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Extractive industries lifecycle and benefit distribution

A report prepared for the Department of Industry, Innovation and Science on behalf of the COAG Land Access for Resources Working Group

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Contents

Figures

Tables

Executive summary

This report identifies socio-economic benefits and impacts of mining at a State and Territory level across the lifecycle of the industry. The report considers cross-sectoral effects and draws attention to ways the mining sector is changing relative to other sectors such as agriculture and manufacturing. Throughout these changes there are a series of challenges to contend with and opportunities to seize.

The report has been prepared for the Department of Industry, Innovation and Science on behalf of the COAG Land Access for Resources Working Group and forms part of a wider set of projects conducted by CSIRO on the social and economic dimensions of the resources sector.

Signs of recovery in the mining sector exist for terms of trade and for mining employment since 2016. Employment is stronger in non-metropolitan regions.

The report is presented in two parts, with the first part investigating changes in the mining sector's development based on key indicators including exports, employment and income inequality.

At the national scale the mining industry continues to make a significant contribution to the economy, 7.4% to GDP in 2016-17. This figure nudges above the manufacturing sector and is more than twice that of agriculture in the same year. Mining continues to be Australia's most valuable sector for goods exports and recent price increases for iron ore and coal have added additional value to the sector. The outlook for Australian resources reflects expectations for increasing global demand at least until 2019.

Nationally, employment in mining has grown to reach a similar level to agriculture at around 2-3% of the Australian workforce. At the local scale, the resources sector is an important employer in regional areas. Around 60% of the mining workforce is located outside of capital cities where mining is the largest employer in 23 Local Government Areas (LGAs).

Mining employment trends vary considerably across states and territories. Mining employees mostly live in regional areas for New South Wales, Queensland and Tasmania. However, in Victoria, South Australia and Western Australia most mining workers are located in capital cities including head-office staff and fly-in fly-out workforces. The location and distribution of the extractive industry workforce can lead to different outcomes for indirect employment outside of the cities, where resident labour force can contribute substantially to local jobs in other sectors.

Income distribution is an important issue and the report presents key findings from statistical analysis of the 2016 Australian Census data and how income distribution has changed over the preceding decade. On average, change in income distribution was similar for mining regions and non-mining regions outside of capital cities. However, it is also important to consider differences for individual towns and regions. For example, income inequality increased in some mining regions such as Kalgoorlie and the Pilbara while conversely incomes became more even in others such as Central West WA.

The second part of the report highlights ways in which the mining sector has contributed to innovation in the economy and how, in turn, innovation has affected the sector. Nationally, the mining sector has been a substantial contributor to research and development, particularly during the mining construction boom. Australian mining businesses are sources of innovation, but this innovation tends to be concentrated in a relatively small number of companies. At state level, the mining sector continues to be the largest contributor to research and development in Queensland and Western Australia.

In 2014–15 the mining sector had the highest proportion of businesses which introduced globally new or significantly improved goods or services.

An outcome of innovation in the mining industry is the technological change which has the potential to transform the sector. In particular, automation can reduce demand for some types of employment such as machinery operators, while increasing demand for other types of employment such as remote operators and maintenance staff. Technological innovation contributes to reduced operational costs in the sector and employment of a highly educated workforce. These changes in costs and workforce together have the potential to lift Australia's competitiveness in the global mining industry. Moreover, innovation in exploration, extraction, enterprise systems and safety processes can also provide opportunities for new markets in the form of knowledge exports.

Overall, the report notes signs of recovery and innovation in an industry responding to cyclical effects and a changing global context. The key message with regard to processes of innovation in mining is that Australian companies are well positioned to bring globally new or improved goods and services to the market. The sector is active in improving its productivity and maintaining its competitive edge. In doing so, the mining sector has been, and continues to be, a source of considerable research and development in Australia.

Table 1. Mining industry characteristics across the Australian states and territories.

Characteristic	WA	QLD	NSW	VIC	SA	NT	TAS	ACT
Direct employment numbers, rounded to the nearest thousand (2018) (1)	95,000	65,000	40,000	11,000	8,000	5,000	4,000	115*
Percentage of mining employees living in regional areas (2016) (2)	36%	75%	85%	51%	48%	40%	87%	n.a.
Mining businesses R&D expenditure proportion of state R&D expenditure (FY 2015-16) (3)	49%	26%	2%	1%	16%	17%	8%	0%
Income distribution in mining regions compared to state average (2016) (4)	more even	more even	similar	n.a.	more even	less even	less even	n.a.

(1) * ACT data is from the Australian Census of 2016. Other data source: Australian Bureau of Statistics (2018b) (2) Regional areas are areas outside of the Greater Capital City Statistical Area. Due to the boundary structure, the Australian Capital Territory regional employment cannot be estimated. Data source: Australian Bureau of Statistics (2017c). (3) Data source: Australian Bureau of Statistics (2017e); (4) Compared to average state income distribution coefficient calculated at Local Government Area level. Mining regions are Local Government Areas where the industry is a top five employer. 'More even' means the income is more equally distributed than the state average. 'Similar' was attributed for an absolute difference smaller than + / - 0.01. Not available (n.a.) means the state does not have LGAs where Mining is a top 5 employer based on 2016 Australian Census data. Data source: Australian Bureau of Statistics (2017c); author's calculations.

The **Western Australian** (WA) mining industry has the highest number of employees compared to other states, accounting for more than 7% of total state employment. Employment numbers reduced slightly from a peak in 2013 and have remained steady from 2014 to 2017. While total employment numbers are not fluctuating much, the industry has an increasingly urbanising workforce: from 64% in 2016 to about 75% in 2018. While WA always had a higher proportion of FIFO/DIDO workers, growth of remotely managed operations through the use of driverless trucks, drills and other technology underlie these rapid changes (e.g. Rio Tinto's Perth Operations Centre). The importance of this sector to the State is reflected in the research and development (R&D) expenditure numbers which account for almost half of the State's business R&D expenditure. WA mining businesses spend the most in the nation and their expenditure is more than double the amount in QLD in the same year of 2015-16. While more of the mining workforce is located in the capital city area (64% in 2016), the income in WA's regions where mining is a top five employer is distributed more evenly than in the rest of the State. The Pilbara and Kalgoorlie-Boulder regions have each boasted a lower level of income inequality than the non-mining regions both in 2006 and 2016.

Queensland (QLD). In terms of cyclical affects, Queensland had a similar trajectory to Western Australia reaching an employment peak in 2013. It then suffered a drop from a topmost level of 3.5% mining employment out of State totals to a low of 2.2% in 2016. Continued increase in employment from 2016 has added more than 6,000 jobs, with the ratio of the industry from State total employment rebounding close to 2.6%. However, in terms of the location of mining employees QLD is quite different to WA. More of QLD's workforce lives in rural and regional areas, with three quarters of workers in the mining sector being based outside the capital city of Brisbane. This distribution of the labour force represents the potential for more rural and regional spillover effects in the form of jobs and income to other sectors (e.g. services, manufacturing) to occur when mining industry employment grows. Mining businesses in QLD are the top R&D spender in the State, with the amount totalling a quarter of the funds invested in 2015-16. Also, in QLD like in WA, income is more evenly distributed across all income brackets in mining regions, including the Surat, Bowen and Galilee Basin areas, than on average for non-mining local government areas.

New South Wales (NSW). In terms of total numbers, NSW has less than half of the mining workers than WA. In terms of cyclical affects, NSW experienced a sharp drop in employment from 2013 to 2014 and then experienced a gradual recovery. At the beginning of 2018, more than 5,000 jobs have were added to the sector from 2014 average levels. Another important aspect of the NSW mining industry is that it has a high proportion of mining employees who live outside of the capital, Sydney (85%). A large proportion of these workers live and work around the Hunter Valley region where income inequality appears low. Income distribution is considerably more even in the Hunter mining region than in other areas, such as the Sydney city region which displays a higher than average income disparity. A diverse economy in the State means that out of the total $6.4 million R&D expenditure in 2015-16, only about 2% originates from businesses in the mining sector.

Victoria (VIC) is home to around 11,000 mining workers, a quarter of the total in NSW. In this State as in others, employment ebbed from 2013 to 2015 from a level of more than 14,000 to less than 9,000. Employment in the mining industry is traditionally low in the State and the 2016 Australian Census data confirmed this. Victoria did not have a Local Government Area where mining is a top five employer. In this context, it is not surprising that mining R&D expenditure is 1% of the total. Yet, at a difference to WA, QLD and NSW, the mining workforce urban-rural split is not as polarised.

In 2016, the number of people working in the Melbourne metropolitan area was similar to the number working outside of it. This distribution may be changing as employment figures at the beginning of 2018 show an increase to 64% of the mining workers being based in regional areas.

South Australia's (SA) employment numbers oscillated more than other states over the 2013 – 2018 period. From more than 15,000 on average through 2014 to less than half of that figure in 2016 and to closer to 8,000 in the beginning of 2018. These cyclical fluctuations show how for a smaller industry, any changes can have a higher relative employment impact. Not just employment numbers, but the distribution of the mining sector labour force can fluctuate from quarter to quarter, although the annual average tends to hang around 40% regional workers. Mining R&D expenditure levels are on par with the professional and scientific services and for the most recent year they were half those of manufacturing. Nonetheless, the dollar amount for 2015-16 R&D is close in value to that of NSW and double the value of VIC.

For the **Northern Territory** (NT) the mining industry continues to play a significant role in the State through its workforce and R&D expenditure. The cyclical variation of employment has been less pronounced in the Northern Territory compared to other states. In fact, marginal increases were observed since 2013, with a slight drop in 2016, but with no major drop in the workforce. Although the size of the workforce is similar to that in TAS, in percentage terms this represents around 4% of the State population, double the ratio in TAS. In absolute figures, the mining R&D expenditure in the state in 2015-16 may be small compared to other states, but is still the second highest in NT at 17%. Previously, mining business R&D expenditure (until 2013-14) represented 75% of the total.

Tasmania (TAS) has seen a doubling of the workforce in the State since 2015: from 2,000 to more than 4,000 workers. In terms of cyclical changes in the industry, states like QLD also had a strong recovery in their employment numbers, but only TAS figures reached previous peak employment levels (attained in 2012-2013). Most of this increase is located in regional areas, which are home to about 85% of mining employees. This growth in the sector has the potential to bring flow on effects in the future, such as for the industry's share of R&D investment to increase.

Part I Mining sector activity

1 The mining investment boom and changes in the mining sector

Recent signs of recovery emphasise the cyclical nature of the resources sector. Mining investment has experienced a growth over the last decade against a background of rising commodity prices. This growth originated in favourable terms of trade starting from around the year 2000 and peaked in 2011 (Figure 1)[1], resulting in an increase in capacity levels, relatively low unemployment with steady opportunities for the construction sector, and other positive spillovers in the economy. As operational phases take over from construction and investment phases, there are a series of challenges to contend with and opportunities to seize. One of the fundamental questions pertains to understanding how such phase transitions in mining industry cycles play out within the broader Australian economy and lead to changes at the local scale.

At the national scale, the value of mining exports increased in 2016–17. A price appreciation in coal and iron ore has led to sustained improvement in the terms of trade for the economy after March 2016. This halted the downward trend from peak values in September 2011 (Figure 1). The higher the index, the more revenue is received for exports relative to the cost of imports, thus adding more revenue to the economy. This resulted in an increase in mining investment which in turn led to growth in resources exports.

In 2017, mining exports continued to represent the most valuable sector for goods exports, with values above 50% since 2005 (Figure 2). The demand for Australian mineral exports is forecast to continue to be strong overall in the years leading to 2021–22 with a net compound annual growth rate of 8.5% across 12 resources (Office of the Chief Economist, 2017a).[2] Still, the value of these exports is forecast to drop over the next five years (Reserve Bank of Australia, 2017). The unexpected increase in the price for iron ore and coal (metallurgical and thermal) led to an upward revision in expected export earnings for 2017–18. While the Reserve Bank of Australia does not expect this to be a continuing trend, structural changes in the world economy, particularly with regard to China, make forecasts quite uncertain (Heath, 2015; Reserve Bank of Australia, 2017).[3] Overall, global demand for Australian resources is forecast to increase over at least until 2019 propped up by an increasing global demand for gas (Office of the Chief Economist, 2017b).

[1] The terms of trade index (or index of commodity prices) is defined by the Reserve Bank and measured by the Australian Bureau of Statistics as the ratio of export prices to import prices (Australian Bureau of Statistics, 2018a). It measures the prices received for exported materials compared with the prices for imported materials.

[2] Alumina, aluminium, copper, gold, iron ore, nickel, zinc, LNG, metallurgical coal, thermal coal, oil, uranium.

[3] China is the world's largest producer of steel, accounting for 50% of global production. Demand for these two Australian major resources, coal and iron ore, and energy exports could also decrease due to a slowdown in Chinese economic activity and investment in its own infrastructure.

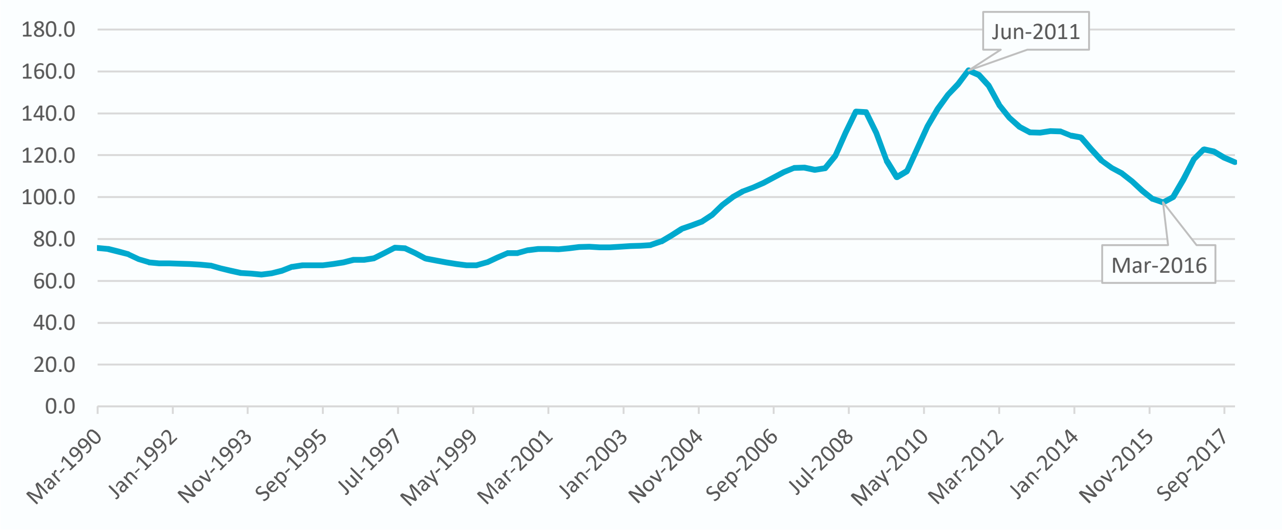

Figure 1. Terms of trade, goods, quarterly trend

Data source: Australian Bureau of Statistics (2018a)

Figure 2. Extractive industries share of the value of total goods exported

Note: extractive industries exports includes metal ores and minerals; coal, coke and briquettes; other mineral fuels and metals (excl. non-monetary gold). Data source: Australian Bureau of Statistics (2018a)

The changes in prices on the international market have also affected the industry's contribution to Australia's Gross Domestic Product (GDP). Yet, despite the mining cycle investment boom slowing down, the industry still makes a significant contribution to the nation's GDP. The gross value added from mining to GDP in 2016-17 was 7.4%, nudging ahead the manufacturing sector and was more than twice that of agriculture in the same year (Figure 3). The bulk of the gross value added as share of GDP in the economy comes from services, which amounts to about 61%.[4]

The gross value added from mining to GDP in 2016–17 was 7.4%, nudging ahead the manufacturing sector.

[4] The services industries correspond to the ANZSIC divisions D, F–S.

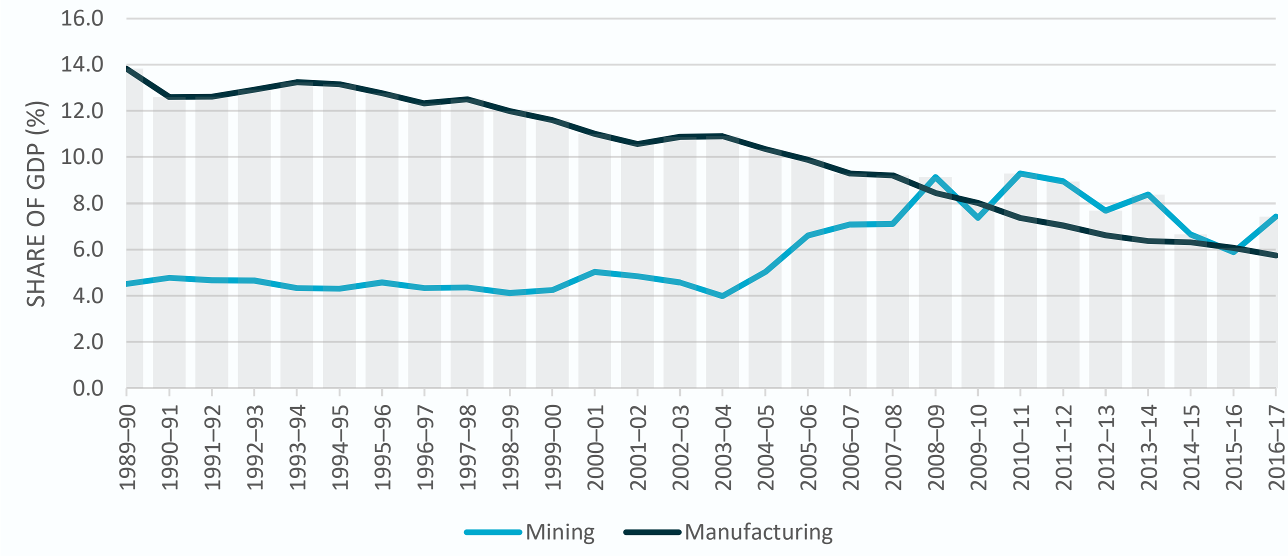

Figure 3. Industry gross value added as share of national Australian GDP, added annually, current prices

Data source: Office of the Chief Economist (2018)

An indicator of potential future investment and growth in the Australian resources extraction sector is the level of exploration investment.[5] Mining investment reached a peak in 2012–13. The slump in international petroleum prices has translated into less petroleum exploration investment in recent years. In addition, energy exploration expenditure has decreased due to a fall in coal exploration expenditure: in 2017 this expenditure was on average six times lower than 2011 and has almost halved from 2015 levels. The drop is reflected in the decrease of energy exploration expenditure to a level close to half of peak expenditure around 2012-13 (Figure 4).[6]

On the other hand, metals and other minerals expenditure on exploration makes up more than 50% of this expenditure for 2017. The minerals exploration investment picked up since 2015, with gold expenditure increasing by more than 50%. In the December quarter of 2017, 75% of gold and 96% of iron ore exploration expenditure was spent in Western Australia (Australian Bureau of Statistics, 2018c). In fact, Western Australia may benefit the most from an increase in gold prices over the next five years as its gold exploration expenditure cycle is at a peak, close to 2011 average levels and double the levels in 2014. Notably, despite an appreciation in value for iron ore in 2017, the iron exploration expenditure has decreased to 30% of the value in 2011. Notwithstanding the steady decline in iron ore exploration expenditure and price decrease projections, Australia is still the world's number 1 exporter of the commodity, with China being the world's biggest importer.

[5] This refers to expenditure by private organisations in exploration for minerals and petroleum (excludes water). Exploration refers to activities to search for 'concentrations of naturally occurring solid, liquid or gaseous materials and includes new field wildcat and stratigraphical and extension/appraisal wells and mineral appraisals intended to delineate or greatly extend the limits of known deposits by geological, geophysical, geochemical, drilling or other methods' Australian Bureau of Statistics (2017b).

[6] Decreasing activity in petroleum exploration is seen in onshore exploration investment. Actual expenditure has been quite consistently only half of expected expenditure since the middle of 2012. On the other hand, offshore expenditure frequently exceeded 200% of expected costs.

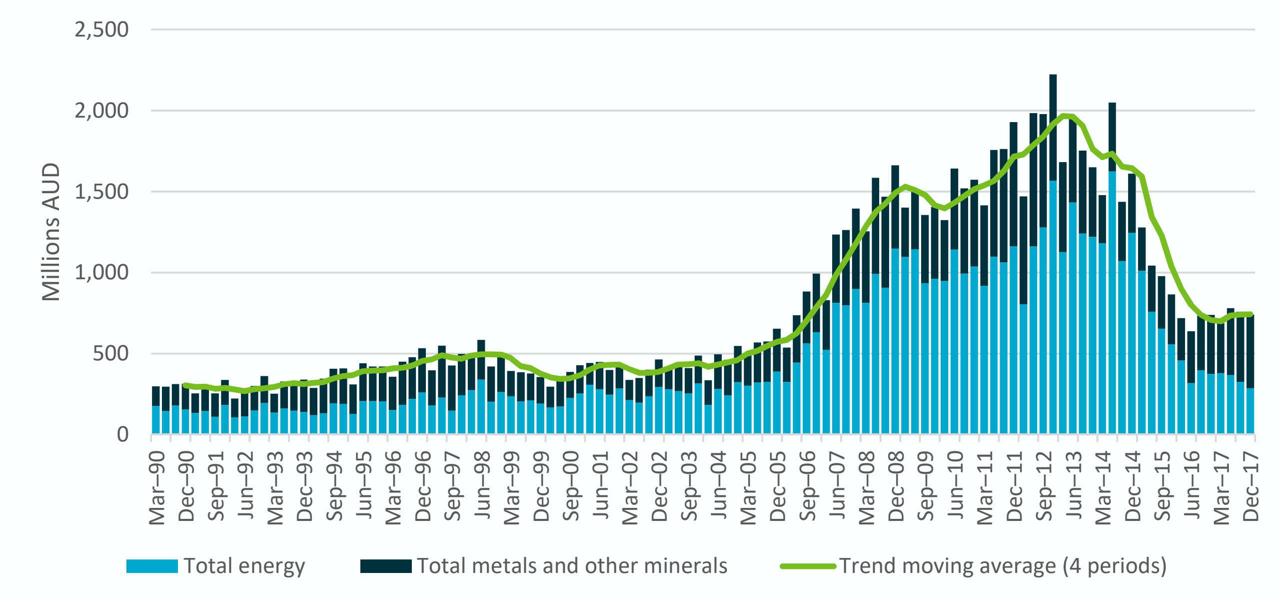

Figure 4. Quarterly private resources and energy exploration expenditure

Notes: (a) figures include offshore and onshore exploration; (b) expenditure figures are seasonally adjusted. Data source: Australian Bureau of Statistics (2017b); Office of the Chief Economist (2018)

2 Employment and income benefits distribution

2.1 Mining employment

Employment numbers show over two hundred thousand people are working in the mining industry (Figure 5). Mining employment trends vary considerably across states and territories. One common element is the presence of a dip in employment for each state between 2013 and 2015, followed by a slight recovery in the subsequent period. Recent increases in employment across most states and territories suggest broad underlying strength in the sector. In absolute numbers, Western Australia, Queensland and New South Wales have the largest workforces in this sector. As a proportion of the total State workforce, the top three states are Western Australia (7.1%), the Northern Territory (3.9%) and Queensland (2.6%) (Australian Bureau of Statistics, 2018b).

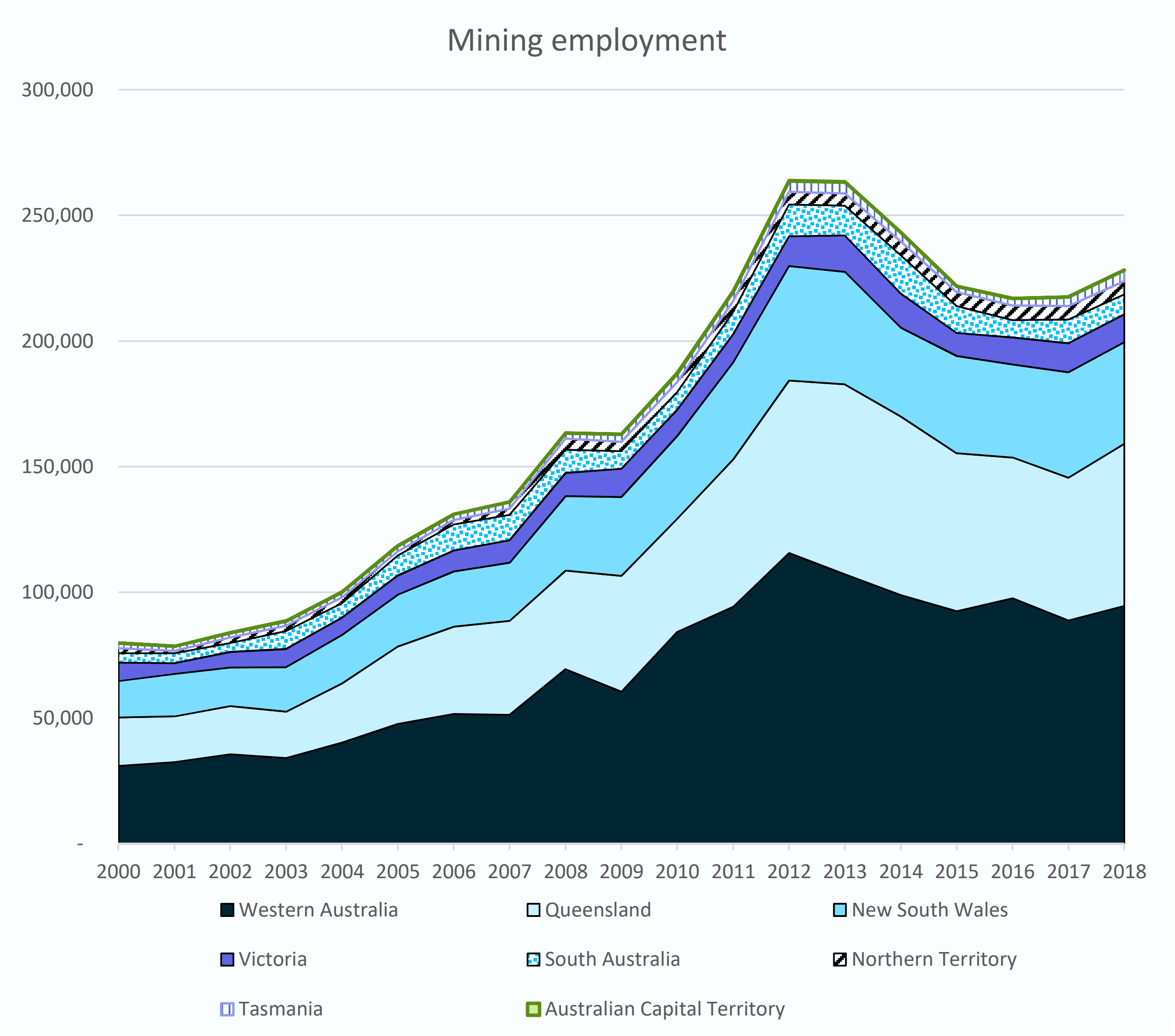

Figure 5. National employment in mining: cumulative figures by state over time.

The State by State proportion of the national mining workforce is represented by the size of the shaded area for each jurisdiction. The overlaying of the employment for each state shows cumulative national figures. Data source: Australian Bureau of Statistics (2018b)

The mining industry is an important source of income for the communities outside the major cities where operational activities occur. Almost 60% of the workforce employed in this sector is located in regional Australia (Figure 6) (Australian Bureau of Statistics, 2017a).[7] Mining has a lower ratio of people employed in rural or regional areas than agriculture (83%), but higher than manufacturing and professional services, which are predominantly urban (71% and 80% respectively). Since 2006, the percentage of people employed in regional areas in mining has remained fairly constant. The peak regional Australian employment totals in the sector was reached 2013-14, and was close to 150 thousand people.

Almost 60% of the workforce employed in mining is located in regional Australia.

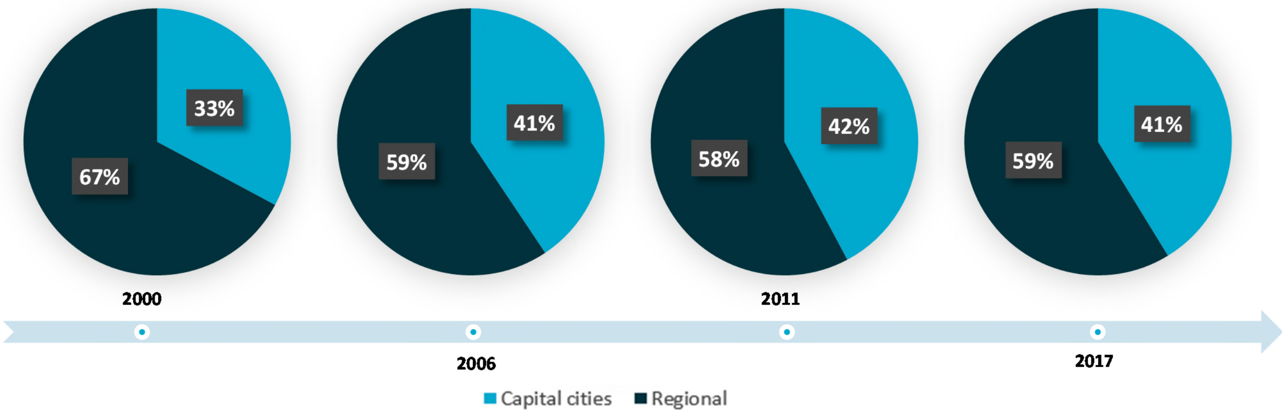

Figure 6. Mining employment: Australian regional areas vs capital cities ratios. Moving average trend, calculated based on four quarters' average

Note: Regional figures include whole of Northern Territory, exclude Australian Capital Territory. Capital cities figures exclude Australian Capital Territory. Data source: Australian Bureau of Statistics (2017a)

Employment in mining remains predominantly regionally-based in New South Wales, Queensland and Tasmania, but in other states mining jobs tend to be located in the capital city labour market region (Table 1).[8] While Western Australia and Queensland can sometimes be referred to generically as 'the mining states', the two have different distributions of their mining employment between capital city and regional areas. In WA, more of the mining workforce is located in the capital city area: 64% in 2016 and this figure increased to 76% at the beginning of 2018 (Australian Bureau of Statistics, 2017c; 2018b). It remains to be seen from future data whether this change is an indication of a transition to a more urban workforce due to a shift in how mines operate. By comparison, in QLD, NSW and TAS, the ratio of workers located in a major urban centre versus workers located elsewhere has remained fairly constant. About three quarters of the employees in the mining industry in QLD are based in rural and regional areas (75-78%). For NSW and TAS about 85% of the labour force continues to be in regional areas. An increase in mining activity in QLD and TAS is

[7] This estimate includes the whole of the Northern Territory and excludes the Australian Capital Territory. In general, regional areas for each state exclude the state's Greater Capital City Statistical Area (GCCSA). While the Northern Territory has a capital city area, the Greater Darwin GCCSA, the quarterly labour employment data reported by the ABS only includes state totals. GCCSAs are geographical areas designed by the Australian Bureau of Statistics (ABS) to represent the functional extent of the state and territories' capital cities, namely the labour market of each capital city (Australian Bureau of Statistics, 2016a).

[8] Regional areas refer to state areas excluding greater capital city statistical areas – GCCSAs. Regional figures exclude the Australian Capital Territory and, due to data reporting limitations, include the whole of the Northern Territory (Australian Bureau of Statistics, 2017d). For the same reason the Northern Territory regional versus capital area employment trend diagram is not available.

suggested by recent upward trends in employment numbers since 2016. Other states have seen increases in overall employment since 2015-16, with numbers appearing to level off or slightly dip at the beginning of 2018. These differences in the state distribution of the workforce show further employment growth in the mining sector and indirect benefits associated with this growth could be shifting towards urban areas in WA, but remain fairly regional based for QLD, NSW and TAS.

The percentage of employment in mining and in agriculture have reached comparable levels.

Nationally the mining investment boom brought a larger percentage of the total workforce to work in the mining industry from 2006 onwards. During the same period, a decline in the percentage of people employed in the agricultural sector occurred. In fact, whereas agriculture used to employ five times more people than mining out of the total workforce, over a period of a quarter of a century, the percentages of people employed in these two sectors reached similar levels, around 2-3% each of Australian employment totals (Figure 7). For regional Australia however, agriculture still employs twice as many people as mining in 2017 (Australian Bureau of Statistics, 2018b). Notwithstanding this, Australia's largest share of employment in regional areas is in the services industries with figures steadily increasing beyond 50% since 2009.

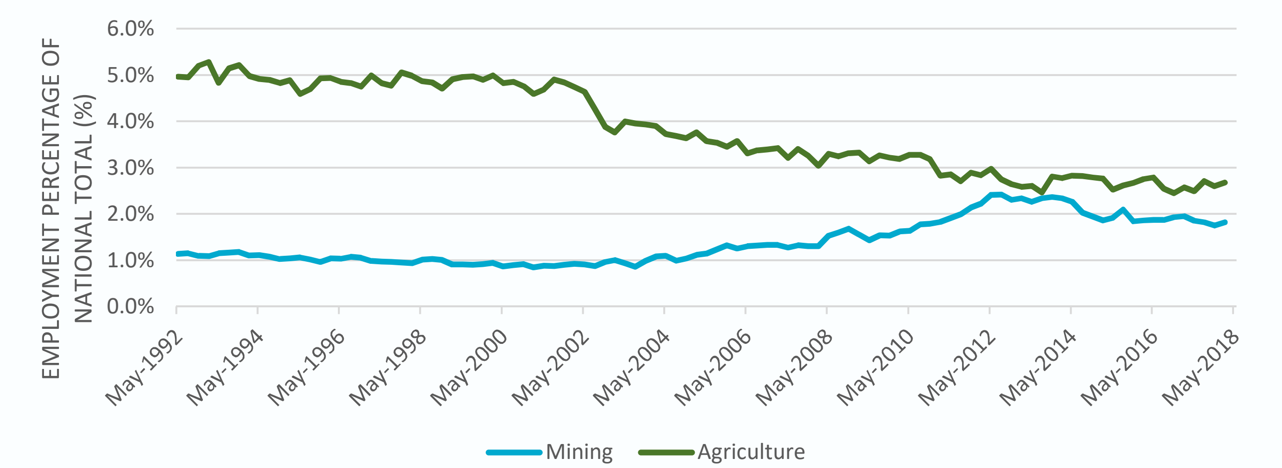

Figure 7. Mining employment: Percentage of national employment in mining vs agriculture industry

Data source: Australian Bureau of Statistics (2018b)

There are 73 local government areas (LGAs) across Australia where the mining industry is a top five employer, according to 2016 Australian Census data (Figure 8). Mostly these areas spatially coincide with traditional mining regions in non-metropolitan areas, but exceptions also occur. Notably, in Western Australia there are five LGAs which have some significant overlap with Perth's metropolitan area.[9] In 23 of the 73 LGAs mining is the largest employment sector.

[9] These LGAs are: Perth, Claremont, Cottesloe, Mandurah and Murray. The overlap refers to these LGAs' centroid area being located within the boundary of a greater capital city statistical area (GCCSA). Note that Perth LGA and Perth GCCSA cover different areas, with the latter referring to the broader labour market of Perth capital city.

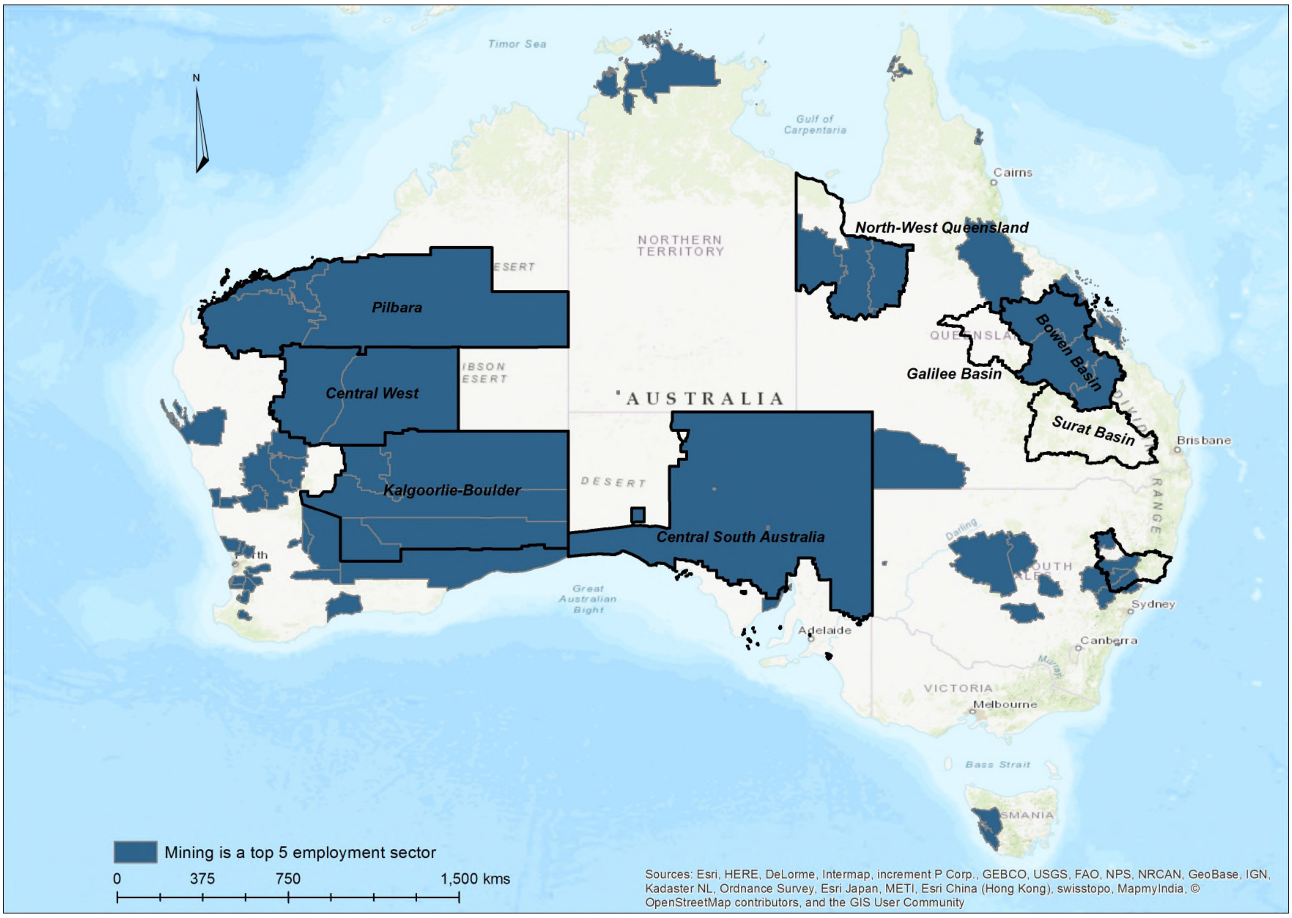

Figure 8. LGAs where employment in 2016 in the mining sector was among the top five employment sectors

Note: Employment percentages in mining calculated at local government area (LGA) level. Data source: Australian Bureau of Statistics (2016c)

In terms of trends, there is some variation in employment patterns. For example, parts of Western Australia grew (e.g. Goldfields) and parts of Queensland experienced reduced mining employment (e.g. Mt Isa) for 2011–2016 suggesting they were more affected by the downturn in mining commodity prices, the decline in ore quality, and other factors (Productivity Commission, 2017).[10] The reduction in employment could partly be related to technological change occurring in mining processes. Due to reliance on low skilled employment, very remote communities can be among those most affected by the changes towards more efficient, automated technologies and integrated processes. Employment in areas with low economic diversity, where the mining industry plays a key role, can have increased exposure to automation in the industry and to any potential downturn in the sector (Robertson et al., 2017).

Unconventional fossil fuels such as shale gas, shale oil and coal seam gas (CSG, also known as coal-bed methane) provide an example of the changes in the lifecycle of mining operations which can underlie employment figures. Instead of a single location of extraction, the cycle of exploration for coal seam gas relies on multiple (thousands of) extraction points over a wider area (Measham et al., 2016). Research in the United States suggests that the construction phase of CSG may be shorter and less distinguishable from the operational phase and the processes more reactive to market conditions, starting/stopping and moving to other locations more frequently (Fernando and Cooley,

[10] The comparison is made between Mount Isa local government area (LGA) and the Kalgoorlie/Boulder LGA.

2016; Jacquet and Kay, 2014). This means fluctuations in mining employment occur more frequently and local businesses need to be prepared for the possibility of a rapid change and adjust their supply chains and cost structures in accordance with changing industry conditions.

2.2 Distribution of income change

Research in Australia has confirmed that mining localities can experience higher incomes and reduced income inequality between residents of the same region while the mining sector is active in the region (Fleming and Measham 2015). Growth in the mining sector since the turn of the century is known to have had positive income effects, with estimates of a 13% increase in real per capita household income from about 2000 to 2013 (Downes et al., 2014). Mining areas can have larger populations and lower unemployment. However, they tend to rely on jobs in a narrow spectrum of industries which makes them more exposed to a downturn or any changes reducing their need for local employees (Kotey and Rolfe, 2014). For example, the income effect benefits experienced from specialising in energy resource extraction from the short run may reduce in the long run (Betz et al., 2014; Haggerty et al., 2014). This section of the report considers the degree to which economic benefits in the form of reduced income inequality have been sustained in mining regions over the decade leading up to the 2016 Australian Census.

Defining the exact time period when a cycle begins and ends can be complicated. The resources investment phase varies for different forms of exploration and from project to project. At a macroeconomic level fluctuations in prices of commodities on the international market are associated with the ebb and flow of mining investment in the Australian market (section 1). Subsequent to the peak of the terms of trade in 2011 (Figure 1), it is likely that for many mining regions across Australia there was less investment and development of new projects as operational phases took over. The investment phase is considered to have lasted until about the end of 2013 (Productivity Commission, 2017). As such this study uses the Census years of 2006, 2011 and 2016 to delimit time periods in the analysis.

In order to understand the change in the distribution of family income over the period 2006 to 2016 in mining versus non-mining regions, the Gini coefficient of inequality is calculated for the entire country at Local Government Area (LGA) and Statistical Area 2 (SA2) levels.[11] The Gini coefficient is one measure of financial wellbeing where the emphasis is on inequalities in income distribution.[12] The values of the coefficient vary between zero and one, where a value closer to zero means income is more equally distributed for any particular region. The lower the value of the Gini coefficient, the better the social outcome is considered to be.

Figure 9 reflects the percentage change in Gini coefficient between 2006 and 2016 in local government area based on 2016 Census data (Australian Bureau of Statistics, 2016c). The areas

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[11] SA2s are Australian Census geographical units defined in the Australian Statistical Geography Standard (ASGS). They are one of the most disaggregated levels of reporting data publicly other than the Census. These areas are defined based on a combined set of population and functional criteria, with a mean population of about 10,000 people. In the boundary design of SA2s, the Australian Bureau of Statistics took into consideration the boundaries of other types of geographical areas with local significance, such as suburbs and local government areas, but SA2s may not always align with these areas (Australian Bureau of Statistics, 2016a).

[12] The Gini coefficient is defined as the size of the area between the 45 degree line of equality and the Lorenz curve. The Lorenz curve is drawn to represent the relationship between the percentage of the income earned by a cumulative percentage of the population e.g. (De Maio, 2007).

outlined using grey lines contain a series of well-established mining regions: North-west Queensland (QLD), Galilee Basin (QLD), Bowen Basin (QLD), Surat Basin (QLD), Hunter Valley (NSW), Central South Australia (SA), Kalgoorlie-Boulder (WA), Central West (WA) and Pilbara (WA). Further technical details of the data and method for calculating the Gini coefficients are contained in Appendix A.

For interpretation, it is important to note that there are no clear thresholds for what represents very high or low inequality change and that colours used in the following figures to interpret change in the coefficient are for illustrative purposes only. A decrease in the coefficient is considered to be a positive outcome, while an increase in the coefficient reflects an increase in inequality. Both Figure 9 and Table 2 appear to show a small or moderate increase in the coefficient of inequality in both mining and non-mining areas. Based on the table, Kalgoorlie-Boulder in Western Australia, North-West Queensland and the Pilbara appear to show the highest mean percentage increases, between 14 and 21%. Central West and the Bowen Basin, on the other hand, see a small reduction in inequality, 2.7% and 1.8% respectively. It is worth noting that the mean values calculated for 2006 and 2016 are all under 0.5, the midway point of the coefficient, and hence none of the family income distribution factors indicate extreme levels of inequality.

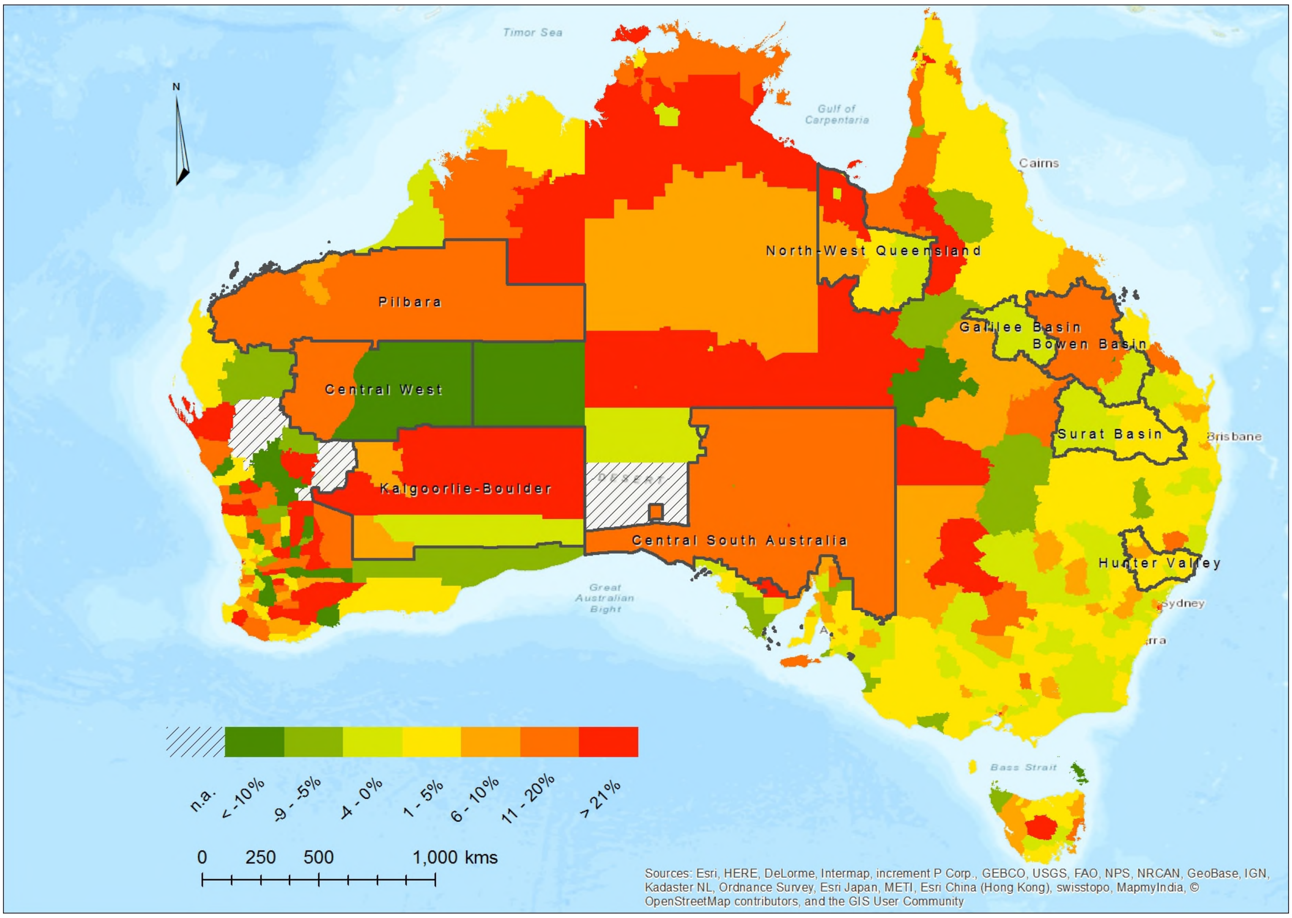


Figure 9. Percentage change in the inequality Gini coefficient in mining regions, 2006–2016

Data source: analysis based on Census family income data Australian Bureau of Statistics (2016c), LGA level regions.

In order to understand whether changes observed in the Gini coefficients in the Local Government Area mining regions are statistically significant or could show natural variations in the data, several 't-tests' were applied. The first test was for 2006 to 2011. The test found the mean percentage change in the Gini coefficient in mining regions was not statistically different from non-mining regions. The test for the 10 year period (2006–2016) found similar results. On the other hand, the test for 2011 to 2016, showed that the mean percentage increase (of income inequality) in mining LGA regions was statistically significantly different from non-mining regions. To reconcile these statistical differences, analysis drilled down to a finer scale of data collection (ABS SA2), which showed that the mean percentage change was not statistically significant for any of these periods at that scale (see Appendix A).[13] Overall the different results of the t-tests for data at different scales indicate the increase in income inequality between 2006 and 2016 was not significant.

Changes in family income distribution for mining regions for 2006–16 are not statistically different from non-mining regions.

Table 2. Gini coefficient of inequality and its change during the 2006–2016 period for LGAs

	Gini 2006	Gini 2016	% Change 2006–2016
Mining LGAs [n=34]	0.314	0.340	8.2
Non-mining LGAs [n=507]	0.327	0.342	4.5
Non-mining regional [n=286]	0.326	0.344	5.2
Mining regions			
Pilbara, WA [n=4]	0.289	0.329	13.9
Central West, WA [n=2]	0.349	0.339	–2.7
Kalgoorlie-Boulder, WA [n=5]	0.264	0.319	20.9
Central, SA [n=3]	0.290	0.325	12.1
Hunter Valley, NSW [n=7]	0.338	0.347	2.6
Surat Basin, QLD [n=3]	0.332	0.337	1.3
Bowen Basin, QLD [n=4]	0.333	0.336	0.8
Galilee Basin, QLD [n=1]	0.333	0.327	–1.8
North-West, QLD [n=5]	0.322	0.377	17.1

Data source: authors' calculations based on 2016 Australian Census data

[13] The Modifiable Area Unit Problem is a common problem in geographical analysis, where research has endeavoured to find solutions for a long time. While certain methods can alleviate parts of the problem, like the zoning issue, they might not deal with the scale problem. One of the simplest and most practical minimum solutions recommended, in a digital technology and GIS-enabled world, is to repeat the analysis at different scales and verify whether the results hold (Fotheringham and Rogerson, 2009).

Table 3. Gini coefficient values' change t-test analysis, LGA level analysis

	Test 1: 2006–11	Test 2: 2011–16	Test 3: 2006–16
Gini mean change (%), non-mining regions (standard error)	4.99 (1.75)	3.22 (3.33)	5.98 (0.79)
No. of observations for non-mining regions	510	508	507
Gini mean change (%), mining regions (standard error)	1.69 (3.33)	10.97 (4.79)	10.72 (3.84)
No. of observations for mining regions	34	34	34
t-test statistic	0.48	–3.09	–1.47
Prob (|T| > |t|)	0.6302	0.0021***	0.1415
Degrees of freedom	542	540	541

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Part II Mining innovation

3 Innovation in mining and regional areas

3.1 R&D expenditure in Australian mining

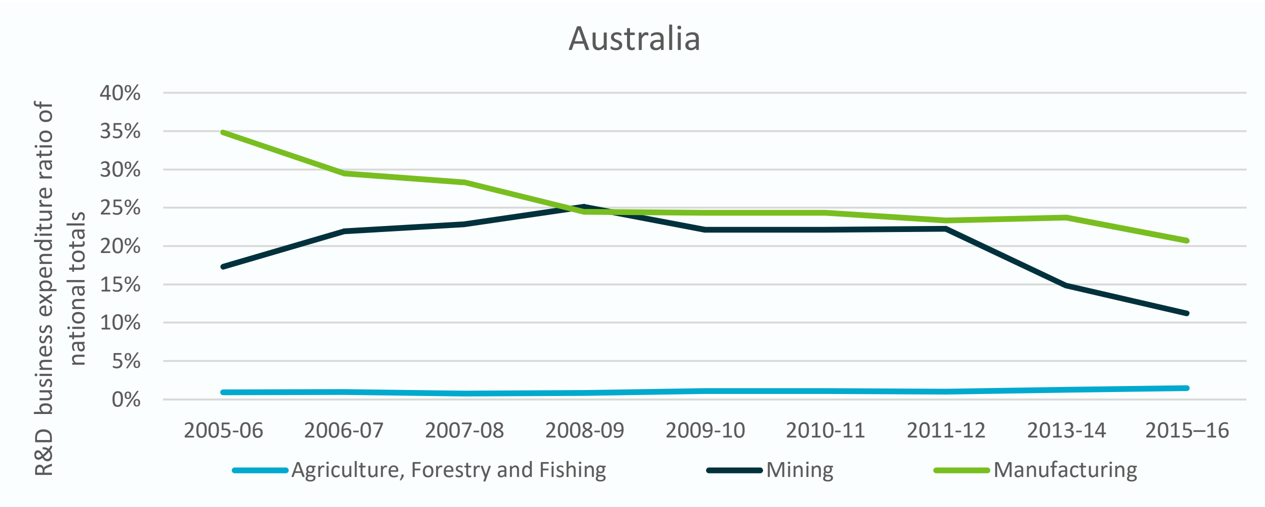


Figure 10. Research and development business expenditure ratio of national totals

Notes: (a) excludes overseas investment; (b) survey data does not exist for 2012–13. Data source: Australian Bureau of Statistics (2017e)

The mining boom resulted in a higher share of mining business expenditure on research and development out of the national total. Mining companies ranked second in research and development (R&D) expenditure only to manufacturing enterprises throughout 2005–2012 (Figure 10). However, the 2015–16 survey of business R&D expenditure reveals that mining investment has fallen to fourth place. Nationally, the top three industries in terms of research and development business expenditure are: professional, scientific and technical services; manufacturing; and financial and insurance services. Agriculture, forestry and fishing R&D expenditure is considerably smaller, being the tenth largest expenditure.

Mining companies ranked second in R&D expenditure only to manufacturing enterprises throughout 2005–2012.

The shape of the national R&D expenditure graph for mining is mirrored in Western Australia, the Northern Territory and to some degree in Queensland, where mining innovation represents the highest share of state-wide R&D expenditure (Figures 11, 12). Mining is also the dominant private sector contributor to Northern Territory innovation, where most research and development funds throughout 2005 to 2015 were spent by the industry. However in absolute terms, the total amount spent on innovation in the Northern Territory represents 1% of national R&D expenditure. New South Wales and Victoria's investment appears to reflect the underlying national economic structure: a growing services sector is seeing a decrease in the percentage of R&D expenditure from mining and manufacturing. The national top three industries for R&D investment are also the largest three industries in these two states.

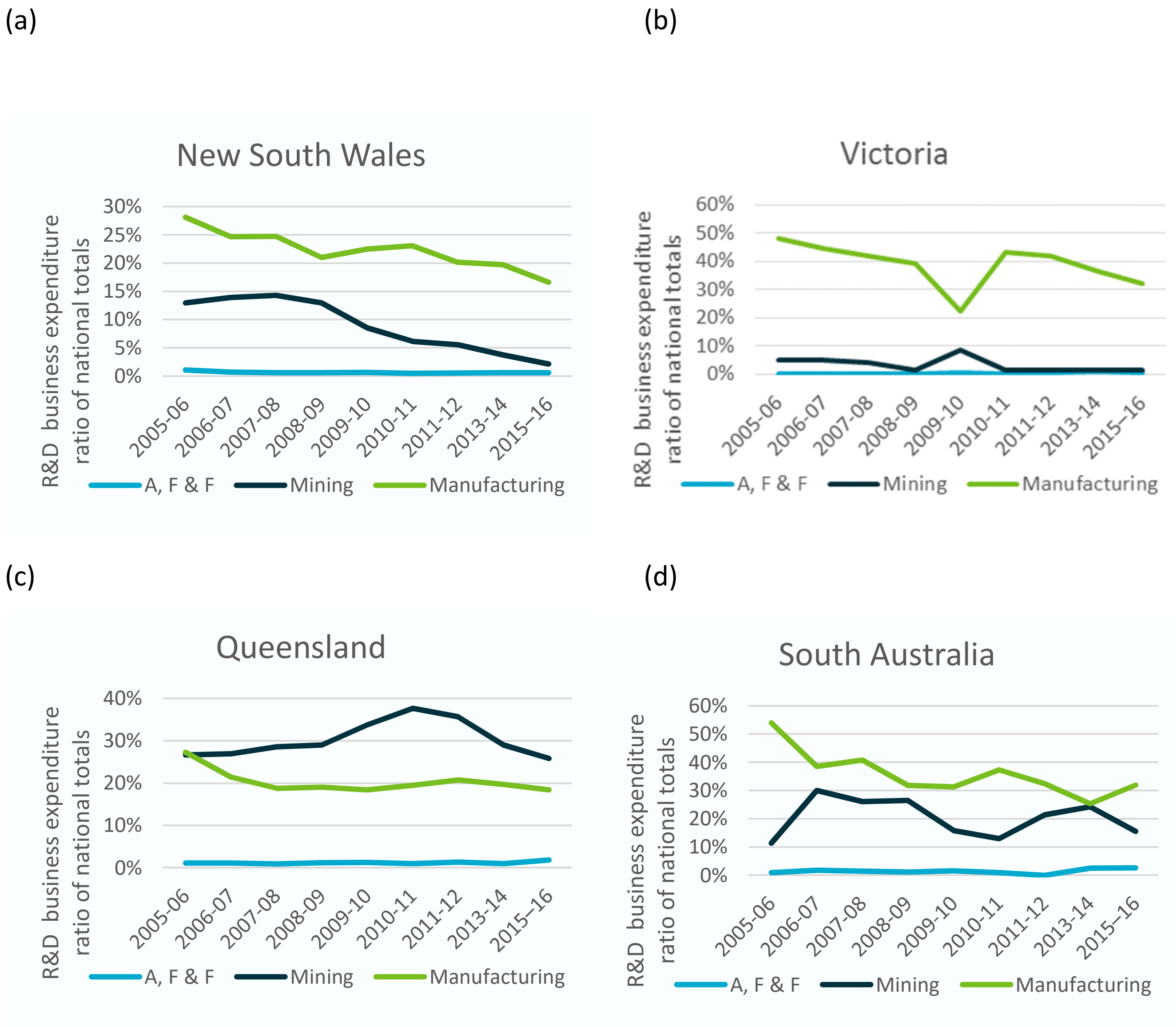


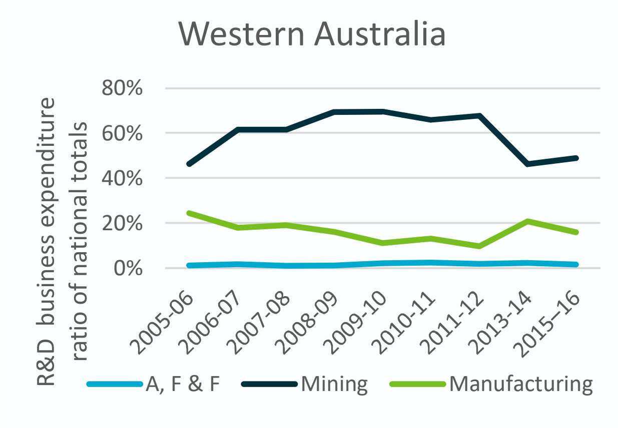
Figure 11. Research & development business expenditure ratios of state totals (part 1)

Notes: (a) A,F & F stands for Agriculture, Forestry and Fisheries; (b) survey data does not exist for 2012–13. Data source: Australian Bureau of Statistics (2017e)

Mining in South Australia was typically the second or third largest contributor to private enterprises innovation investment over the period 2005 to 2016. South Australian R&D investment is a constant of three industries being at the top throughout the period: manufacturing continuously dominates mining and professional services. In Tasmania, mining is either the third or fourth highest industry to invest in innovation. While manufacturing traditionally is the top innovation investor in Tasmania, the latest survey showed manufacturing almost converging with agriculture, forestry and fisheries.[14]

[14] The manufacturing sector has still not reached the agriculture, forestry and fisheries sector. Tasmanian data seems to indicate that abrupt changes occurred. Based on survey methodology explanatory notes of the ABS, there is no particular reason to believe the methodology has suffered major changes and that these outcomes could be the result of such changes.

(e)



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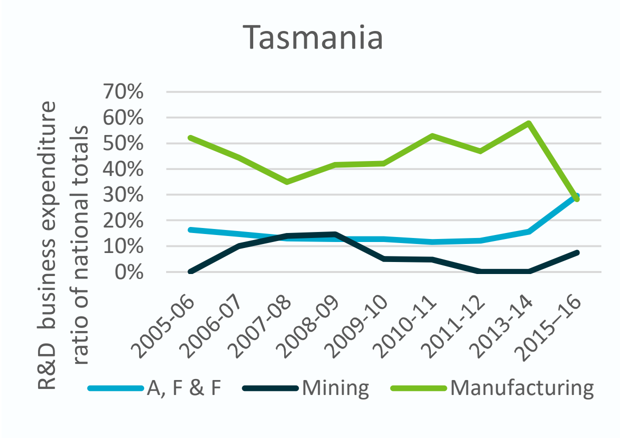

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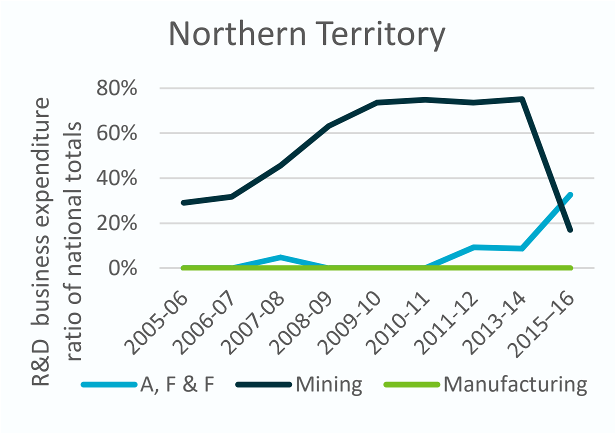


Figure 12. Research & development business expenditure ratios of state totals (part 2)

Notes: (a) A,F & F stands for Agriculture, Forestry and Fisheries; (b) survey data does not exist for 2012–13. Data source: Australian Bureau of Statistics (2017e)

3.2 Enablers and barriers to innovation in Australian mining

Innovation is crucial to maintain Australia's mining industry competitiveness globally. It can occur with regard to product, production processes, marketing or organisational methods (OECD, 2005). More than a third of mining businesses are innovating, according to the Business Characteristics Survey for 2014–15 (Australian Bureau of Statistics, 2016b). Innovation can increase productivity by reducing costs of operation, leading to higher yields and longer life of mines, and increasing safety. Innovation in exploration, extraction, enterprise systems and safety processes can also provide opportunities for new markets in the form of knowledge exports.

Innovations in extraction, processing and transport are gradually changing the way mining operations are conducted.

Innovations in extraction, processing and transport are gradually changing the way mining operations are conducted. Technology is improving processes at every stage of mining operations. There are advances in communication technology, sensing and navigation technology, systems and control processes (McNab and Garcia-Vasquez, 2011). Driverless trucks, drills and trains are some of the common technological solutions adopted by mining companies. These changes mean that remote operations centres are and will continue to be established in cities. For example, Rio Tinto's Operations Centre for the Pilbara iron ore network is located in Perth. At the Rio Tinto's Operations Centre more than 400 workers manage 15 mines, four port terminals, 1700 km of railway, and carry out site data analysis and process adjustments (Rio Tinto, 2017).

Other outcomes of a transition to more efficient processes could be a transition to flexible employment arrangements, jobs being located off the mine site and a more varied workforce demographic (McNab and Garcia-Vasquez, 2011). Automation can reduce employment for lower-skilled workers, like machine operators, but increase the number of jobs for supervisors and maintenance personnel. One operation increasingly substituted by automation is truck driving (McNab and Garcia-Vasquez, 2011). Some groups of workers may be more affected by automated processes than others, particularly if they are in lower-skilled level roles. Benefit-cost analysis can reveal how this capital cost compares to operating costs (labour). Estimates for a case study in a Western Australian mine show that 258 haul drivers were needed to run a fleet of 60 trucks, compared with 30 dispatch operators for automated haul systems (four shifts of one operator for eight trucks) (Bellamy and Pravica, 2011). The case study finds that after taking into account all categories of personnel needed and total salary packages, the savings are high: automated haul operations were around 82% cheaper than manual labour workforces (Bellamy and Pravica, 2011).[15]

Automation can reduce employment for lower-skilled workers, like machine operators, but increase number of jobs for remote operators and maintenance personnel.

Rio Tinto's iron ore operations had 72 autonomous haul trucks in 2016, representing 20% of the fleet, with each truck running at 15% lower costs than a regular haul truck (Rio Tinto, 2016). An

[15] These estimates excluded a series of costs, such as setting up the monitoring room, GPS and Radar requirements, and training costs for technical specialists.

autonomous drill, like an autonomous truck, can be used on average 1,000 hours more than conventional versions and four drills can be controlled by one operator (Rio Tinto, 2016). Mining site operations automation systems for surface mines are expanding: Rio Tinto operates orebody 3D visualisation software within its Mine Automation System at 85% of surface mines (Rio Tinto, 2016). Rio Tinto's iron ore operations have also implemented an automated rail in the Pilbara, expected to run in full autonomous mode from the end of 2018.[16] These changes can signal further decreases in personnel may occur in this company and others. Nonetheless, for the broader economy, reduced operational costs, together with a highly educated workforce, do have the potential to lift Australia's competitiveness on the global mining industry stage.

Australian mining businesses are sources of innovation which can be entirely original on the world stage. In 2014–15 mining was the industry sector with the highest proportion of businesses, 23.8%, which declared they had introduced new or significantly improved goods or services which were new internationally (Australian Bureau of Statistics, 2016b). Still, this innovation tends to occur in a relatively small number of companies. New goods and services originate in a relatively small percentage of businesses surveyed, 12.6% for 2014–15 (Australian Bureau of Statistics, 2016b).[17]

Australian mining businesses are sources of innovation which can be entirely original on the world stage, but this innovation can occur in a relatively small number of companies.

Innovation benefited mining businesses in 2014–15 most frequently in terms of increasing revenue and reducing costs. These benefits can also refer to improvements in customer service or to gaining a competitive edge in general. A third of mining businesses surveyed by the Australian Bureau of Statistics (ABS) reported that innovation implementation translated into one or more benefits, with the most frequent benefits cited being increases in revenue and reduced costs (Australian Bureau of Statistics, 2016b).[18]

Further innovation in the mining industry can be hampered by barriers to innovation. These barriers are not uncommon for mining businesses. Perceived issues tend to consist of a lack of sufficient funding, demand uncertainty and the costs of innovation development or implementation, rather than access to skilled workers, knowledge or technology. More than half of mining businesses surveyed by the ABS state they encountered barriers to innovation. A third of these businesses declared they faced a lack of access to funding, the highest percentage of all industries. This answer can be related to uncertain demand and cost faced by the industry. Mining has the second highest percentage of businesses, across all industries, which assert they face uncertain demand and cost barriers (16.7% and 18.6 % respectively).

[16] According to an October 2017 media release, 'Rio Tinto operates about 200 locomotives on more than 1,700 kilometres of track in the Pilbara, transporting ore from 16 mines to four port terminals'.

[17] Out of 17 ANZSIC categories, the mining industry had the fourth lowest ratio of businesses with any innovation in goods or services, 12.6%, as opposed to trade and manufacturing at the top end of the scale, with 31.7 and 28.5%. Yet, in terms of the percentage of mining businesses which introduce new or improved methods of manufacturing, 12.2%, this figure represents the second highest percentage (after manufacturing). A much smaller percentage of businesses surveyed by the ABS innovate other operational processes, such as logistics or activities supporting business operations. In terms of organisation processes innovation, mining businesses are situated relatively low on the scale when compared to other sectors, but were in third place in 2014–15 with regard to methods of organising external relations with other businesses or public institutions.

[18] The percentage is the fourth highest behind three other industries: (a) Electricity, Gas, Water and Waste Services; (2) Administrative and Support Services; and (3) Retail Trade industries.

Appendix A. Inequality coefficients calculation and analysis

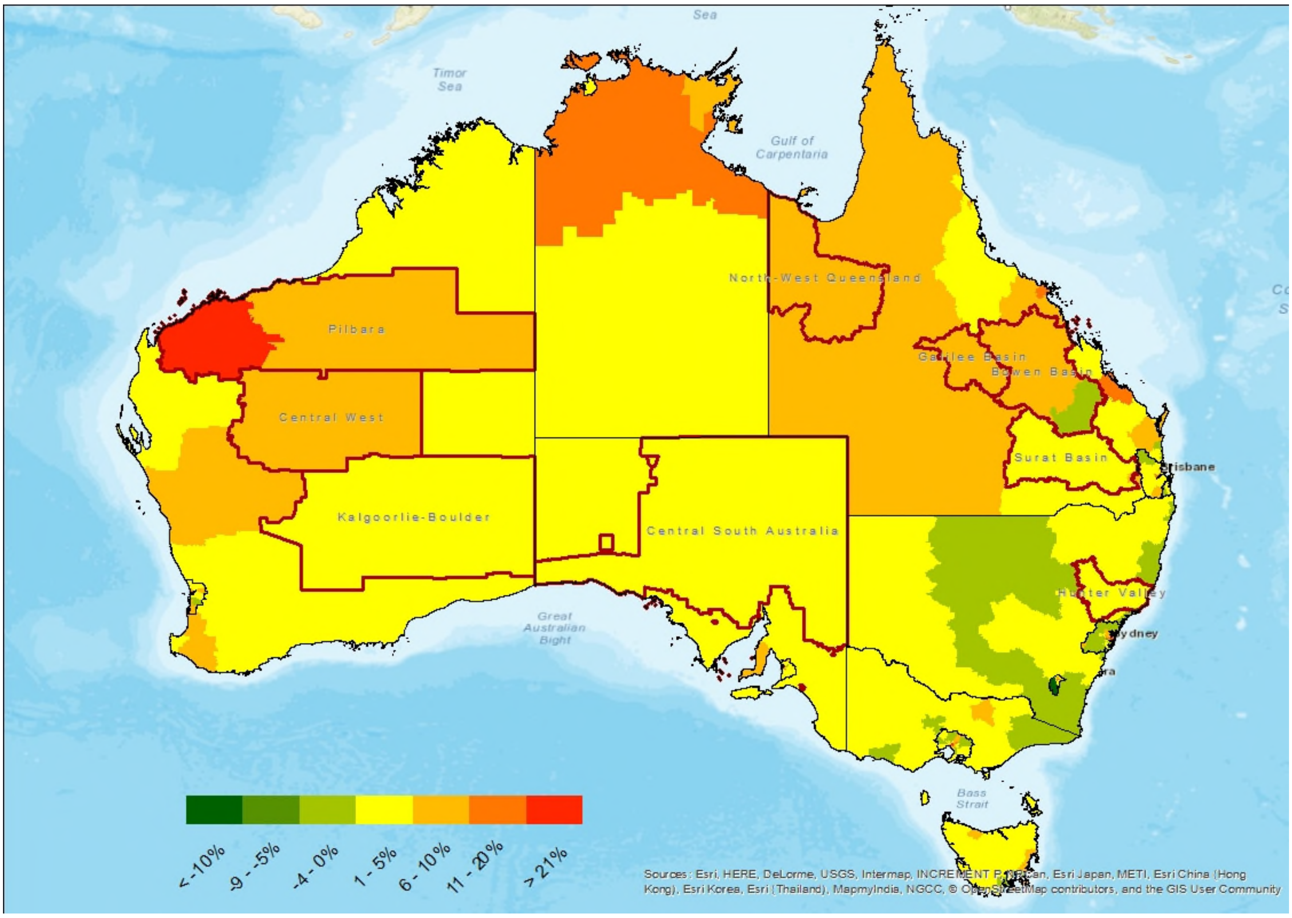
A.1 Data and method

The Gini inequality coefficients are calculated based on Australian Census 2016 data (Australian Bureau of Statistics, 2016c). Calculations of the Gini coefficient of inequality were based on total family income, regardless of employment status, and in this case includes couple and one parent families with children. For the highest income bracket the open-ended class median is calculated based on the algorithm described by Parker and Fenwick (1983). By using the Parker and Fenwick method, the truncation error is avoided (cf. Fleming and Measham, 2015).

Table Error! No text of specified style in document.**.1 Mining regions included in the analysis**

North-West Queensland, QLD • Cloncurry LGA • Mount Isa LGA • McKinlay LGA • Burke LGA • Doommadgee LGA Galilee Basin, QLD • Barcaldine LGA Bowen Basin, QLD • Banana LGA • Central Highlands LGA • Isaac LGA • Woorabinda LGA Surat Basin, QLD • Maranoa LGA • Toowoomba LGA • Western Downs LGA Central South Australia, SA • Coober Pedy LGA • Roxby Downs LGA • Unincorporated SA	Hunter Valley, NSW • Dungog LGA • Mid-Coast LGA • Gunnedah LGA • Liverpool Plains LGA • Muswellbrook LGA • Singleton LGA • Upper Hunter Shire LGA Kalgoorlie-Boulder, WA • Coolgardie LGA • Kalgoorlie-Boulder LGA • Laverton LGA • Leonora LGA • Menzies LGA Central West, WA • Meekatharra LGA • Wiluna LGA Pilbara, WA • Ashburton LGA • East Pilbara LGA • Port Hedland LGA • Karratha LGA

The mining regions considered are listed, together with the local government areas which form them, in Table 3 (Fleming and Measham, 2015; KPMG, 2013).



Apx Figure Error! No text of specified style in document.**.1 Percentage change in the inequality Gini coefficient in mining regions, 2006–2016**

Data source: analysis based on Australian Census income data, SA3 level regions.

To illustrate the incremental change in the Gini coefficient from 2006 to 2011 and from 2011 to 2016, additional figures are included below. However, no significant changes at the SA2 level were found.

Table Error! No text of specified style in document.**.2 Gini coefficient values' change t-test analysis, SA2 level analysis**

	Test 1: 2006–11	Test 2: 2011–16	Test 3: 2006–16
Gini mean change (%), non-mining regions (standard error)	0.83 (0.24)	4.32 (0.37)	4.60 (0.28)
No. of observations for non-mining regions	2066	2098	2087
Gini mean change (%), mining regions (standard error)	–0.03 (0.83)	5.03 (1.41)	4.92 (1.07)
No. of observations for mining regions	72	73	73
t-test statistic	0.67	–0.36	–0.21
Prob (|T| > |t|)	0.5005	0.7184	0.8305
Degrees of freedom	2136	2169	2158

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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