 2019-20, the increase in GSP under Scenario 4 is cumulatively $7.8 million.

Table 8 below outlines the effects to State Government revenues (in real terms) of MRIWA's funding of the five projects to 2019-20 (as a deviation from the base case). Figure 3-3 illustrates the profile of impact to Western Australian Government revenue under each of the four modelled scenarios.

Figure 3-3: WA – WA Government revenue, deviation from the base case ($m)



Source: Deloitte Access Economics analysis; Industry sponsor input

Table 8: Summary of cumulative impacts to output, employment and State Government revenue (deviation from the base case)

Economic indicator	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GSP increase, gross (2014-15 $m)	54.5	111.8	43.6	83.0
GSP increase, NPV (2014-15 $m)	59.5	120.8	48.0	90.4
Employment (average FTEs)	2.7	7.8	2.1	6.2
WA Government revenue, gross (2014-15 $m)	4.4	9.7	3.4	7.1
WA Government revenue, NPV (2014-15 $m)	4.9	10.5	3.9	7.8

Source: Deloitte Access Economics analysis; Industry sponsor input

The total economic impacts outlined in Table 8 above represents a significant net return to the WA economy from the research funding provided by MRIWA. As noted in chapter 3.1.7 above, the cost of all projects funded by MRIWA / MERIWA for all minerals related research projects since 1990 amounts to $25.7 million in 2015 dollar NPV terms. [46] In comparison, the five projects in this study are expected to yield an additional $90.4 million worth of economic output to the State between 2008-09 and 2019-20, also in current dollar NPV terms.

[46] This excludes the cost of operational funding provided to MRIWA / MERIWA. Operational funding to the organisation is small in any case compared to the funds provided to support the research. In nominal terms, the value of this aggregate funding contribution by MRIWA / MERIWA is $7.8 million.

4 Case studies: innovation, education and capacity development in WA

Along with the quantitative economic benefits resulting from MRIWA-funded research, this study also seeks to highlight the less quantifiable but nonetheless important outcomes MRIWA has achieved in relation to innovation, education and capacity development in WA.

These qualitative aspects of MRIWA's work are described below through two case studies relating to funding and support MRIWA has provided. These case studies have been developed via consultations with researchers and industry participants.

The most prominent benefit evident across the case studies is the ability to transfer the knowledge and capabilities developed by Western Australian-based researchers to global industry sponsors. This benefit of "exporting WA knowledge" is having significant, continuing impacts on the global operations of respective sponsor companies.

In addition to strong investment in research projects, MRIWA also initiated a tertiary scholarships program with the intention of not only benefitting students, but also minerals research and industry.

4.1 Case study 1 – MRIWA Scholarship Program

A key example of MRIWA's contribution to education and capacity development in WA is encompassed in its new tertiary scholarship program. MRIWA recently established the new scholarship program to succeed the previous tertiary scholarship scheme, which was operated for many years by the former MERIWA. Four universities partner with MRIWA in the new edition of this program – Curtin University, Edith Cowan University, Murdoch University and the University of Western Australia.

The purpose of the MRIWA Scholarship Program (MSP) is to support graduate research training in disciplines underpinning the minerals industry in WA by enabling students of exceptional research promise to undertake higher degrees by research at the participating universities in WA.

The scholarships are typically awarded to PhD students enrolled in the Faculties of Engineering, Computing and Mathematics and Science. However, relevant applications are considered from candidates in other Faculties also.

The MSP is expected to total approximately $0.9 million over the three years from 2013-14 to 2015-16 (inclusive)[47]. The MSP comprises three elements:

- The Directors' PhD Scholarships – the scholarships are offered to encourage postgraduate research by students of exceptional research promise in particular fields which MRIWA Directors believe to be critical to the future development of the

[47] In 2013-14, the total value of MRIWA scholarships awarded was $16,000 (MRIWA Annual Report 2013-14, pg. 15).

minerals industry in WA. Support is to be made available for three areas of high priority to the MRIWA Board, including mineral data analytics, in situ learning, and scale up of research outcomes to production. MRIWA has awarded full PhD scholarships in 2015 for the first time.

- The MRIWA Postgraduate PhD Scholarship – these scholarships will often (but not necessarily) be awarded within major MRIWA projects, commencing from 2015.
- The MRIWA Odwyn Jones Awards – The Odwyn Jones Awards program seeks to honour Emeritus Professor Ifan Odwyn Jones, AO and his contribution to the development of fundamental understanding and innovative technologies enabling the long term future of the minerals industries in WA. The awards are offered as stipends to high achieving students applying to fourth year Honours by research or a final year engineering project.

It is planned that over the first three years of MRIWA's operation (from 2014), the new tertiary scholarships program will offer two Directors' PhD scholarships (with a total value of $240,000); eight Postgraduate PhD scholarships (with a total value of $560,000); and the Odwyn Jones Awards (up to 15 scholarships annually of $2,000 each). The funding profile of the MSP is illustrated in Table 9 below.

Table 9: MRIWA Scholarship Program – total offering and value from 2014 to 2016

Scholarship type	Number offered	Total value
Directors' PhD Scholarship	2	$240,000
PhD Scholarship	8	$560,000
Odwyn Jones Awards	15	$90,000
Total	25	$890,000

Source: MRIWA Annual Report 2013-14

Under the old scholarship program (between 1994 and 2013), [48] scholarships were offered to 68 students at a total value of $877,892 over the 19 year period. Evidently, MRIWA is placing a growing focus on supporting high performing students and fostering research outcomes for the minerals industry, demonstrated in its increasing provision for scholarship funding (with a planned investment of $890,000 over the three years from 2014 to 2016, inclusive).

MRIWA's new MSP will continue to play an important role in encouraging and supporting high performing PhD and Honours students, allowing them to embark upon careers in the minerals industry.

[48] Data on scholarship offerings and value was obtained from MERIWA Annual Reports and scholarship registrations. Detailed records of the MERIWA scholarship program offerings were not available prior to 1994.

4.2 Case study 2 - Exporting WA research outcomes

Although the aim of the economic impact component of this study is to quantify the economic value of research outcomes to Western Australia specifically, two research projects sponsored by MRIWA was found to have resulted in significant benefits to both the Western Australian and global economies. Both entailed benefits that could not be readily quantified, but nonetheless demonstrated the transfer of engineering and scientific expertise and capability developed in WA (via MRIWA funding support) to the world. These were:

- Solvent Extraction Technology (M418); and
- Hydrothermal Footprints of Magmatic Nickel Sulphite Deposits (M413)

These case study projects are discussed in more detail below. The evidence and issues discussed below were extracted via direct stakeholder consultations with researchers and sponsor companies involved.

4.2.1 Improving Solvent Extraction Technology (M418)

For many Australian and global mining entities, efficient solvent extraction performance is crucial to the cost effective separation of metals. This is applicable to a broad range of mineral processing operations, including cobalt, copper, nickel, platinum group elements, rare earth elements, uranium, and zinc).

As a result, new techniques and combinations of reagents are continuously being developed and tested for new (or improved) applications.

The MRIWA sponsored project, "Improving Solvent Extraction Technology 2, [49]" aimed to build on the physical and two-phase computational fluid dynamics models developed in the preceding AMIRA P706, and MERIWA M401 solvent extraction technology projects.

The project's primary goal was to achieve improved performance of solvent extraction operations – chiefly through the reduction of entrainment. In addition to expanding the fundamental knowledge and capabilities developed in the earlier projects, particular emphasis was placed on delivering the specific research outcomes for each operating sponsor.

Several of the researchers involved in this project (from the University of Western Australia, and CSIRO's Perth operations) actively engaged with industry sponsors, even after the completion of the project. In one particular instance, researchers from CSIRO interacted with one of the project's global sponsors in the USA to assist the sponsor company, a major gold miner, to implement the knowledge and capabilities developed in this project.

A relationship between one of the key researchers from CSIRO and the sponsor company was initially developed through regular interactions at conferences and throughout preceding projects. Subsequent meetings organised by the researchers with the sponsor company focussed upon outlining the potential commercial benefits of the research to the firm. This facilitated regular interaction between the company and the research team

[49] Barnard, K.; Robinson, D.; Lane G; Zhang W.; Yang W.; and Wu, J., 2013, "Improving Solvent Technology"

featuring a close working relationship to set up the parameters of the project and develop options for several aspects of the research.

Based on the techniques developed in M418, the sponsor company implemented a new design to existing mixer settlers. This new approach eliminated previous challenges relating to the operation of the settlers, and effectively allowed smoother production and lower associated costs.

The sponsor company has confirmed that knowledge derived directly from this research will also be applied to future projects undertaken by the firm. The sponsor company also indicated that the commercial outcomes of M418 were well received within the organisation. Visibility and appreciation of the research being conducted in WA was generated among the company's executive leadership team.

4.2.2 Hydrothermal Footprints of Magmatic Nickel Sulfide Deposits (M413)

The purpose of this project was to enlarge the detectable footprint of magmatic nickel-sulfide deposits, with an emphasis on Archaean Western Australian komatiite-hosted systems.[50] Due to the limited extent of their magmatic footprint, these deposits often prove to be challenging exploration targets. Therefore, new (or improved) techniques, which create a significantly larger geochemical 'halo' for potential deposits improve the exploration process.

Consultations undertaken with one of the project's industry sponsors revealed that this research (through the use of hydrothermal fluids to remobilise and re-precipitate base metals and platinum group elements from magmatic sulfide deposits into country rocks) was successful in providing the knowledge and capabilities to enlarge the detectable footprint of magmatic nickel-sulfide deposits. The outcomes in this case were applied to global mining operations with significant positive feedback.

The global reach was achieved when three of the WA-based researchers involved in M413 initiated a training program with the head office of one sponsor company; a major global miner of multiple base metals. The program was conducted on-site at its offices in Europe [51] and involved a one-day lecture on basic geological principles associated with particular (Ni-Cu-PGE) deposits; a half-day lecture on the premise of M413 and its findings; as well as ongoing informal discussions with company geologists during data collection and sampling, which were conducted throughout the researchers' (two-week) tenure in Europe.

Material that was covered in the sessions was left for the sponsor company to draw upon as required, and became a 'textbook' guide to the knowledge and capabilities developed in the research project.

The training provided an opportunity for the company geologists to get more involved in the research and teaching program by providing access to the expertise of the WA-based researchers. Additionally, the research utilised novel instruments not available in Europe at the time which enabled knowledge transfer to occur from WA-developed research findings and to the firm's European operations.

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[50] Vaillant, M.; Fiorentini, M.; Barnes, S.; and Miller, J., 2014, "Hydrothermal Footprints of Magmatic Nickel Sulfide Deposits"

[51] The research was conducted by a research professor and PhD student from the University of Western Australia. At the time of the lectures, 12 geologists were working on-site, and all attended the sessions.

The concept of enlarging the geochemical halos, or footprints, of magmatic nickel-sulfide deposits established in the research is being implemented by the company sponsor in their active Ni-Cu exploration programs globally.

The case studies developed in M413 continue to act as a template and guide the company's scale of exploration conducted in a specific area. This template is facilitating the evaluation of potential investment or acquisition of existing Ni-Cu exploration and mining projects by the sponsor with much more confidence and at lower cost.

Appendix A: Direct impact assumptions

The quantification of results for this study relied on information provided by project sponsors (industry participants), researchers as well as publically available information (where information gaps existed). The assumptions underlying each project are discussed in detail below.

Universal assumptions

Key underlying parameters and assumptions common to all projects include:

- An assessment period of 15 years from 2005 to 2020 (although research funding costs were captured for projects that delivered benefits post 2005 that had related funding incurred before 2005)
- A discount rate of 7% is applied to calculate the Net Present Value (NPV) of both costs and benefits of the research projects. Under the time-value principle, projects with research costs applicable prior to year 0 (i.e. 2015) were discounted forward to year 0 by the appropriate discount factor respective of the year in which the cost was realised (i.e. the funding cost involved in developing the research through related past projects were also recognised in the study)
- Likewise, expected benefits (2015 to 2020) were discounted back to 2015. However, unlike costs, any benefits earned prior to 2005 were not recognised
- All benefits and costs are reported in 2015 dollar terms
- A further 20% discount is applied to all benefits projected between 2015 and 2020 to account for the uncertainty of future cash flows
- Industry contributions are assumed to be limited to allocations for research funding only. Any additional costs borne by industry for implementation of the research is not accounted for.

Project 1 - Advancing the strategic use of seismic data in mines (M406)

Methodology

A series of consultations were conducted with three WA-based project sponsors involved in the research. Each of the industry participants provided estimates of the three key commercial benefits that were gained from the application of the research (the percentage of the site required to be closed following blasting; the number of times per annum that blasting occurs at the various sites[52], and the average time savings resulting from the application of the mXrap software).

[52] One sponsor was unable to provide an accurate indication of the number of times blasting occurred on average per annum. Therefore, a conservative approach was applied to estimate this, whereby the lowest number of annual occurrences across all industry participants who did provide an indication of blast frequency was adopted.

Two sponsors provided feedback on the percentage of the site affected by blasting on a site-by-site basis.[53] While the other sponsor was unable to provide site-by-site estimates, it provided an estimate for one of its key sites, which was then applied as across all of its producing sites in WA.

The commercial benefit to industry from the reduced time to return to site following blasting was measured purely as a labour productivity cost saving. Other cost savings are also applicable (e.g. fuel and vehicle operating costs) but were not measured due to limitations in data. This makes the estimate of commercial benefit derived a conservative one.

Average labour costs were estimated using ABS average weekly earnings[54] and subsequently converted to an hourly wage rate, assuming a 12-hour work day. Employment statistics (employment numbers for 2013 and 2014) were obtained from the Department of Mines and Petroleum for each site included in the study.

These three factors (blast frequency; average annual time savings; average earnings; and employment numbers) facilitated the calculation of average annual site-based labour cost savings attributable to mXrap software.

Future benefits were projected through to 2020 by inflating the calculated baseline benefits for the two years to 2014 (plus inflation) to 2020. However, at the CBA stage of analysis, these values were brought back to 2015 dollars.

Extrapolation

A further four WA-based sponsors were involved in this project but were unable to directly engage to discuss impacts. To estimate the benefit to these sponsors under the extrapolation scenarios (scenarios 1 and 2), employment numbers for each sponsor were established using data on Western Australian mining site employment available from the Department of Mines and Petroleum.

The time saving for these sites was estimated as the average of those of the three respective sponsors used in the baseline calculation (i.e. with which consultations were held). The lowest blast frequency identified for the baseline sites was adopted as the frequency measure for extrapolated sites. The same hourly average weekly earnings data from ABS was used to calculate the annual average extrapolated benefit for the four sponsors. The same escalation method as above was also used to extrapolate future benefits through to 2020.

Project 2 and 3 - Improving thickener technology (M279) and; Gold processing technology (M238)

Methodology

The estimated commercial impacts of both of these projects were derived from existing reports published by the AJ Parker Cooperative Research Centre for Hydrometallurgy (Parker Centre), who also engaged the STEM Partnership (STEM) to undertake the analysis. These reports outlined the following key elements:

- NPVs for both projects

[53] One sponsor identified two sites to be included in the study; the other sponsor identified one site.
[54] Obtained from the Australian Bureau of Statistics 2014, Average Weekly Earnings, 6302.0 (Mining industry average ordinary weekly earnings; full-time adult in 2013 and 2014).

- A discount rate of 12% to derive NPVs
- Measurement of 10 years of benefits (assumed to commence in 2005, when the report was published. This also represented a fair passage of time from the commencement of the research to commercialisation of the findings)
- For projects that were yet to be fully implemented, the costs and risks associated with their further development and final implementation had been assessed in the report and adjusted by a risk factor. These were reported as "expected values."

The total NPV of benefits provided in the reports were back-solved to estimate yearly nominal values from 2005 to 2014. The benefits calculated in the report were assumed to be adjusted for inflation (of 2.5% per annum) and therefore adjustment was incorporated in deriving the annual nominal benefit.

The benefits outlined in the report were on a national basis. To estimate the proportion of benefits attributable to WA, the share of WA's production nationally of the six commodities[55] for which Project 2 research was applied to, and the share of gold production from WA for Project 3, were used as adjustment factors [56]. This had the effect of attributing only 45% of the benefits derived to WA for Project 2 and 70% of the benefits for Project 3. Additionally, it was assumed that all outcomes of this research were applicable to Australian operations only and not extended to global operations.

Extrapolation

Further extrapolation to other industry sponsors was not calculated for these projects due to a lack of data on the amounts of industry contribution. Therefore, for the two projects, MRIWA's share of the total project funding (as outlined in the Parker Centre report) was used to determine the value of benefits attributable to MRIWA. This amounted to a share of 0.4% of estimated WA benefits for Project 2 and 33% of estimated WA benefits for Project 3.

Future benefits were projected through to 2020 by inflating the calculated baseline benefits for the two years to 2014 (plus inflation) to 2020. However, at the CBA stage of analysis, these values were brought back to 2015 dollars.

Project 4 – Mine waste rock dump design (M415)

Methodology

Savings in haulage costs formed the primary benefit identified for this body of research. The yearly return trip haulage (in metres) was obtained from a confidential research report undertaken for the project.

The report identifies three mathematical programming models using Mixed Integer Programming (MIP). These included a Location Optimisation model, a Truck Balance model and a Combination model. These models worked in combination to generate an optimum waste rock placement and dump schedule for mine sites.

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[55] The six commodities that the Parker Centre research supports are alumina, gold, copper, nickel, lead and zinc.
[56] WA's proportion of production of the above commodities (as a percentage of national production over the last two financial years) was obtained from the Department of Minerals and Petroleum, and the Bureau of Resources and Energy Economics. The overall proportion of benefits attributable to WA was taken to be an average of these proportions.

The Location Optimisation model aims to minimise the overall haulage distance and volume of re-handling; therefore reducing operating costs over the life of the mine. The Truck Balance model minimises opportunity cost by reducing the over or under-budgeting of track capacity. The Combination (Combo) model, combines the objectives of the other two models and aims to generate a balanced rock placement schedule, which considers both the haulage distance and the deviation in truck budgeting.

To calculate the baseline benefits for this study, haulage estimates of the "Combo" model were utilised. The report utilised identifies this as the recommended option for attaining an optimal solution to operations (generating an optimal waste rock placement and dump schedule). Therefore the Combo model was selected as the 'base case' against which the commercial benefits of this research were estimated.

Savings in haulage costs were calculated as the average ratio of the Net Present Cost (NPC) savings between the "Combo 1" and "Combo 2" models and the Manual Method [57]. A cost factor of one cent per billion cubic metres (BCM) per flat metre hauled was used as the cost savings benchmark (this benchmark saving rate was provided in the report).

The report included yearly return trip haulage forecasts through to 2022. However, benefits for this study were only calculated until 2020 to ensure consistency with the other projects assessed in the study.

Extrapolation

The commercial outcomes of this research were extrapolated to only one other industry sponsor beyond those in the confidential report. In quantifying the benefits to this individual sponsor, it was assumed that haulage cost savings estimated from the report was incurred in a proportional fashion to the 2014 volume of production from the additional firm.

Project 5 – Greenfields Geochemical Exploration (M411)

Methodology

Two project sponsors were engaged by DAE for they study. Both provided estimates of exploration cost savings directly resulting from this research project. The feedback unanimously pointed to the commercial application of the technology yielding an approximate 10% reduction in discovery costs.

Evidence of this research first yielding commercial benefits emerged in relation to a deposit discovered in March 2010.

Therefore 2010 was employed as the base year from which the research was taken to have had tangible implications on the broader sponsor group. To calculate the savings to industry sponsors from the 10% reduction in discovery costs, SNL Financial [58] was used to extract gold exploration expenditures for each of the sponsors involved in the project for the period from 2010 to 2014.

One sponsor directly engaged as part of the study could only be certain that the research had been applied to one of its two sites in WA. For this firm, the baseline benefit was only

[57] The Combo 1 model presents a solution for a lift-by-lift dump construction sequence; the Combo 2 model presents for a multi-lift dump construction sequence. In addition to the cross model comparison, the classical Manual Method was employed to schedule the waste rock to the appropriate rock dumps, so that the overall haulage cost was estimated and compared with that of the MIP models.

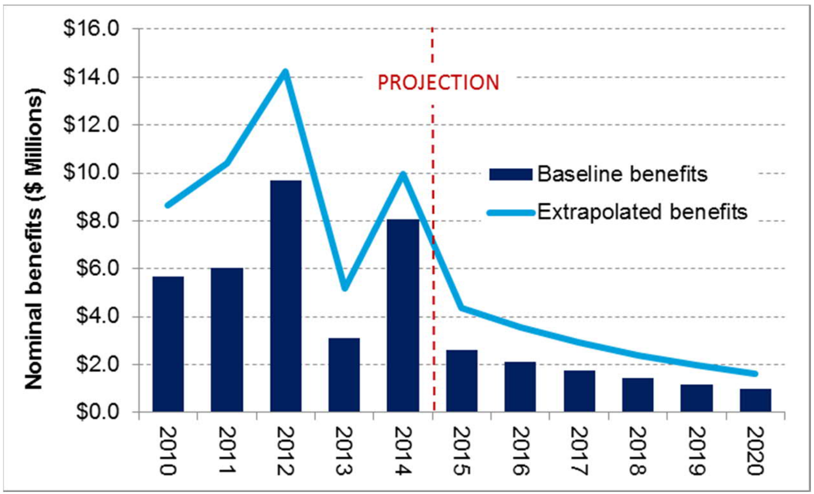
[58] A database that includes financial data and analysis on a range of business sectors

calculated for this one site, while the other site was included as part of the extrapolation scenarios. For this case, it was assumed that the sponsor's WA exploration budget was split evenly (50-50) between the two sites[59].

Because company exploration budgets are highly volatile from year to year, the forward projections of exploration spend beyond 2014 for the sponsor group was highly conservative to avoid overestimating expected benefits from future application of the research by sponsors.

Therefore, the lowest aggregate annual exploration spend of the sponsor group in the four years to 2014 was chosen as the basis upon which to project forward exploration expenditure for 2015. Future benefits beyond 2015 were then projected through to 2020 by inflating the 2015 estimate forward by 2.5% per annum. Figure A-1 illustrates the conservatism adopted for the future nominal benefits related to this project.

Figure A-1: Profile of nominal benefits, 0% inducement, Project 5



Source: Deloitte Access Economics analysis; Industry sponsor input

Extrapolation

Benefits were extrapolated to five other sponsors utilising the same methodology as above to generate a profile of nominal benefits through to 2020. This profile is also illustrated in Figure A-1.

The benefits related to this project account for just under half of the combined estimated value of benefits from all five projects examined in this study. Therefore, the economic impacts modelled are sensitive to the benefits generated from this body of research specifically. While this is a risk in terms of the robustness of the study outcomes, feedback from industry sponsors involved in this project suggested that this research had achieved seminal status among industry. The anecdotal feedback suggested that the approach and techniques developed are now industry standard practice.

[59] Although SNL had information as to the approximate proportion of each company's exploration spend in WA relative to the rest of Australia, it split between sites in WA was less clear

Appendix B: CGE modelling concepts and assumptions

Approach and concept

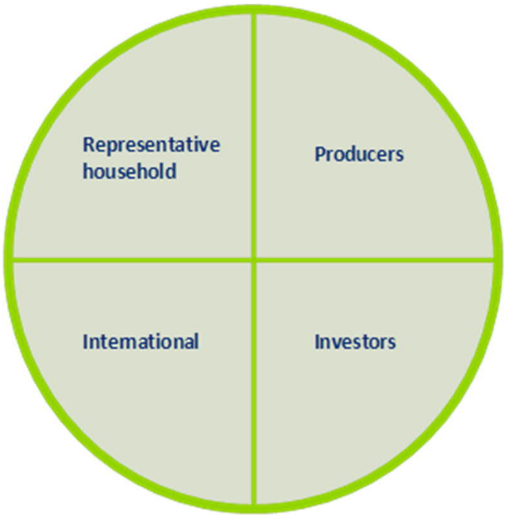
As noted in chapter 2.5.2, the Deloitte Access Economics – Regional General Equilibrium Model (DAE-RGEM) is used to determine the economic impact to WA from the five research programs funded by MRIWA.

DAE-RGEM is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy. The model has been customised to include the Western Australia and the Rest of Australia

The model allows policy analysis in a single, robust, integrated economic framework. This model projects changes in macroeconomic aggregates such as GDP, employment, export volumes, investment and private consumption. At the sectoral level, detailed results such as output, exports, imports and employment are also produced.

Figure A shows the key components of the model for an individual region. The components include a representative household, producers, investors and international (or linkages with the other regions in the model, including other Australian States and foreign regions). Below is a description of each component of the model and key linkages between components. Additional technical detail is also provided.

Figure A - Key components of DAE-RGEM



Source: Deloitte Access Economics

The DAE-RGEM is based on a substantial body of accepted microeconomic theory. Key assumptions underpinning the model are:

- The model contains a ‘regional consumer’ that receives all income from factor payments (labour, capital, land and natural resources), taxes and net foreign income from borrowing (lending).

- Income is allocated across household consumption, government consumption and savings so as to maximise a Cobb-Douglas (C-D) utility function.

- Household consumption for composite goods is determined by minimising expenditure via a CDE (Constant Differences of Elasticities) expenditure function. For most regions, households can source consumption goods only from domestic and imported sources. In the Australian regions, households can also source goods from interstate. In all cases, the choice of commodities by source is determined by a CRESH (Constant Ratios of Elasticities Substitution, Homothetic) utility function.

- Government consumption for composite goods, and goods from different sources (domestic, imported and interstate), is determined by maximising utility via a C-D utility function.

- All savings generated in each region are used to purchase bonds whose price movements reflect movements in the price of creating capital.

- Producers supply goods by combining aggregate intermediate inputs and primary factors in fixed proportions (the Leontief assumption). Composite intermediate inputs are also combined in fixed proportions, whereas individual primary factors are combined using a constant elasticity of substitution (CES) production function.

- Producers are cost minimisers, and in doing so, choose between domestic, imported and interstate intermediate inputs via a CRESH production function.

- The model contains a more detailed treatment of the electricity sector that is based on the ‘technology bundle’ approach for general equilibrium modelling developed by ABARE (1996).

- The supply of labour is positively influenced by movements in the real wage rate governed by an elasticity of supply.

- Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. A global investor ranks countries as investment destinations based on two factors: global investment and rates of return in a given region compared with global rates of return. Once the aggregate investment has been determined for Australia, aggregate investment in each Australian sub-region is determined by an Australian investor based on: Australian investment and rates of return in a given sub-region compared with the national rate of return.

- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.

- Prices are determined via market-clearing conditions that require sectoral output (supply) to equal the amount sold (demand) to final users (households and government), intermediate users (firms and investors), foreigners (international exports), and other Australian regions (interstate exports).

- For internationally-traded goods (imports and exports), the Armington assumption is applied whereby the same goods produced in different countries are treated as imperfect substitutes. But, in relative terms, imported goods from different regions are treated as closer substitutes than domestically-produced goods and imported composites. Goods traded interstate within the Australian regions are assumed to be closer substitutes again.

- The model accounts for greenhouse gas emissions from fossil fuel combustion. Taxes can be applied to emissions, which are converted to good-specific sales taxes that impact on demand. Emission quotas can be set by region and these can be traded, at a value equal to the carbon tax avoided, where a region's emissions fall below or exceed their quota.

The representative household

Each region in the model has a so-called representative household that receives and spends all income. The representative household allocates income across three different expenditure areas: private household consumption; government consumption; and savings.

Going clockwise around in Figure A, the representative household interacts with producers in two ways. First, in allocating expenditure across household and government consumption, this sustains demand for production. Second, the representative household owns and receives all income from factor payments (labour, capital, land and natural resources) as well as net taxes. Factors of production are used by producers as inputs into production along with intermediate inputs. The level of production, as well as supply of factors, determines the amount of income generated in each region.

The representative household's relationship with investors is through the supply of investable funds – savings. The relationship between the representative household and the international sector is twofold. First, importers compete with domestic producers in consumption markets. Second, other regions in the model can lend (borrow) money from each other. Key issues to note include:

- The representative household allocates income across three different expenditure areas – private household consumption; government consumption; and savings – to maximise a Cobb-Douglas utility function.

- Private household consumption on composite goods is determined by minimising a CDE expenditure function. Private household consumption on composite goods from different sources is determined by a CRESH (utility function.

- Government consumption on composite goods, and composite goods from different sources, is determined by maximising a Cobb-Douglas utility function.

- All savings generated in each region are used to purchase bonds whose price movements reflect movements in the price of generating capital.

Producers

Apart from selling goods and services to households and government, producers sell products to each other (intermediate usage) and to investors. Intermediate usage is where one producer supplies inputs to another's production. For example, coal producers supply inputs to the electricity sector.

Capital is an input into production. Investors react to the conditions facing producers in a region to determine the amount of investment. Generally, increases in production are accompanied by increased investment. In addition, the production of machinery, construction of buildings and the like that forms the basis of a region's capital stock, is undertaken by producers. In other words, investment demand adds to household and government expenditure from the representative household, to determine the demand for goods and services in a region.

Producers interact with international markets in two main ways. First, they compete with producers in overseas regions for export markets, as well as in their own region. Second, they use inputs from overseas in their production. Key issues to note include:

- Sectoral output equals the amount demanded by consumers (households and government) and intermediate users (firms and investors) as well as exports.
- Intermediate inputs are assumed to be combined in fixed proportions at the composite level. As mentioned above, the exception to this is the electricity sector that is able to substitute different technologies (brown coal, black coal, oil, gas, hydropower and other renewables) using the 'technology bundle' approach developed by ABARE (1996).
- To minimise costs, producers substitute between domestic and imported intermediate inputs is governed by the Armington assumption as well as between primary factors of production (through a CES aggregator). Substitution between skilled and unskilled labour is also allowed (again via a CES function).
- The supply of labour is positively influenced by movements in the wage rate governed by an elasticity of supply (is assumed to be 0.2). This implies that changes influencing the demand for labour, positively or negatively, will impact both the level of employment and the wage rate. This is a typical labour market specification for a dynamic model such as DAE-RGEM. There are other labour market 'settings' that can be used. First, the labour market could take on long-run characteristics with aggregate employment being fixed and any changes to labour demand changes being absorbed through movements in the wage rate. Second, the labour market could take on short-run characteristics with fixed wages and flexible employment levels.

Investors

Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. The global investor ranks countries as investment destination based on two factors: current economic growth and rates of return in a given region compared with global rates of return. Key issues to note include:

- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.

International

Each of the components outlined above operate, simultaneously, in each region of the model. That is, for any simulation the model forecasts changes to trade and investment flows within, and between, regions subject to optimising behaviour by producers, consumers and investors. Of course, this implies some global conditions must be met such as global exports and global imports are the same and that global debt repayments equal global debt receipts each year.

Appendix C: Limitations of our work

General use restriction

This report is prepared solely for the:

- internal use of the Minerals Research Institute of Western Australia; and
- use by Minerals Research Institute of Western Australia in public forums, subject to Minerals Research Institute of Western Australia providing relevant context when using only extracts from the report.

This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. Except as otherwise expressly permitted herein, you should not refer to or use our name or the advice for any other purpose.

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Limiting assumptions

Some of the core assumptions which underpin the analysis have been developed by Deloitte Access Economics Pty Ltd with significant input from stakeholders related to the work carried out by the Minerals Research Institute of Western Australia, as well as publically available data and information. Deloitte Access Economics Pty Ltd has not independently tested or verified any of the inputs and advice received from these sources regarding the assumptions. Therefore, Deloitte Access Economics Pty Ltd takes no responsibility for the accuracy of the assumptions adopted in the analysis or the outcomes.

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