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EMPLOYMENT LEAKAGE BY LOCAL GOVERNMENT AREA IN THE NORTHERN TERRITORY, AUSTRALIA: THE ROLES OF INDUSTRIES, INCLUDING MINING

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ABSTRACT

Leakage of employment income is a pressing issue in the economic development of regional and remote communities. Using Australian Bureau of Statistics 2011 census employment data by place of usual residence and place of work, we identify for all 17 Local Government Areas (LGAs) of the Northern Territory (NT), workers commuting out of and into each LGA. Using summary graphs, geospatial visualizations, and principle component analysis we find that while there is substantial leakage out of most LGAs there are also gains from those leaving an LGA to work and then returning home with their income. Overall, for most LGAs and all remote LGAs there is net leakage. In contrast, Wagait, Palmerston, Litchfield and Alice Springs experience net gains from work commuting. Core-Periphery theory (Krugman 1991, Carson 2011) helps explain these net gaining LGAs but cannot be used to consistently explain net leakage or net gain for population centers and nearby periphery LGAs. However, remote LGAs that experience net leakage are typically associated with an employment concentration in mining by sourcing workers from outside local LGAs. Employment concentration in manufacturing exists for leakage oriented LGAs regardless of their remoteness and can therefore not explain leakage in remote areas *per se*. Our geospatial visualizations also help to identify the leakage vulnerability of regions but this vulnerability from labor mobility also offers increased flexibility to deal with job losses during downturns. Undertaking our analysis for a number of census years could help decision makers build scenarios for future economic development and employment.

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INTRODUCTION

The internal migration of labor in Australia is an evolving phenomenon, particularly in the mining sector. Like Queensland and Western Australia, the Northern Territory (NT), continues to enjoy the benefits of the mining boom, even though most mining in Australia has moved to an operational phase. Most mining operations rely on a mobile and skilled workforce. Shift work and Long Distance Commuting (LDC), including fly-in fly-out (FIFO), are standard practices, particularly in remote locations.

If we take a step back and consider migration in a broader context we can reflect and define its place for the human existence in current times. In the natural sciences, migration is used to describe the annual movement of animals, coinciding with seasonal climatic and landscape changes, across large distances of the continental plains (Dingle 1996). This form of animal migration occurs in a cyclical fashion such that periods of residence occur time and time again in the same locations at around the same times of year (Dingle & Drake 2007). Following these animal migrations for millennia, humans have sought subsistence and profit, such as the North American Indians who hunted the Buffalo on the continental plains (Sturtevant & DeMallie 2001). We therefore define human migration as the occurrence of moving one's home location to that of work. In contrast, we define 'commuting' as residing in one's home location but travelling to and from one's work location.

In more recent times and in contrast to animal migration, human migration has occurred where people travel from one place to another, again over large distances, with the intention of residing in the new location (Park 1928). However, for humans there is often no intention, at least in the short term, of returning to the old

location in the following season or year. The European gypsies are an example of an exception who habitually return to an old location and move-on to yet another return location with the change of season (Hoyland 1816).

Human migration is particularly relevant to the study of family decision making and efficient labour markets (Mincer 1978, Sjaastad 1962). For example, with the advent of improved technologies in transportation networks and work related practices, e.g. LDC, the tendency for migration, i.e. relocating one's home to the new place of work is less necessary (Simpson & van der Veen 1992, de Silva, Johnson & Wade 2011). This supply-side factor has given rise to increased labor mobility (Champion, Coombes & Brown 2008, Eliasson, Lindgren & Westerlund 2003). By reducing the costs of 'seasonal' or shift related travel, FIFO and drive-in, drive-out (DIDO) opportunities have improved the efficiency of the movement of labor and helped realise the benefits to a family of staying in the home location at a reduced cost to businesses.

Other supply factors have also impacted how humans spatially determine their move to work. For example, housing shortages can create a gravitational pull for urban development at the periphery of cities (Hugo, Feist & Tan 2013) raising the demand for the daily commute to work (e.g. for Sydney see Wade & Cormack 2014). Supply factors like these have resulted in labor becoming highly mobile with a resultant burgeoning literature on labor mobility since Krugman's original contribution (Krugman 1991).

Furthermore, LDC is not limited to internal migration, i.e. contained within national spatial domains (Walker 2008), and can occur internationally. However, limiting factors are travel time, distance and cost (Gimenez-Nadal & Molina 2014). For local government areas (LGAs) in the states and territories of Australia, the movement of people from their home LGA to a different LGA for work can occur on a more regular basis (e.g. daily) where time and travel costs are lower (from synthesis of Clawson & Knetsch 1966, Greenwood 1975). As we will see from the findings presented in this article, this is particularly the case where a regional centre lies near the border of multiple LGAs.

The various forms of commuting to work have returned humans to what is more typical of animal migration, where markets drive the seasonality of work rather than a change in the season. The inescapable fact is that people migrate or commute in order to pursue a better life for themselves or their families – they do so for subsistence and profit (as in previous millennia), that is to improve their wellbeing by investing in their human capital (Schultz 1961). This is not to suggest that human migration does not still occur, rather that there has been a paradigm shift in working and travel arrangements such that commuting is now a more viable substitute for migration in investing in one's human capital while maintaining the comforts of home. Within the theory of labor mobility, there has been a temporal shift in drivers that mean that some labor markets in Australia (e.g. mining) have become more flexible.

These discussions of labor mobility and migration also need to be considered in context. It is important to stress the peculiar or *sui generis* nature of the NT, remote NT and individual NT LGAs (Blackwell 2012). In the case of the NT and relative to the states, the Commonwealth of Australia has increased powers of intervention on issues such as uranium, national parks, offshore petroleum, and human rights. The NT also has the smallest population out of all mainland states and territories, even when compared with Tasmania and the Australian Capital Territory. Population centers outside of Darwin and its surrounds, lie within the NT along the main highways to other states, rather than along its coast like on the east Coast of Australia. In these inland centers the local populations are still smaller compared to inland centers in many regions of other Australian jurisdictions. Demand for labor therefore is typically filled from outside local and particularly remote regions. These factors therefore coalesce providing a strong tendency for leakage to areas outside a given LGA.

The remainder of the article is setout in four sections. Section 2 outlines the methods and data used to calculate the number of people commuting into and out of each LGA and the associated leakage patterns. Section 3 provides the results and section 4 a discussion of these results. The article ends with an outline of limitations and area for future research in Section 5.

APPROACH, DATA AND METHODS

In order to better understand the dynamics of inter LGA work commuters we measure two variables. The first is the number of people commuting from their LGA of residence to their LGA of work, regardless of the number of trips taken, distance travelled, time taken, cost incurred or benefit received. By definition, it therefore includes daily commuters, LDC shift-workers, and seasonal workers. It does not analyze migration *per se*. It defines commuters in and out of their resident LGA via two questions from the 2011 Australian Bureau of Statistics Census which sequentially asks people for (i) the address of their work, and (ii) the address of their usual residence (Australian Bureau of Statistics 2013a).

By considering commuters within a given census year and not their change of residential address over a number of years, our contribution here is new and different to what has been considered previously in academic

journals and texts, none less so for Australia and indeed the Northern Territory (NT). While in short supply, the most noteworthy of the Australian studies is Carson (2011) who analyzed the empirical internal migration of skilled labor for the NT – looking at the change in people's place of residence from 2001 to 2006 to test core-periphery (C-P) patterns of migration found overseas. Carson found that the C-P pattern does exist for Australian states but not for the NT and there are weak C-P migration patterns with South Australia and via regional ties with associated regions of northern Queensland and Western Australia. Our study in this article differs from Carson's by considering the inbound and outbound movement of workers from home to an outside LGA in a given census year in order to better understand the patterns of medium term (I year) commuting in and out of specific LGAs.

There are two reports (Productivity Commission 2014, KPMG 2013) and one conference paper (de Silva, Johnson & Wade 2011) that coincidently have used our general approach of comparing place of work and place of usual residence. The Productivity Commission (2014) used the ABS's statistical area level 4 (SA4) classification which provides a poor break-down of regional and remote NT (e.g. simply described as Outback NT) compared to our 17 LGAs and 111 industry subsector classification. In addition, we are simply not concerned with LDC but commuting more generally between LGAs regardless of distance and time and the leakage or gain associated with this commuting. The Productivity Commission study does however provide an outline of the limitations of using place of work and place of usual residence for estimating LDC, which may also exist for estimating commuting in general.

Similarly, KPMG (2013) provides a different approach to ours by estimating the distance between place of work and place of usual residence where the distance was greater than 100 km. They also undertook their own surveys because their estimates using the census data were considered to underestimate LDC. Despite these advances, the KPMG report is silent on commuting and its associated leakage for the NT and regions within the NT. In contrast, the Productivity Commission (2014) provides greater insights such as NT having a higher reliance on LDC than other states, yet this is still precursory compared to our analysis with detailed LGA and 111 subsector industry analysis.

Returning to the variables measured by our study, the second variable measured is the leakage to each LGA, subsector and industry that results from this commuting activity. An important definitional distinction for commuting is how commuter travel between residence and place of work determines our assessment of the leakage of income from an LGA. Where a person travels out of their resident LGA for work (outbound) they are defined as providing a 'gain' to their LGA in terms of income, because they are assumed to return home to spend the majority of this income. In contrast, people travelling into a given LGA for work (inbound) and returning home to a different LGA are used to calculate the loss of income, called 'leakage' from the LGA under consideration. Naturally, whether commuters are outbound or inbound, they are assumed to spend most of their income from their home location. By industry and subsector, each LGA will have both gains and leakage from commuters. We define the addition of leakage and gains as 'net leakage'. Accordingly, 'negative net leakage' can be interpreted as a net gain from commuting.

Employment Numbers

Using the Australian Bureau of Statistics TableBuilder interface we obtained data on workers' place of usual residence and place of work by all 17 LGAs in the NT for 2011 (Australian Bureau of Statistics 2014). The addresses for place of usual residence and place of work are asked of respondents at question eight and 41 in the 2011 census (Australian Bureau of Statistics 2013a). This enabled us to identify all workers' LGA of residence and LGA of work. For the majority of workers, these two addresses coincide which delivers a measure of local employment. We focused on addresses that did not coincide in order to identify both people travelling out of, or into, a given LGA for work. We did this for each of the 111 subsectors (*i*) relevant for each LGA (*j*). We also subtracted outbound employment (*OE*) from inbound employment (*IE*) to gain a net inbound measure:

$$Net\ IE_{ij} = IE_{ij} - OE_{ij} \quad (1)$$

By summing OE and IE across all subsectors we obtained a total net *IE* for each LGA and the NT as a whole:

$$\sum Net\ IE_{ij} = \sum IE_{ij} - \sum OE_{ij} \quad (2)$$

Income Leakage

We then obtained an estimate of the likely leakage of income from inbound (*L*) and outbound (*G*) workers by using the ABS national average income for each of the 111 subsectors ($\overline{Y_i}$) for the economy (Australian Bureau of Statistics 2012). Outbound workers leave a given LGA to undertake work in an outside LGA, and then return

home with their income. These outbound workers therefore provide a gain in income (*G*) to a given LGA. In corollary, inbound workers arrive from an outside LGA to the LGA under consideration and then return home with their income to the outside LGA. These inbound workers provide for a leakage of income (*L*). From equation (1) we obtain a measure of income leakage and income gain:

$$L_{ij} = IE_{ij} * \overline{Y_\iota} \tag{2}$$

$$G_{ij} = OE_{ij} * \overline{Y_\iota} \tag{3}$$

We then obtained the net income leakage for each subsector of a given LGA through:

$$Net\ L_{ij} = L_{ij} - G_{ij} \tag{4}$$

Again by summing *L* and *G* across all subsectors, *Net L* for each LGA and the NT as a whole can be obtained:

$$\sum Net\ L_{ij} = \sum L_{ij} - \sum G_{ij} \tag{5}$$

For each subsector and LGA we also obtained a measure of *IE* and *OE* and *L* and *G* relative to their respective local employment (*LE*) and local income (*Y*) levels:

$$\sum Net\ IE_{ij}/LE_{ij} = \sum IE_{ij}/LE_{ij} - \sum OE_{ij}/LE_{ij} \tag{6}$$

$$\sum Net\ L_{ij}/Y_{ij} = \sum L_{ij}/Y_{ij} - \sum G_{ij}\ /Y_{ij} \tag{7}$$

Geospatial Visualization

We then take these calculations and provide four geospatial visualizations:

1) the industry associated with the highest subsector net leakage for each LGA combined with indicators for the range of leaking jobs and income to help identify, quantify, and visually compare leading 'leaker' or gaining subsectors for each LGA;

2) a distribution of average subsector net income leakage or gain for each industry to visually compare across LGAs to contribution of industries to leakage or gain;

3) a distribution of the percentage attributable to the sum of net subsector income leakage for each industry providing an indication of the industry concentration of net leakage from employment income; and

4) the range of percentage attributable to the maximum subsector net leakage of employment income, to provide a measure of vulnerability from leakage.

These geospatial analyses provide a rapid visual summary of employment and income leakage across the NT by LGA and are novel by developing a staged mapping summary. To date no such approach has been used in the literature to visualize and summarize the structure of leakage in an economy and this approach has a number of advantages over traditional methods. In the first visualization, shading is provided for each LGA corresponding to the industry represented by the highest sub sector leakage. Indicators for the magnitude of jobs and income and then superimposed for each LGA.

In the second visualization, a distribution graph for each LGA is presented representing the average net leakage (or gain) of income across all subsectors for each industry. Average net leakage for an industry is useful for decision makers where the highest net leakage does not represent other subsectors within an industry. Also, because sub sectors classifications are not typically even in number across industries, an average measure is a better summary indicator compared with only viewing the shaded variation of highest sub sector leakage.

The third and fourth visualizations provide respectively a distribution of the percentage contribution to overall income net leakage of an LGA by a given industry and shading to each LGA based on the percentage of income net leakage associated with the highest subsector industry. Visually, these summaries provide a rapid indication of those LGAs which are vulnerable to concentrated leakage of employment income and which

industries are contributing. For example, in this article those with darker shading are likely to have a greater loss of jobs and employment income to outside LGAs, while those which are less vulnerable have a lighter shading reflecting a smaller percentage of sub sector income leakage. The bar charts can then be considered to identify which industries are contributing most to this vulnerability.

Data Summary Bar Graphs

We also present graphs of local employment (coincidence of LGA of residence and work) and income, inbound and outbound employment and income for each LGA, the net income and employment leakage or gain for each LGA in the NT, and net leakage relative to local employment. Together these graphs provide a rapid identification of those LGAs that are suffering from net leakage and in what relative magnitude. The graphs also help to identify those LGAs, which are enjoying employment and income gains, and to reflect upon possible policy implications for commuting and leakage in the NT.

Principal Component Analysis

One of the difficulties inherent in the analysis and interpretation of large economic data sets is the problem of visualizing data that has many variables. In this case, the economies of the LGAs are driven by regional income leakage across many industries and subsectors. Principal component analysis is a quantitatively rigorous method for simplifying multiple variables into a singular set of variables. The method generates a new set of variables, called principal components.

In data sets with many variables, groups of variables often move together. One reason for this is that more than one variable might be measuring the same driving principle governing the behavior of the system. When this happens, you can take advantage of this redundancy of information and simplify the problem by replacing a group of variables with a single new variable. We undertake such an analysis with employment leakage for LGAs in order to corroborate evidence about the characteristics of leakage in groups of LGAs, including associations with mining oriented LGAs and remote LGAs.

Full Rankings of Subsector Net Leakage by LGA

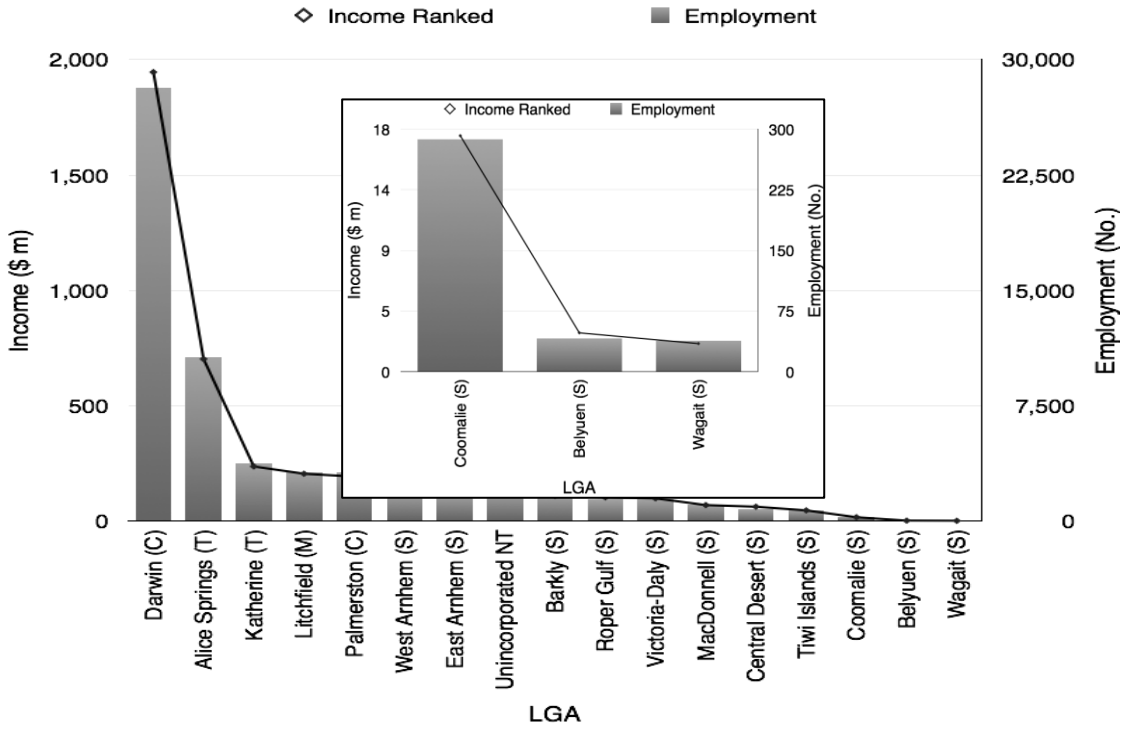
The full rankings of LGA subsector net employment and income leakage, using the ABS' 111-subsector classification at the two-digit level were also prepared in order to further identify key subsectors of concern or interest for a given LGA. In addition to the Principle Component Analysis, these are useful to decision makers in moving from the geospatial visualization at the broader macro spatial scale of analysis in order to assess and further analyze the performance of particular subsectors of interest at the micro scale.

RESULTS

Local Employment and Income

Figure 1 shows employment and ranked employment income for LGAs in the NT from 2011. Darwin is outstanding with almost $2 billion from employing close to 30,000 people. Alice Springs is the next largest local employer with close to $700 million from around 10,000 people. Katherine, Litchfield and Palmerston are then the next highest ranked LGAs by local employment income and numbers. After these, remote LGAs follow, including Unincorporated NT. Employment concentrated LGAs like Victoria-Daly, Central Desert, Barkly, West Arnhem and Roper-Gulf and MacDonnell all have relatively low levels of local employment income and numbers. Also, Coomalie has relatively small levels of local income and employment having close to $18 million from around 300 people. Belyuen and Wagait offer extremely small levels relative to Darwin, having approximately $2.5 million in employment income locally from around 40 people.

FIGURE 1. LOCAL EMPLOYMENT AND INCOME



Inbound and Outbound Employment and Income

Figure 2 provides both the inbound and outbound employment and leakage income and income gain for each LGA in NT, ranked by income leakage. Figure 3 provides an improved scale for smaller magnitude LGAs. In Figure 2, we see that Darwin has the greatest inbound employment and associated income leakage of all LGAs. Interestingly, Palmerston has the greatest outbound employment and gain of employment income of all LGAs followed by Darwin and then Litchfield. Litchfield also has the third highest inbound employment but its outbound employment is far greater than its inbound. These results represent for Darwin and its adjacent LGAs the first suggestion of their labor confluence.

Unincorporated NT is interesting in that it has the second highest employment related income leakage to that of Darwin. Furthermore, Darwin, Palmerston, Alice Springs, and Wagait (see Figure 3 for the final two) have noticeable 'spikes' of employment income gains compared to all other LGAs in Figure 2.

Most if not all remote or very remote LGAs have inbound employment and leakage income that is greater in magnitude than outbound employment and income gain: East Arnhem, MacDonnell, West Arnhem, Roper Gulf, Central Desert, Victoria-Daly, Barkly, Tiwi Islands, Belyuen, and also the more populated Katherine. Given the LDC nature of remote mining operations, included in this group are all mining employment concentrated LGAs (Blackwell et al. in prep.). In contrast, Palmerston, Litchfield, Alice Springs, and Wagait have outbound employment and gain which is greater in magnitude than leakage. We are conscious of the commuting confluence of Palmerston, Litchfield and Wagait with Darwin, leaving Alice Springs as quite different. These four LGAs, excepting Darwin, offer places for people to live – people who are prepared to commute to outside LGAs for employment in the Northern Territory.

FIGURE 2. INBOUND AND OUTBOUND EMPLOYMENT AND INCOME BY LGA

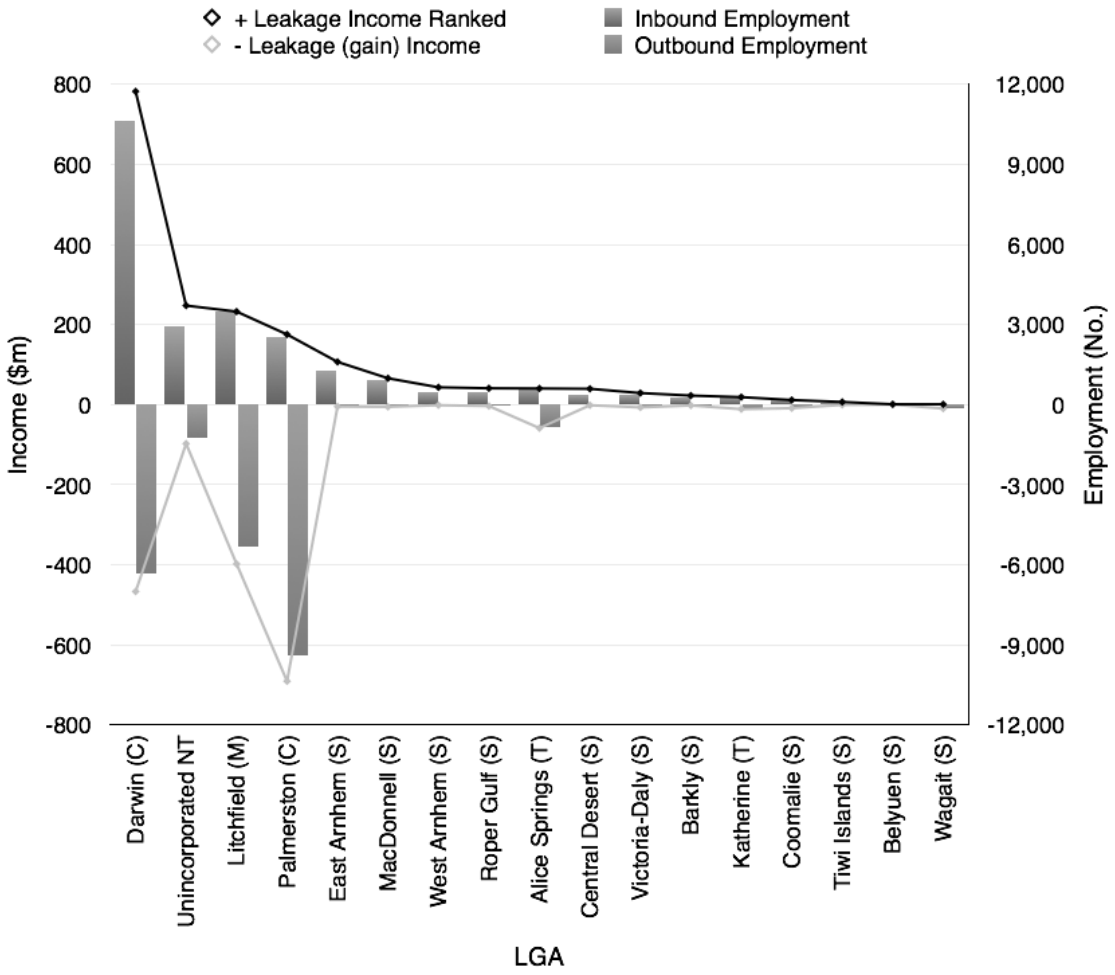
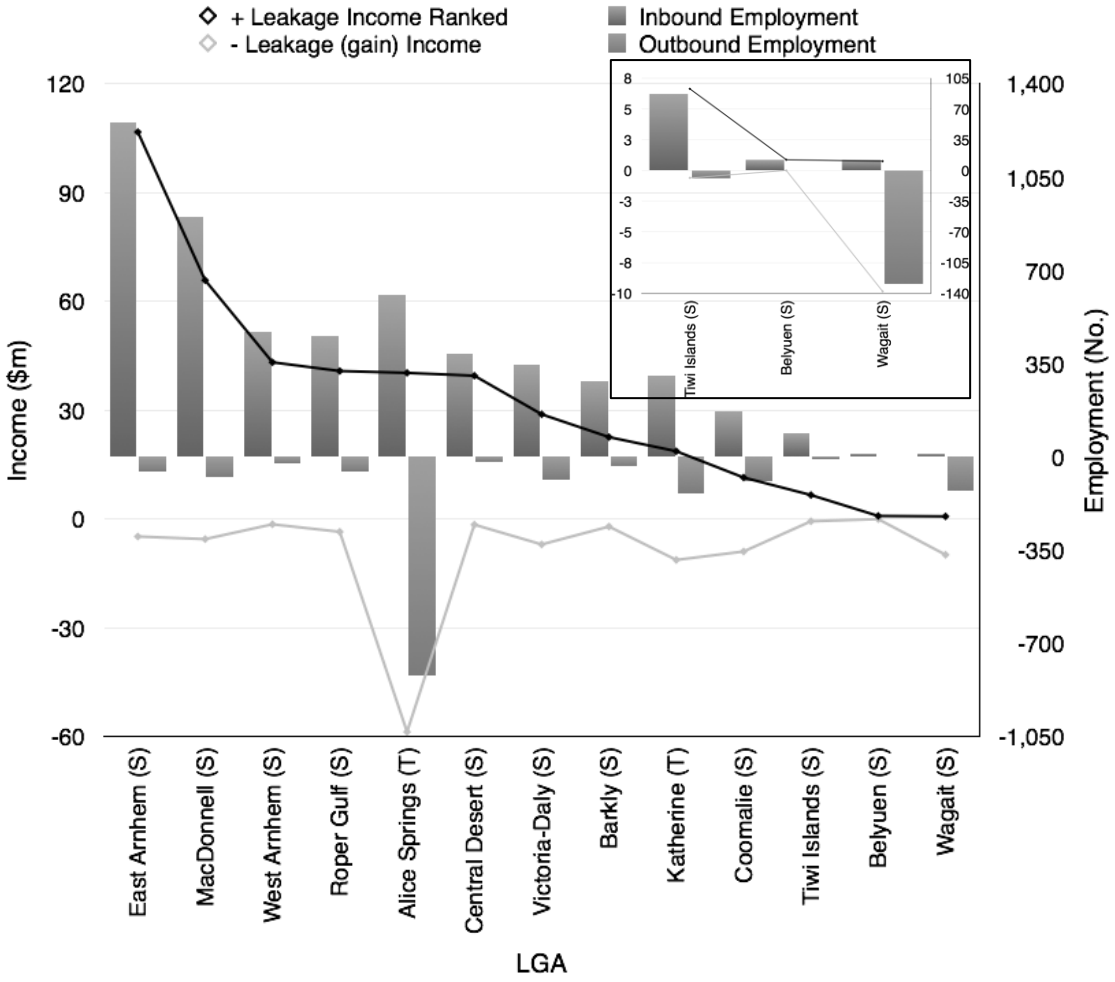


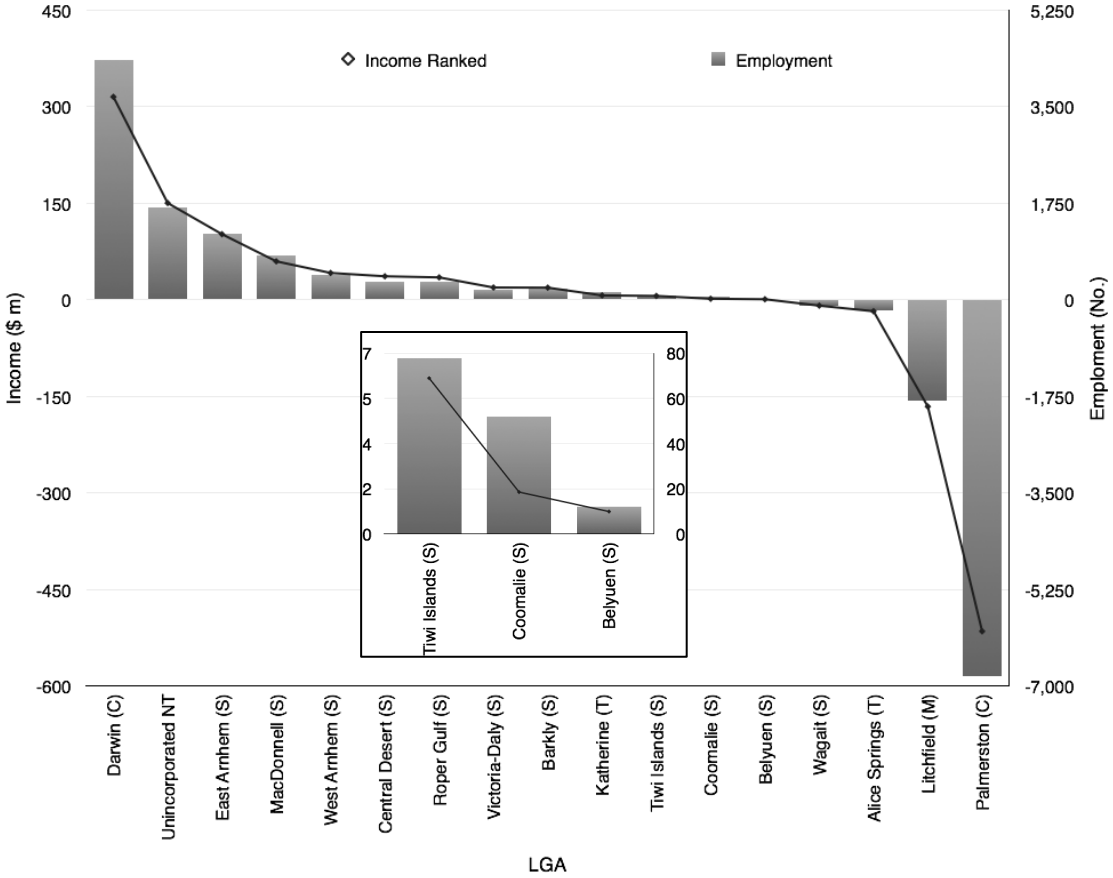
FIGURE 3. SMALLER INBOUND AND OUTBOUND EMPLOYMENT AND INCOME LGAS



Net Leakage

Figure 4 provides an indication of the net leakage of income and associated net leakage of employment for each LGA in the NT. A larger exposure is provided in the figure for LGAs where leakage is indistinguishable from the majority of LGAs. Darwin experiences the greatest absolute amount of net leakage ($315m from 4,344 workers) with Palmerston experiencing the largest amount of net gain in income and employment ($515m from 6,829 workers) and overall in absolute value terms. Litchfield is the next largest LGA with a net gain. This initial finding provides some interesting insights because Palmerston and Litchfield are commuter LGAs for Darwin. People live in Palmerston and Litchfield and commute to Darwin for work returning home with their income. Alice Springs and Wagait are similar, the latter benefitting from ferry commuters to Darwin and Alice Springs being a relatively small LGA surrounded by large and relatively nearby LGA in very remote NT like MacDonnell, Yulara (part of Unincorporated NT), Central Desert, and further afield, Barkly. All these surrounding LGAs as well as the remaining, most of which are remote, are experiencing net leakage of jobs and income.

FIGURE 4. NET INCOME AND EMPLOYMENT LEAKAGE BY LGA



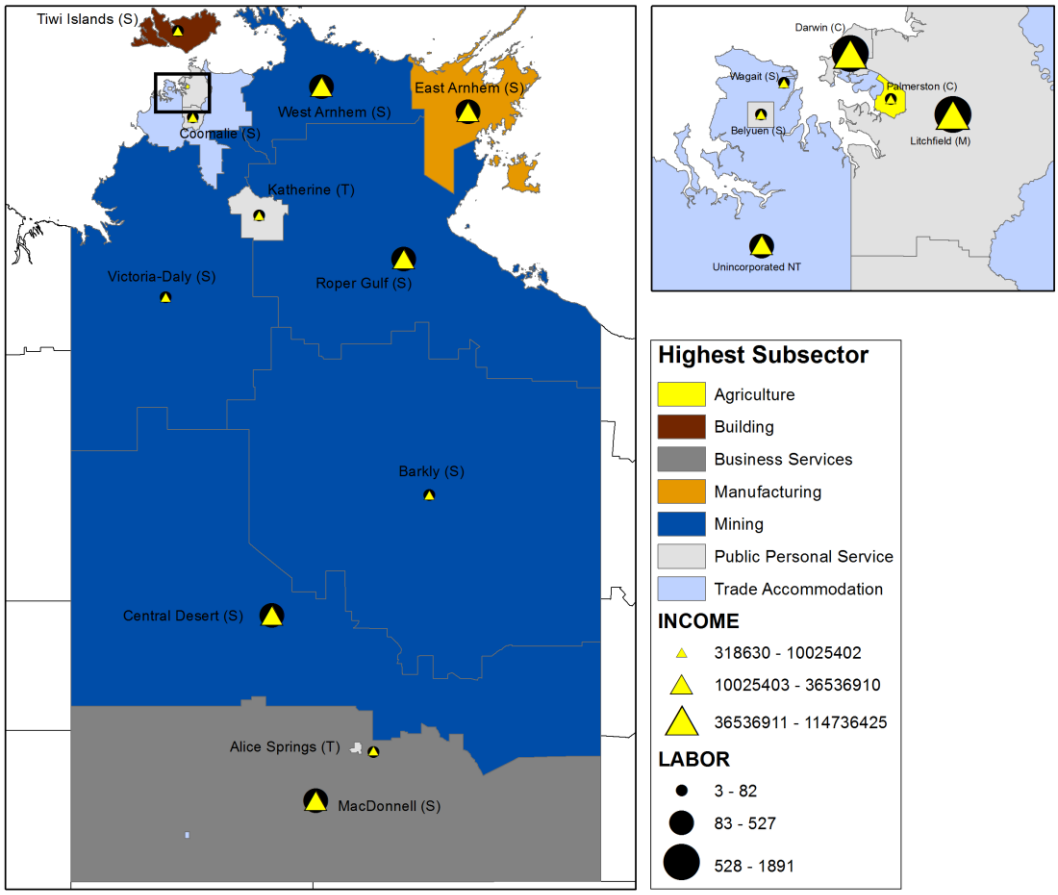
Furthermore, in total for the NT there is net leakage that is relatively mild at $86 million in lost net income from 838 workers. This results from a sum of positive net leakage of $794 million from 9,803 workers and a sum of negative net leakage (i.e., net gain) of $708 million from 8,965 workers. In theory, outgoing and incoming works for all LGAs in NT should balance. The reason for the 838 worker imbalance can be explained by a rounding error and is small relative to the total 99,481 people employed in the NT in 2011 (calculated from Australian Bureau of Statistics 2014).

In LGAs where mining has a high concentration of employment, such as Central Desert, Victoria-Daly, Barkly and West Arnhem, mining contributes to the leakage of jobs and income.

Unincorporated NT is complex because it includes areas in East Arnhem and Yulara but also areas relatively close to Darwin. We expect results from the category to be generally more representative, because of the higher population levels, of results in those unincorporated areas close to Darwin rather than more remote areas. In net, most people commute into Unincorporated NT for work (approx. 1,684) creating a substantial absolute leakage to their home LGAs of nearly $151 million.

Further details on the highest industry subsector source of leakage for individual LGAs is geospatially visualized in Figure 5 with the number of jobs and associated income indicators presented as circles and triangles respectively. As can be seen, mining has the greatest geographical coverage for the highest levels of leakage in the remote LGAs of West Arnhem, Victoria-Daly, Roper Gulf, Barkly, and Central Desert. West Arnhem, Roper Gulf and Central Desert have medium levels of leakage with hundreds of jobs and tens of millions in income leaking to outside LGAs. In contrast, Victoria Daly and Barkly have lower levels of leakage with tens of jobs and millions of dollars in income leaking net to outside LGAs. Coomalie and Belyuen have lower levels of industry subsector net leakage measured in both income and job terms but both are associated with Public and Personal Services. The provision of public services in these locations from non-locals is contributing to leakage for these LGAs.

FIGURE 5. GEOSPATIAL VISUALIZATION OF HIGHEST INDUSTRY SUBSECTOR NET LEAKAGE OR GAIN



In contrast, for those LGAs that are experiencing a net gain, that is, Wagait, Alice Springs, Palmerston and Litchfield (as per Figure 4), the leading subsector industries (as presented by the shading in Figure 5) are Trade and Accommodation, Public and Personal Services, Agriculture and Public and Personal Services respectively. Litchfield has the highest subsector measured net gain with tens to hundreds of millions of dollars in income associated with thousands of jobs. Interestingly, while Palmerston has the highest level of total net gain measured through jobs and income (see Figure 4), its highest subsector net gain is relatively lower than that of Litchfield (as represented by the smaller labor circles and income triangles in Figure 5). This result can be explained at least in part by Palmerston's greater diversity of industry subsectors.

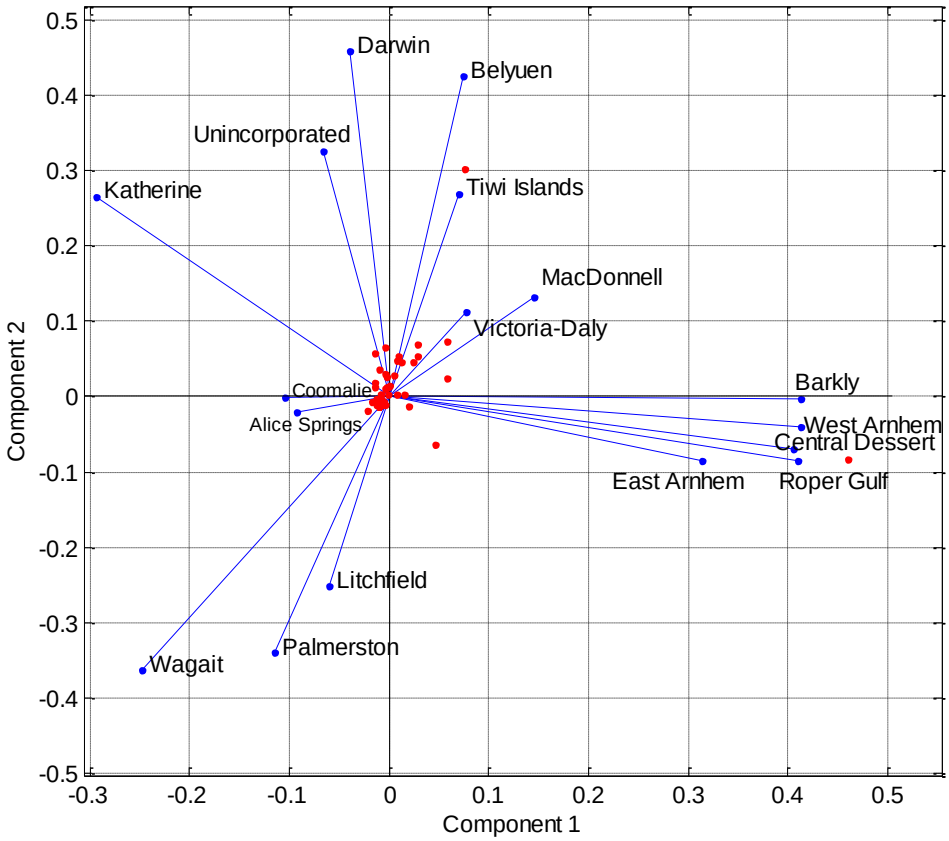
Tiwi Islands' highest subsector net leakage is from Building, Unincorporated NT's is from Trade and Accommodation[1], East Arnhem is from Manufacturing, Darwin and Katherine are both from Public and Personal Services, and interestingly MacDonnell is from Business Services.[2] Of these, Darwin has the highest measured net leakage for an individual industry subsector with tens to hundreds of dollars in net leakage income resulting from the net loss of thousands of jobs. Marrying Darwin's net leakage with the net gain for Litchfield (also the largest in magnitude of jobs and income in its grouping) indicates the two are connecting with significant leakage from Darwin in Public and Personal Services to Litchfield. Wagait also would appear to be draining worker income in Trade and Accommodation from Darwin. Determining the flows between Darwin and other surrounding areas like Palmerston and Unincorporated NT requires more detailed analysis (e.g. see Figures 6, 7, 8 and 9). However, the role of port facilities at Blade Point and Gove no doubt play a role and will continue to do so in future censuses with employment growth from the recent INPEX gas processing facility at Blade Point and significant loss of employment from the shutdown of the alumina processing facility at Gove.

[1] Unincorporated NT's result may be explained by Yulara (lighter shading square in middle left of MacDonnell of Figure 6, established by the Commonwealth as a tourism resort town in 1976) being particularly close to Uluru (Ayers Rock) and Kata Tjuta (the Olgas) and draining workers income from the surrounding MacDonnell.
[2] People working in specialized services such as those that are supply Business Services to Pine Gap may explain MacDonnell's result.

Principle Component Analysis

The PCA results further corroborates the findings from the bar graphs on net leakage but has the added advantage of removing an number of explanations which are irrelevant, to help focus attention on the principle components of association. We can visualize the principal component coefficients for each variable and the principal component scores for each observation as depicted in Figure 6. Each of the 17 variables (LGAs) is represented in this plot by a vector, and the direction and length of the vector indicates how each variable contributes to the two principal components in the plot. For example, the first principal component, represented in this bi-plot by the horizontal axis, has positive coefficients for nine of the LGAs. That corresponds to the nine vectors directed into the right half of the plot (Belyuen, Tiwi Islands, MacDonnell, Victoria-Daly, Barkly, West Arnhem, Central Desert, Roper Gulf and East Arnhem).

FIGURE 6. PRINCIPLE COMPONENT ANALYSIS OF NT LGA EMPLOYMENT LEAKAGE



The second principal component, represented by the vertical axis, has positive coefficients for Katherine, Unincorporated NT, Darwin, Belyuen, Tiwi Islands, MacDonnell and Victoria Daly and negative coefficients for the remaining ten variables (LGAs). That corresponds to vectors directed into the top and bottom halves of the plot, respectively. This indicates that this component distinguishes between sites that have high values for the first set of variables and low for the second, and sites that have the opposite.

Each of the 111 subsectors is represented in this plot by a red point, and the point locations indicate the score of each observation for the two principal components in the plot. The clustering of the five LGAs on the right side of the plot indicate that, in terms of leakage, they are driven by similar subsectors with Non-ferrous Metal Ore Mining (red point) being the main leakage driver.

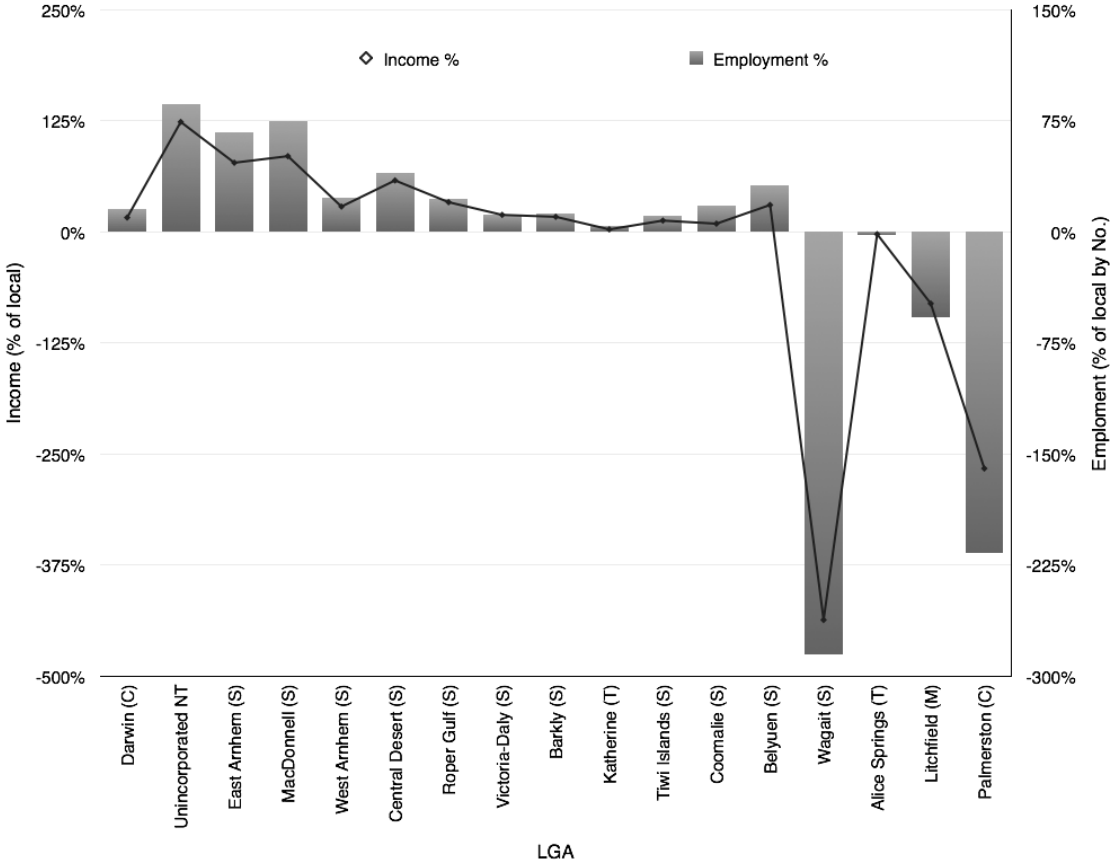
Similarly, Darwin, Belyuen and Tiwi Islands also show similar leakage characteristics being influenced by the subsector Public Administration and Regulatory Services. In addition, the clumping of the LGAs of Wagait, Palmerston and Litchfield in the lower left side of the plot indicate that across all the subsectors examined, these three LGAs retain similar characteristics with regard to their leakage across all of the subsectors examined, that is, negative leakage in Mining and positive leakage in Public Services.

Relative Net Leakage

When compared to their local employment and income levels, the ranked relative incomes and employment provide a different perspective on net leakage as shown in Figure 7. Darwin's leakages, while being the greatest positive net leakages in absolute terms, become insignificant relative to local components. The more populated areas of Katherine and Alice Springs are similar, except that Alice Springs has marginal relative net gains. In contrast to Darwin, Palmerston has amongst the highest relative negative leakages (net gains) in absolute terms. Wagait is outstanding with a very high relative net gain from commuting in net income and employment terms. The very strong growth in employment in the building and trade sectors of Wagait and the existence of a regular ferry service to Darwin help explain these commuting patterns (Blackwell et al. in prep.).

The next grouping of LGAs, while not extremely high still have very high relative leakage levels, include Unincorporated NT, MacDonnell, East Arnhem, Central Desert and Belyuen. Litchfield is also in this grouping but it has a high relative net gain from commuting, most likely to Darwin. The remaining group of LGAs: West Arnhem, Roper Gulf, Tiwi Islands, and Coomalie have mild relative leakages. For relative leakage, all LGAs with high mining employment concentrations standout and include Central Desert, MacDonnell, and East Arnhem. Of particular note, Unincorporated NT has the highest relative net leakage in positive terms of all LGAs. Again this reflects low local employment as depicted in Figure 1 and income and high relative leakages.

FIGURE 7. NET LEAKAGE RELATIVE TO LOCAL EMPLOYMENT BY LGA

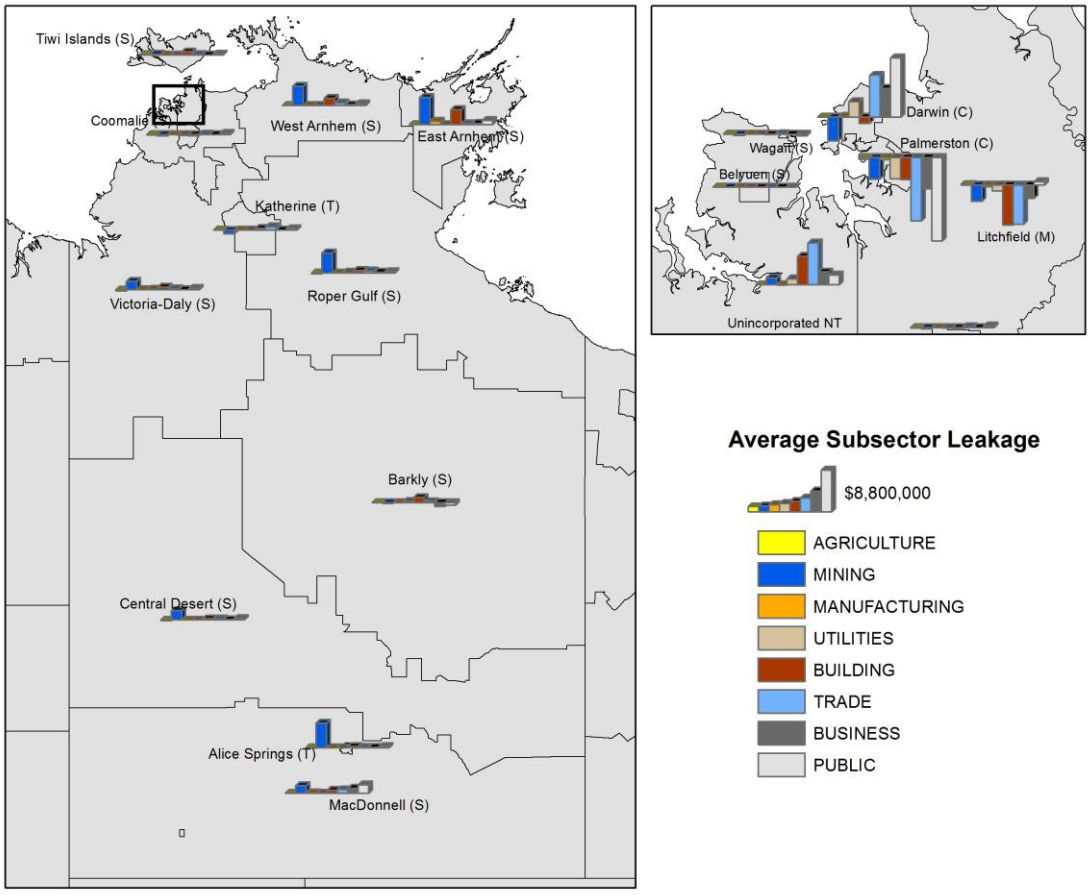


A further way to analyze relative net leakage or gain is via average industry subsector net leakage as depicted in Figure 8. Again mining dominates average industry net leakage for incomes in most LGAs, particularly remote LGAs. However, for Darwin, Litchfield and Palmerston, mining offers a strong inflow of income. An industry that is related to servicing the mining industry is Building, and this too is exhibiting net gains for the same LGAs. Trade and Accommodation and Business Services are also exhibiting net gains for Litchfield and Palmerston but net leakage for Darwin, reflecting the commuting of workers from these outlying LGAs to Darwin for employment.

These results are interesting, because they also provide inklings for where workers of particular industries prefer or can afford to live. For example, Mining sector workers from Darwin, Litchfield and Palmerston work outside these locations but prefer to live here. This insight is confirmed through the higher levels of average industry net leakage in Mining occurring in LGAs outside of Darwin, Palmerston and Litchfield, particularly for remote LGAs as well as Alice Springs.

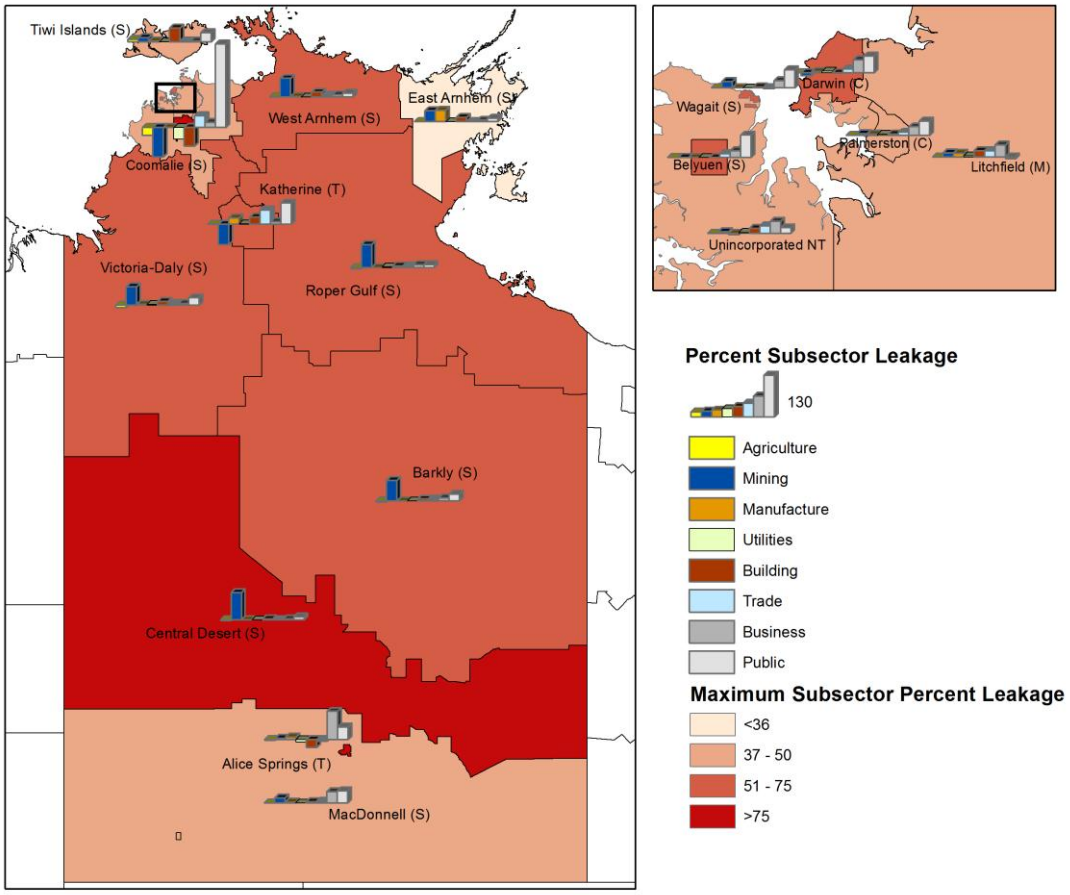
In contrast some workers in Trade and Accommodation, Business Services, and Utilities may prefer (or can only afford) to live on the periphery of Darwin in Palmerston and Litchfield. This appears to be confirmed in the differential of wage and salary incomes of mining relative to other industries (Blackwell, McFarlane & Blake 2014). Public and Personal Services are similar, exhibiting average subsector net leakage from Darwin to Palmerston – people from this industry prefer (or can only afford to) live in Palmerston with some draining of income from Litchfield.

FIGURE 8: GEOSPATIAL VISUALIZATION OF AVERAGE INDUSTRY SUBSECTOR INCOME NET LEAKAGE



Outside of Darwin and its surrounds and relative to other remote LGAs, East Arnhem appears to have the highest average net leakage of income across the most diversified distribution of industries, pointing to its overall vulnerability as a remote LGA. Common to all remote LGAs is a dominance of average net leakage income from Mining being directed into Darwin and surrounds. Out of all the remote LGAs, West Arnhem, East Arnhem, Roper Gulf and Alice Springs have significant levels of average industry net leakage income. For West and East Arnhem, Building, an industry associated with mining, is also contributing to average industry subsector net leakage income. Victoria Daly, Roper Gulf and MacDonnell are also experiencing average net leakage of income in Building associated with average net income leakage in Mining. Barkly is also experiencing average net income leakage in Building but dissimilarly with a small average net gain in Mining, Business Services and Public and Personal Services. There appears to be small average net gains to income from Agriculture in Victoria-Daly, Roper Gulf and Central Desert. These LGAs surround what is a significant cattle industry in the Barkly tablelands, and stock routes and associated industries in the surrounding interstate areas of north western Western Australia and Central Queensland (Blake et al. 2014).

FIGURE 9: GEOSPATIAL VISUALIZATION OF PERCENTAGE OF INDUSTRY SUBSECTOR INCOME NET LEAKAGE



Geospatial visualizations of the vulnerability of LGAs to income net leakage or gain are presented in Figure 9 along with bar charts that identify the main source of percent of income net leakage. Overall, the majority of remote LGAs have greater than 50 percent of their net leakage sourced from a single subsector industry. LGAs that have more than 75 percent of net leakage or gain in a single industry subsector include Coomalie, Central Desert, and Alice Springs. The bar charts for these LGAs show the industry source of this leakage and gain; Mining is the source in Central Desert, and for Coomalie, Public and Personal Services, while in Alice Springs Business Services is the main source. Note the particular concentration of leakage for Coomalie that is countered by considerable spread in other industries such as Mining, Agriculture, Utilities and Manufacturing.

Just as in Figure 8, across most remote LGAs mining plays a role in contributing to net leakage, with the shading for each LGA indicating the extent of net percent of leakage for the highest industry subsector. Note that as in Figure 8, Katherine appears to be a sink for mining net gain from surrounding remote mining LGAs such as Victoria-Daly, Roper Gulf, Barkly, and West and East Arnhem. These LGAs however are not experiencing the concentration of leakage compared to Central Desert. Katherine also appears to be incurring considerable leakage in Public and Personal Services and Trade and Accommodation as well as other industries. Regardless of remoteness, Public and Personal Services appear as a point of leakage, the only exception being Litchfield. Business Services are also relatively important to Alice Springs and MacDonnell and Darwin and surrounds, the latter depicted in the right hand map of Figure 9.

East Arnhem is interesting in having a moderated concentration of the percent of net leakage coming from a single subsector because of the dual role played by Mining and Manufacturing (see the similar bar charts for both industries in Figure 9). Despite this lesser measure of net leakage vulnerability, we found considerable employment concentration vulnerability for East Arnhem as reported in Blackwell et al. (in prep.). The expected connection between Mining and Manufacturing for East Arnhem may be hiding the extent of leakage concentration.

DISCUSSION

As per the internal labor migration theory and practice (e.g. Greenwood 1975, Sjaastad 1962), it is imperative to consider both the leakage and gains from commuting workers to establish the net leakage for each LGA. Looking at the single leakage flow associated with inbound workers is insufficient to gain a full picture of income leakage for a given LGA. Our contribution here therefore provides an important distinction in this regard and provides an indication of the order of magnitude of miscalculation where only leakage for inbound workers is considered.

As to be expected, because of the LDC nature of modern mining operations and given their usual distance from populated towns, we have also shown that mining has consistently contributed to the net employment income leakage for LGAs. This is particularly so for the remote LGAs where mining has an employment dominance, e.g. Central Dessert, MacDonnell, Roper Gulf, Barkly, Victoria-Daly, East Arnhem and West Arnhem. We do not presume to direct mining companies as to how they should conduct their business. Employing local people has found some resistance both from companies and from communities. People may not be well suited to working underground, even where they have the necessary skills, training and education and jobs are available. Dictating to communities and to companies as to employment arrangements runs contrary to the economic theory of fluid, flexible and efficient labor markets, precisely what LDC has provided the mining industry.

Dictating where people should live and work also runs contrary to the fluidity of associated markets such as the housing market and freedom of choice. We saw from the geospatial visualizations of average net income flows between Darwin, its surrounds and remote regions that decisions of where commuting workers prefer or can afford to live will ultimately be determined by their income and we argue should be left to the individual. Mining appeared to play a role in allowing workers to live in and around Darwin rather than in remote areas, while in other sectors such as Trade and Accommodation, Business Services, and Public and Personal Services, commuting workers lived in LGAs surrounding Darwin.

In contrast to the net leakage experience by most LGAs, only in a handful of LGAs is there a net gain from commuting to work such as in Alice Springs, Wagait, Litchfield and Palmerston. These occurrences of net gain, appear to be more a case of C-P theory (Krugman 1991) reflecting labor confluence with nearby LGAs. They reflect relatively close geographical locations for home on the periphery of employment centers rather than any driver from the nature of their industries. The exception is Alice Springs and there are at least three explanations for the net gain to Alice Springs. Firstly, it is only a relatively small geographical area, surrounded by much larger LGAs. Only a small distance needs to be travelled for workers to fall into another LGA and for the income gain to be recorded as received by Alice Springs.

Secondly, Alice Springs has a history of strength in the sectors other than agriculture and mining. These other sectors include Trade and Business Services with strong diversification also in Manufacturing, Utilities, Public Services and Building (and relatively low profiled average LQ spread – see Blackwell et al. in prep.). Alice Springs is renowned for its competitive advantage in trade sectors such as tourism, particularly natural and cultural tourism. Most of these tourism related operations might lie outside Alice Springs itself in neighboring areas and towns, e.g. Uluru and Yulara. Therefore people commute to work in these locations and then return home to Alice Springs.

Thirdly, Alice Springs has experienced a decline in particular types of economic activity in recent years, no longer being a stop-off route to nearby locations for workers, such as in the case of mining in the Central Desert LGA, flights now go directly from Darwin or other capital cities to mine sites rather than via Alice Springs. With reduced economic activity, people from Alice Springs may have needed to look outside their LGA to secure employment and income.

The other interesting explanation for net employment and income leakage for remote LGAs for NT is the dominance of employment concentrations in manufacturing in Roper Gulf, MacDonnell, Katherine, Tiwi Islands, and West and East Arnhem. Added to these are those LGAs on the periphery of Darwin (and including Darwin itself) such as Coomalie. However, Palmerston and Litchfield also have the highest average industry employment concentrations in Manufacturing but have a net gain of employment and income. Manufacturing therefore only tells some of the story.

Finally, Wagait and Belyuen are different from all other LGAs. Wagait has the highest industry average employment concentration in Building followed by Trade and Business and Public Services, but we understand its specialty as a place for people commuting to work in Darwin by Ferry and then returning for rest and relaxation in the form of a home LGA. This is the reason for its net gain in employment and income. Belyuen has its highest industry employment concentration in Public Services followed by Business Services and Trade. In common to all three LGAs that make a net gain in employment and income is a dominance of Trade and Business Services employment concentrations. These sectors therefore appear to be the reason for people being prepared to travel out of their home LGA for work in another LGA, bringing home income. Again, this finding appears to be consistent with C-P theory.

Three salient points can be made in light of the results from the geospatial visualizations presented in this article. Firstly, these visualizations provide a particularly powerful tool for summarizing the geographical dynamics resulting from labor related income flows between LGAs. As we saw in Figures 6, 9 and 10 and given the remoteness of most of the Northern Territory and the shortage of labor within its remote regions, it was shown that the demand for labor from Mining was met in part by commuting workers from other LGA's within the Northern Territory. We saw that much of the leakage resulting from Mining in remote NT was being sourced from Darwin and its surrounds as well as from Coomalie and Katherine. What this means is that even though some LGA's may lose income, others will also be benefitting, and the role of FIFO and DIDO has helped to facilitate increased choices for workers as to where they would prefer or can afford to live.

A second consideration is that the industrial relationships of a region determine the ability of labor to move between industries and LGAs during economic cycles of up and downturns. Consequently, the complexity of the economic structure of a region reflects the relative influence of local industries, as measured by their regional links such as leakage or gain as well as the local industrial structure. This means that if a region has a greater economic dependence on two or less industries but draws on outside labor then the failure or removal of one industry will spread the shock more broadly across the source economies where workers live. In this case, not only are the benefits of the mining boom in the words of the Productivity Commission 'enjoyed more widely', but some of the downside risk from recent job losses will also be shared rather than simply residing solely with local remote economies.

Thirdly and related to the previous point about sharing downside risk, the geospatial visualization in Figure 10 helps to identify the extent of a region's ability to disperse employment vulnerability. For example, a shift in mining activity from a significant phase of capital investment to an operational phase will not only create reduced demand for housing for nearby mine associated towns but also in source towns or cities where workers live. The reduced demand for property puts downward pressure on rents. The previous higher prices of properties will only remain where other industries can substitute for any loss in demand. Highly structurally diverse regions are inherently guarded against failure of any one industry, because it has other industries to fill the gap, can quickly draw or disperse labor from or to outside regions, and can thus proceed with minimal economic loss. This means regional economic complexity, depends not only local industrial diversity, but also an ability of labor to be mobile across regions.

LIMITATIONS AND FUTURE RESEARCH

There are at least six limitations associated with our research, which in most cases warrant areas for future research. Firstly, where place of work and place of usual residence diverge, people are assumed to be commuting to work. While this is a reasonable assumption to assess leakage generally, how often, for what period of time, and how far away commuting to work occurs will determine the degree of leakage or gain for any given LGA. Certainly, the survey work of KPMG (2013) showed that using place of work and place of usual residence tends to underestimate LDC. Similarly, with our work, we expect that defining leakage by the divergence of place of work and place of usual residence also underestimates the extent of commuting but provides a conservative measure of associated leakage. Similar to the approach taken by KPMG (2013), surveys could be used to test the veracity of our assumptions and associated leakage results as has also been done in the travel cost literature to test assumptions of the method for valuing public goods (Johnson, McKean & Walsh 1995).

Secondly, the estimates used here for subsector average incomes are only indicative and could be supplemented by more accurate NT measures of average incomes by industry subsector. However, we have taken the average income for 111 subsectors in the Australian economy from the Australian Bureau of Statistics that provides a degree of precision.

Thirdly, and related to first point, our calculations of leakage are based on assumptions about where spending of wage and salary income is most likely to occur, that is, from home. Where this expenditure ultimately arrives as income, may be different to the residence location. However, what we have achieved is an initial assessment of likely leakage and gain based on place of work and place of residence. Investigation of where spending ultimately arrives as income, would be useful in testing the net leakage of salary and wage income between LGAs. For example, Blackwell & Dollery (2013) have previously considered this question at the company level using income shares for remote mining operations, the World Gold Council (2013) undertook such an analysis for its member companies, and other researchers, such as Atkinson (2009) and the International Monetary Fund (2007), have undertaken income share analysis for national and international geospatial domains.

Fourthly, a further possible criticism of our analysis derives from it being contained to wage and salary income. People earn income from other sources, like stocks and shares, property and royalties. Given that most people's incomes are predominantly derived from their employment (Australian Bureau of Statistics 2013b, International Monetary Fund 2007), our analysis is likely to be representative of most people rather than any given individual.

Fifthly, while a number of economic theories of labor migration could be drawn to explain the movement of people from home to work, the goal of this article was to simply describe this short-term movement, as one component of labor mobility to better understand the unusual nature of the NT and interaction between LGAs for employment. While we have identified possible reasons for commuting for particular LGAs and industries, providing statistically robust reasons for this commuting has been a fruitful vein of research. The recent international literature on explaining regional labor migration (see for example Biagi, Faggian & McCann 2011, Arzaghi & Rupasingha 2013, Faggian & Biagi 2011, Miguélez & Moreno 2014, Niedomysl & Fransson 2014, Rodríguez-Pose & Ketterer 2012) would be a useful starting point for such future research. Having said this, we have relied on census data, which represents observations of the entire population, unlike sample data. Inferential statistics in the case of censuses are therefore not necessary and descriptive statistics are ample.

Finally, considering short term labor mobility across a number of years, not just a single census year could also help to better describe the dynamic nature of employment and possibly provide greater power in predicting future scenarios for NT policy and decision makers. As national and regional governments prepare regional development plans, undertaking our analysis for a number of census years and regions would help decision makers to build predictive scenarios for future economic development and employment.

ENDNOTES

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