REGIONAL EMPLOYMENT RESILIENCE CAPACITY DURING AUSTRALIA'S EARLY COVID-19 PUBLIC HEALTH RESPONSE: AN ANALYSIS OF THE PAYROLL JOBS INDEX DATA SERIES

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ABSTRACT: The COVID-19 pandemic has had significant impacts on regional economies and, in particular, has been reflected in the ability of some regions to perform better in the face of an economic downturn than others. Set in the context of regional economic resilience and resistance, this paper presents an exploratory analysis of the impact of a national COVID-related shut-down in Australia on employment resilience across regions. Using data on the changes in payroll jobs, the paper identifies clusters of areas that can be differentiated according to their resilience during this period. The paper explores a range of possible determinants of regional resilience differences and suggests an agenda for a more extensive research endeavour.

KEYWORDS: COVID-19; Australia; employment; recession; payroll jobs data

1. INTRODUCTION

The COVID-19 pandemic has caused significant economic disruption in countries across the globe. Within Australia, once initial case numbers began to climb, the Federal Government introduced various measures to stop the virus's spread. While these were aimed at dealing with the public health emergency, the unintended economic consequences were wide-ranging, with significant impacts on labour markets as the national economy faltered. From a regional science perspective, the COVID-19 imposed lockdown provides an interesting case study on the effects of such an exogenous shock on regional economic performance, particularly the

performance of labour markets. It is clear, for example, that in the period following 30th March 2020, when national public health stay-at-home orders came into effect, employment across the country took a significant hit. At the time the Australian Bureau of Statistics Payroll jobs index (Australian Bureau of Statistics, 2020b) recorded a change in total payroll jobs between 14 March and 4 April of -6.0 per cent with an estimated unemployment rate of 6.2 per cent and an underemployment rate of 13.7 per cent (Australian Bureau of Statistics, 2021).

In thinking about this declining labour market performance, we might ask, how, in the wake of the COVID-19 slowdown, have different regions across Australia responded in employment terms? Have some regions done better than others? Have they been less affected by the broader economic slowdown, or put another way, have some regions been more resilient to the impacts of the downturn than others? At a national level, addressing these questions is important as it provides insights into the relative performance of regions when exposed to the same economic shock and in the case of COVID-19, illustrates the unintended consequences for the economy of the nationwide public health measures. In addition, by drawing attention to the uneven regional impact of the economic downturn, understanding these questions draws attention to the spatial inequalities that are created across and between regions and the short and long-run effects on individuals, households and businesses in different regions (Martin *et al.*, 2016).

Of course, these kinds of questions are not new. Understanding how different regions perform in the face of economic shocks has been a feature of the regional science and associated literature for some time (Barrios *et al.*, 2003; Clark, 1998; Fingleton *et al.*, 2012; Jeffrey, 1974). In the decade following the Global Financial Crisis, debates around regional performance continued, focusing on the concept of resilience as a means of framing the research agenda. Borrowing from a long-established tradition in biology and environmental science, regional resilience is defined as:

> The capacity of a regional or local economy to withstand or recover from market, competitive and environmental shocks to its developmental growth path, if necessary by undergoing adaptive changes to its economic structures and its social and institutional arrangements, so as to maintain or restore its previous developmental path, or transit to a new sustainable path characterised by a fuller and more productive use of its physical,

human and environmental resources (Martin and Sunley, 2015, p. 13).

As a concept, although it is recognised that the term resilience has wide-ranging definitions and frameworks for understanding (Martin and Sunley, 2015), it has been presented as a useful lens with which to view the heterogeneous nature of economic shocks across different places (Giannakis and Bruggeman, 2017). One of the more rigorous approaches to resilience within the regional science literature has been the work by Martin (2012) whose framework addressed four related dimensions of economic resilience: 1) resistance, which is related to the severity of the shock; 2) recovery, which is related to how well a region recovers from the initial shock; 3) reorientation, which is related to how the industrial structure of a given region changes during the recovery stage; and 4) renewal, which relates to the resumption of normal economic path-ways and growth trends (Figure 1).

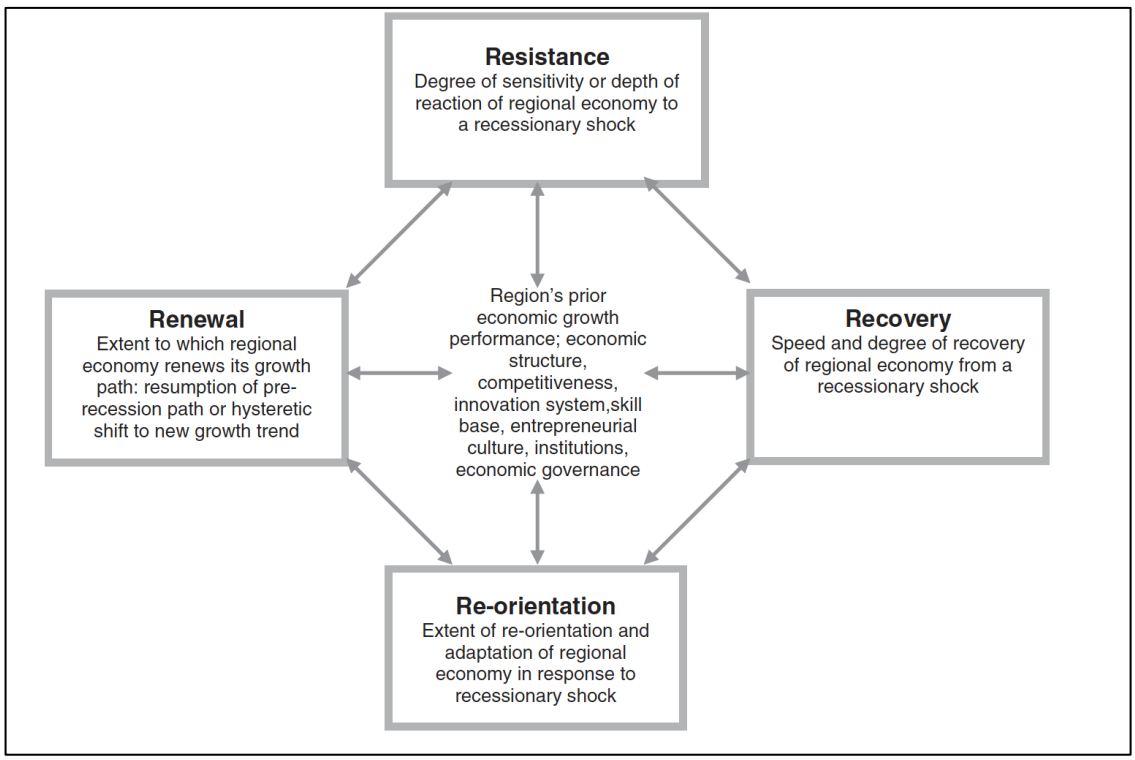

Figure 1. Four Dimensions of Regional Economic Resilience to a Recessionary Shock. Source: Martin, 2012.

In the context of the current paper, it is the resistance dimension which is of most interest and in particular resistance understood in terms of a region's vulnerability or sensitivity to an economic shock. For Martin (2012) a region's resistance to a shock was important as an underlying component with which to understand the processes of recovery, renewal and re-orientation with resistance being a product of a region's economic or industrial structure, its ability to innovate, the existing entrepreneurial culture, the existing formal and informal human capital of the workforce, and its particular governance structure. It is the combination of these characteristics that combine to create a region's level of resistance (Kim *et al*., 2022).

In terms of empirical studies, the analysis of regional resilience/resistance has taken many forms ranging from the use of case studies and the development of resistance indices to more complex time-series and structural economic models (Martin and Sunley, 2015). While some measures simply compare regions according to the percentage rise or fall in a particular indicator (i.e., employment), others have pursued different approaches. For example, Han and Goetz (2013) compared the actual regional output with trend output, arguing that the difference can be considered an illustration of the level of initial resilience/ resistance in any one region. The less a region's actual output deviates from the trend output, the higher the relative level of resistance to the initial shock. Similarly, Martin et al. (2016) measured regional resistance in terms of how regional change deviated from national-level change. In doing so, they argued

> since of interest is how different regions (or localities or cities) are affected by a common (nationwide) recession, a particular type of expected or 'counterfactual' reaction suggests itself, namely, the resistance and recovery of the national economy as a whole (Martin *et al.*, 2016, p. 565).

Over-and-above the measurement issue, an essential question about regional resilience is why it might vary between regions (Grabner, 2021). In a sense, this is the most important question from a policy perspective, as understanding the drivers of resilience provides insights into the kinds of policy prescriptions that might be most appropriate. As noted above, Martin (2012) postulates a range of factors in determining a region's resilience or resistance in the face of an economic shock and has, in a number of subsequent papers, provided empirical analyses.

For instance, Martin *et al.* (2016) considered the impact of recessionary shocks on regions in the United Kingdom and identified several critical factors that may have explained the difference in the level of regional

resilience during different recessionary periods. Although the authors identified different impacts and patterns across time, local industry structure together with regional-specific competitiveness effects appeared important. In a more recent paper, Martin and Gardiner (2019) considered the impact of the major recessions to have hit the United Kingdom between 1971 and 2015 and tested how these shocks impacted the level of resistance across 85 cities. The local industrial structure was once again a significant factor in explaining differences between regions, with those places reliant on manufacturing being less able to resist the initial economic shock than those places less manufacturing-focused. Interestingly, the negative impact of manufacturing declined during later recessionary shocks as manufacturing became less important in the overall economic structure of the country.

Besides, the work by Martin, others have also considered the issues of resistance and resilience, especially following the Global Financial Crisis. In a long-run analysis of economic shocks across Italian regions, Lagravinese (2015) found that the concentration of manufacturing and temporary workers was associated with weaker regional resilience, while concentrations of public sector employees and service industries were associated with greater levels of resilience. Considering the question of regional resilience in the United States, Ringwood *et al.* (2019) used monthly employment data for U.S. counties. They found that differences between regions were dependent on their position in the urban-rural hierarchy and the level of dependence on agricultural production and manufacturing industries. Agricultural-based regions in non-urban localities fared better than non-agricultural-based regions, while places less reliant on manufacturing across metro regions witnessed much better employment outcomes. In a similar paper focusing on US metropolitan regions (MSAs), Doran and Fingleton (2018) compared actual and predicted employment paths to measure the impact of the Global Financial Crisis. In explaining the differences in resilience and recovery between regions, the authors found that the economic crisis more adversely impacted MSAs that exhibited higher levels of specialisation but that the same high levels of specialisation helped during the recovery period. In addition, they noted that negative impacts were reduced in regions that recorded significant structural change during the period, while regional-specific contexts were also important for explaining resilience and recovery. In Australia, Courvisanos *et al.*, (2016) investigated regional resilience across Local Government Areas following the Global Financial Crisis and in the wake of a major drought and identified groups of regions

differentiated by both weak and strong regional resilience. As with other work in the area, the authors identified particular combinations of industry structure that were important in explaining regional resilience. They found, among other things, that strong resilience was found in the high-income areas across rural, regional and metro-core and periphery and it was particularly high in regions with concentrations in mining, construction transport and utilities, especially in rural localities.

Similar questions about regional resilience have begun emerging in a small but growing collection of literature focusing on the economic shocks associated with the COVID-19 pandemic. Importantly, these emerging studies find that regional economic resilience is influenced not only by factors that may be a-priori, thought to help or hinder resilience but also by several factors peculiar to the pandemic, such as the extent of public health measures and the introduction of specific government support packages. For instance, Turgel *et al.,* (2021), analysing data for urbanised regions in Russia, found that there are both significant differences between the impact of the COVID-19 pandemic on the economic performance of regions and that these differences can be explained by several factors including the severity of health-related restrictions on enterprises and the level of regional support. They found regions with significant population shares and large numbers of small and medium-sized businesses were the most vulnerable to the COVID-induced economic slowdown. In contrast, regions where agro-industrial and industrial organisations were strongest, and enterprises could continue operating showed greater stability. Focusing on regional economic resilience in Northeast China, Hu *et al*., (2022) found that regional resilience was shaped by a region's industry structure, the level of regional innovation, industry specialisation, openness and the level of government support. Importantly, they noted that government public-health measures to contain the spread of the pandemic were essential in shaping resilience and the level of recovery in a given region. Brada *et al.,* (2021) focusing on employment changes in Central and Eastern Europe, found that the level of regional economic resilience is driven by the ability of regions to be able to alter their economic structure during the downturn and part because of the presence of strong spatial spillover effects where highly resilient regions feed off other highly resilient regions. Taking selected industrial data for US states, Kim *et al.* (2022) consider how resistance to the COVID-19-induced economic recession differed across space and time noting the importance of industry structure in determining the level of resistance to a local state economy. In particular, they noted that states heavily reliant on non-essential industries

with high levels of interpersonal interactions had lower levels of resistance reflecting the unintended consequences of government public health policy which effectively shut down these kinds of industries. Conversely, they found that higher levels of resistance were measured in states with higher levels of essential industries with lower interpersonal interactions.

The issues outlined above set the context for the remainder of the paper. Using data from the Australian Bureau of Statistics payroll jobs index series (Australian Bureau of Statistics, 2020b), the paper analyses employment resistance/ resilience for Australian regions focusing on the initial period of national lockdown. The paper has several aims:

1. To identify the patterns of employment change across Australian regions and, in turn, scope out variations in levels of regional resistance/ resilience.
2. Consider the variable that may help understand the patterns identified.
3. Illustrate the payroll jobs index's usefulness in measuring employment resistance/resilience across regions.

2. METHODOLOGY, DATA AND APPROACH

The empirical objective of this paper is to undertake a regional-level analysis of the changes occurring in employment during the first phase of the Australian government's COVID-19 public health response, and in particular to present an analysis of regional employment resilience. In doing so, the paper considers two points. Firstly, what are the patterns of employment change across regions, and secondly, how can these differences be understood in terms of a range of possible differentiating variables?

Determining Patterns of Change

The existing literature dealing with the question of regional employment change has offered a range of possible approaches, depending on the data types used and the investigation's overall aim. This paper uses a longitudinal database of fortnightly changes in the Australian Taxation Office's single-touch payroll data available from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2020b). The index is benchmarked to a value of 100 in the week where Australia recorded its 100th confirmed case of COVID-19 (week ending 14 March 2020). For the analysis conducted here, we use data from 14th March 2020 to 25th April

2020 is used (Australian Bureau of Statistics, 2020a). This represents the period from which the country's strict public health lockdowns came into effect to the time when nationwide restrictions began easing (Stobart & Duckett, 2022). Rather than using the raw index provided by the Australian Bureau of Statistics, the data were transformed to measure the deviation in the payroll jobs index of each region at each point in time, compared to the corresponding national level index numbers. This is a similar approach suggested by (Martin and Sunley, 2015) and others. A positive number implies that the region is performing better than the national average (i.e., the index number for a given period is higher than Australia's). In contrast, a negative number reflects the opposite scenario. In this way, we are measuring how, as a result of the public health measures and the subsequent economic slowdown, regions are performing relative to the overall national level trend.

To track the changes in the measure of employment resilience across the period addressed in this paper, it was necessary to use an approach that allowed the outcomes across many regions to be expressed in a straightforward manner. To this end, a data clustering approach was used to develop sub-groups that would help identify the broad patterns of change the paper focuses on. Several methods are available to cluster or partition data into meaningful sub-groups. Clustering methods range from largely heuristic approaches to more formal modelling procedures that adopt statistical models to group data. The challenge of analysing the data used in this paper is to identify a suitable clustering approach that produces robust outcomes when using longitudinal data. In this paper, we use the longitudinal k-means (KML) (Genolini and Falissard, 2010) algorithm in R was used to undertake the analysis. Longitudinal k-means is a widely used approach within the health and social sciences literature and has produced robust results in several comparison studies (Den Teuling, *et al*., 2020; Genolini and Falissard, 2010). The longitudinal k-means approach provides statistical output to aid in selecting the most appropriate number of clusters. It produces output including summary measures and files containing cluster membership that allows further analysis of the groups to be undertaken.

Identifying Differentiating Variables

Apart from clustering the regions to identify the different patterns of employment resilience, the paper aims to consider how the clusters differ from one another. There are several possible approaches, including the use

of some form of multivariate discriminant analysis (Baum *et al*., 2005; Hill *et al*., 1998) or the visual examination of confidence intervals around the mean for each cluster (Masson and Loftus, 2003). For the analysis presented in this paper, we utilise a simple analysis of variance (ANOVA) approach with appropriate multiple comparison tests. This allows us to identify significant differences in group means across a range of variables (see below) and understand how the individual clusters differ from each other.

The data used to compare the cluster outcomes are presented in Table 1. They represent a group of variables that may be assumed, a-priori, to aid in understanding the differential outcomes of employment across regions. They include measures of industry specialisation (Herfindahl-Hirschman Index), data on industry sector employment, levels of employment remuneration, human capital and labour force structure. These types of indicators have been shown in a range of existing research to be potentially significant in explaining differences in regional economic resilience (Brada *et al.*, 2021; Courvisanos *et al.*, 2016; Doran and Fingleton, 2018; Hu *et al.*, 2022; Martin *et al.*, 2016). All of the data relates to the characteristics of people as measured in the Australian Bureau of Statistics' usual residence census geography. This provides the most appropriate alignment with the payroll jobs index, which relates to the residential address of the employee.

Spatial Units

For this paper, the primary consideration when choosing a spatial unit of analysis is to ensure comparability between the units used in the payroll jobs index and the units available within the Australian Bureau of Statistics census geography framework. Payroll jobs data is available at either the Statistical Area 3 or Statistical Area 4 level of aggregation. Whilst either could have been used, the SA3 level was chosen in this instance. The ABS designs SA3s to

> provide a regional breakdown of Australia. They generally have a population of between 30,000 and 130,000 people. In regional areas, SA3s represent the area serviced by regional cities that have a population over 20,000 people. In the major cities, SA3s represent the area serviced by a major transport and commercial hub (Australian Bureau of Statistics, 2017, para 4).

As such, the SA3s provide a good level of aggregation to consider regional employment outcomes.

Table 1. 2016 Census of Population and Housing Data. Source: the Authors.

Specialisation Index for 2016 (Herfindahl-Hirschman Index)
Per cent employed in Agriculture, Forestry and Fishing
Per cent employed in Mining
Per cent employed in Manufacturing
Per cent employed in Electricity, Gas, Water and Waste Services
Per cent employed in Construction
Per cent employed in Wholesale Trade
Per cent employed in Retail Trade
Per cent employed in Accommodation and Food Services
Per cent employed in Transport, Postal and Warehousing
Per cent employed in Information Media and Telecommunications
Per cent employed in Financial and Insurance Services
Per cent employed in Rental, Hiring and Real Estate Services
Per cent employed in Professional, Scientific and Technical Services
Per cent employed in Administrative and Support Services
Per cent employed in Public Administration and Safety
Per cent employed in Education and Training
Per cent employed in Health Care and Social Assistance
Per cent employed in Arts and Recreation Services
Per cent low-income jobs
Per cent part-time jobs
Unemployment rate of sub-region
Per cent of employed people with low education

3. RESULTS

Determining Patterns of Regional Employment Resilience

As indicated above, the first stage of the analysis presented in this paper focuses on determining the broad patterns of regional employment resilience during the initial COVID-19 lockdowns in Australia. Given the

longitudinal nature of the payroll jobs index, a longitudinal k-means (kml) package was initiated in R and produced a set of possible cluster outcomes. As with most clustering approaches, an important decision needs to be made regarding the number of clusters to choose. Many clustering algorithms produce a standard statistical measure to guide the final choice. The default measure in kml is the Calinski and Harabatz criterion, and for interpretation, the R package produces a graphic representation (Figure 2) (Genolini and Falissard, 2010).

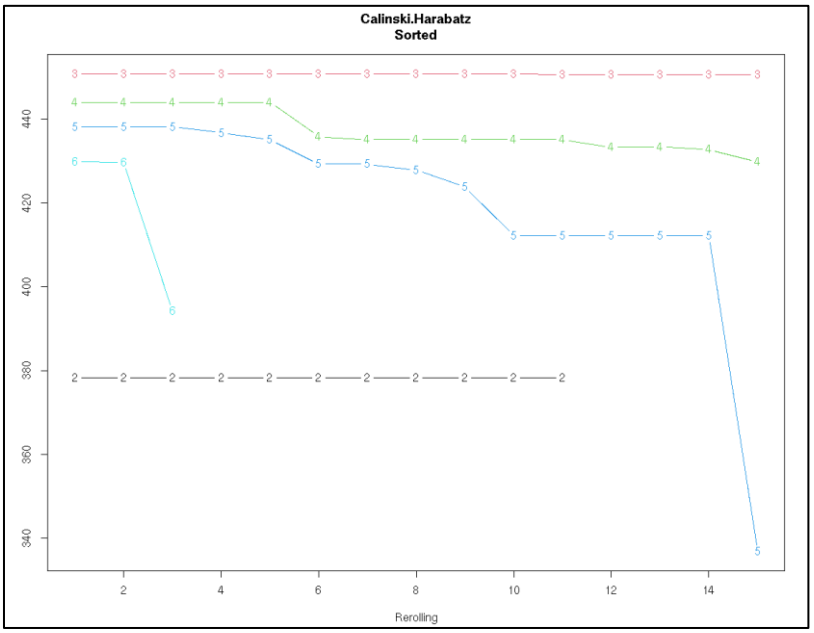

Figure 2. Calinski and Harabatz Scores. Source: the Authors.

Although measures such as the Calinski and Harabatz criterion provide quantitative guidance to the potential final cluster solution, a cluster solution will often be chosen on a more qualitative basis. Gittleman and Howell (1995, p. 424) have argued that 'far more compelling for our purposes than any mechanical rule, however, is whether, …, the cluster analysis produces… groups that are meaningful'. That is, while the standard statistical measure may suggest one cluster solution, the choice of outcomes may also be influenced by whether the groupings of observations allow the researcher to present an analysis that, at face value, provides valuable outputs. Given the results from the Calinski and Harabatz criterion shown in Figure 2, and also considering Gittleman and Howell's

argument it might be reasonable to conclude that either the 3, 4 or 5 cluster solutions provide suitable results, as these provide relatively similar scores, especially in the early stages of the clustering process. Following an initial scan of the clusters, including the membership of each group, it was decided that the output containing 4 clusters would be used for further analysis.

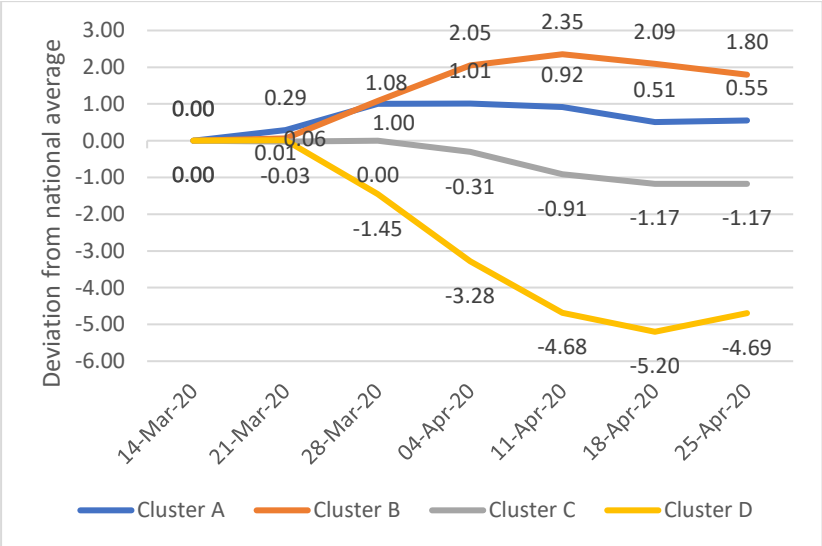

Figure 3. Average Trajectories, Four Cluster Solution. Source: the Authors.

The output of the clustering analysis is presented in various forms in Figures 3 to 5 and Table 2. Figure 3 shows the average trajectories obtained from the longitudinal k-means analysis using the 4-cluster solution. Table 2 provides details of the share of regions in each cluster, together with the average deviation of the payroll jobs index over the lockdown period. The information presented in Figure 3 relates to the relative share of each cluster comparing urban areas with regional and rural areas. Figure 5 presents information on the relative shares of the four clusters between Australian States and Territories. These two figures represent a regional States and Territories. These two figures represent a regional concentration ratio. The regional concentration ratio is a version of a location quotient. It determines the extent to which any region (e.g. state) has an overconcentration of localities in a particular cluster. The RCR is calculated by considering the percentage distribution of particular clusters

in each region divided by the percentage distribution of that cluster across all regions. An RCR greater than 1 indicates that the number of regions in cluster is overrepresented. An RCR of less than 1 means the opposite outcome. Details on individual SA3s included in each cluster can be obtained from the authors. In addition, Figure 6 maps the cluster outcomes across all states and territories.

Given that the payroll jobs index was transformed to represent regional employment resilience, the four clusters represent four different scenarios about resilience across regions. Clusters A and B represent regions that, in general, performed better (more resilient) than the average across time, while clusters C and D represent regions that performed worse (less resilient).

Cluster A contains 117 SA3s, or 35.2 per cent of the total. Over the lockdown period, the deviation from the average payroll jobs index was 0.61. In relative terms, Cluster A regions were more likely to be regional or rural/remote and were relatively overrepresented in Victoria, Western Australia and the Australian Capital Territory. The geographic distribution implied by the regional concentration ratios is also evident in Figure 6. Cluster B represents the second group of regions that may be considered to represent regions with high employment resilience. The cluster contained 34.0 per cent of the entire sample of SA3s and, over the period of analysis, had an average payroll jobs index deviation of +1.35. In relative terms, SA3s in this cluster were more likely to be located in major urban regions. They were more likely to be in New South Wales, Queensland, Northern Territory and the Australian Capital Territory. Again, as with cluster A, the individual state geographies can be seen in Figure 6 and reflect the findings and the relative distributions.

Cluster C represents the first of two groups of regions exhibiting lower resilience. Around one-quarter (25.3 per cent) of the SA3s in the analysis are in this cluster. The overall trend in payroll jobs index deviation can be seen in Figure 2, with the cluster displaying minor deviations early in the period, with larger increases from early April 2020. The negative deviations were only small, as suggested in the average deviation of -0.60. The regions in this cluster are more concentrated in regional or rural/remote areas and the states of Victoria, South Australia, and Tasmania. As with the previous clusters, these patterns are also evident in the maps presented in Figure 6. The final cluster (cluster D) represents the second of the groups with low employment resilience. It is clear from Figure 2 that this group of regions suffered significant job losses during the period, with an average deviation of -2.76. In relative terms, the regions in

this cluster were more likely to be located in regional or rural/remote areas and, although present in each state, were over-represented in Queensland and Tasmania. These patterns are also indicated in the maps presented in Figure 6.

Table 2. Average Deviation from the National Average. Source: the Authors.

	Percent of SA3s	Average deviation
Cluster A	35.20%	0.61
Cluster B	34.00%	1.35
Cluster C	25.30%	-0.60
Cluster D	5.40%	-2.76

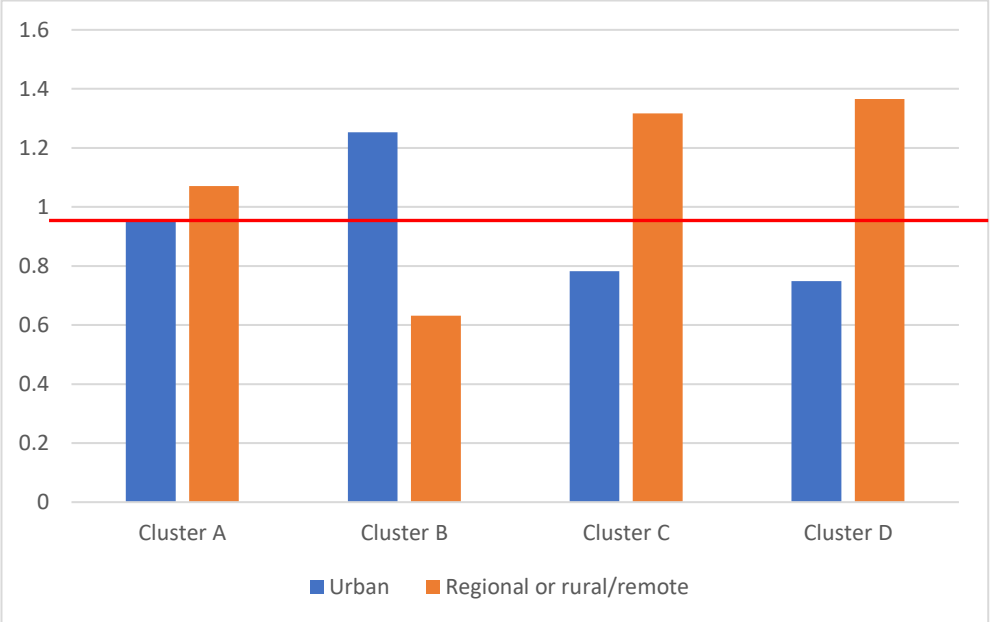

Figure 4. Regional Concentration Ratio, 4 Clusters Urban and Regional or Rural/Remote Areas. Source: the Authors.

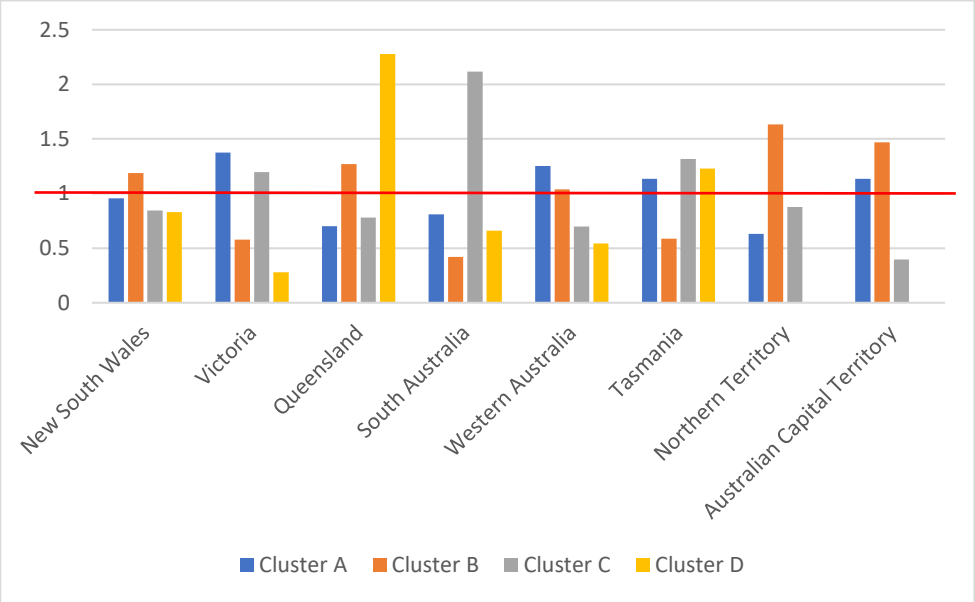

Figure 5. Regional Concentration Ratio, 4 clusters States and Territories.
Source: the Authors.

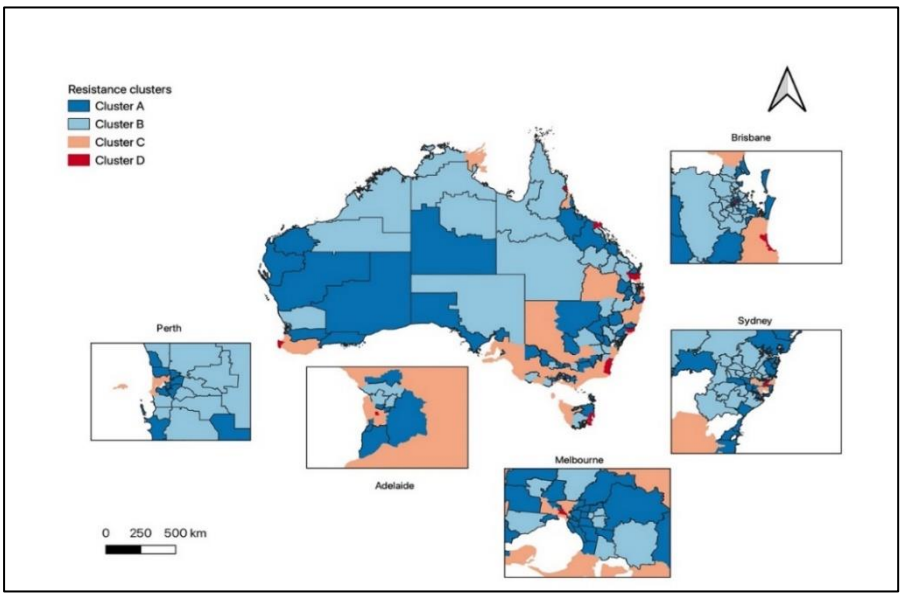

Figure 6. Employment Resistance Clusters, Australia. Source: the Authors.

Identifying Differentiating Variables

So far, the paper has outlined the broad patterns associated with regional employment resilience during the initial COVID-19 lockdown. The second component of the analysis presented in this paper considers the factors that may aid in differentiating the patterns represented by the four clusters outlined above. A range of indicators was thought to provide points of difference between the four clusters (see methodology). Table 3 presents the results of individual ANOVA tests for each variable across the cluster outcomes to consider these differences. Table 4 shows the results of the multi- comparison tests illustrating the significant differences between clusters. Of the 23 variables considered, 12 exhibited significant F-statistics at the 0.05 level:

- Per cent employed in Construction
- Per cent employed in Wholesale Trade
- Per cent employed in Accommodation and Food Services
- Per cent employed in Financial and Insurance Services
- Per cent employed in Rental, Hiring and Real Estate Services
- Per cent employed in Professional, Scientific and Technical Services
- Per cent employed in Administrative and Support Services
- Per cent employed in Education and Training
- Per cent employed in Health Care and Social Assistance
- Per cent employed in Arts and Recreation Services
- Per cent of part-time jobs
- Per cent with low education

While the F- statistics provide an indication of the overall significance of the variable in relation to the four regional employment resilience groups, to understand the differences between the clusters on the globally significant variables, the results of the multi-comparison tests run as part of the ANOVA process are presented. These tests identify which cluster/s differ significantly from others and are presented in Table 4.

One of the first points of distinction from the multi-comparison tests is the outcomes for the 2 clusters exhibiting the smallest levels of payroll jobs index deviation (resilience measure). When clusters A and C are compared, significant between cluster outcomes are recorded for the percentage employed in accommodation and food services and in administrative and support services. The SA3s showing higher levels of employment resilience (cluster A) had lower average employment levels in

accommodation and food services and administrative and support services while cluster C recorded higher levels of employment in these sectors.

Table 3. Analysis of Variance Results. Source: the Authors.

	Cluster A	Cluster B	Cluster C	Cluster D	Total
Herfindahl-Hirschman Index	959.4	961.9	932.8	919.6	951.4
% employed in Agriculture, Forestry and Fishing	4.53	4.86	6.17	3.27	4.99
% employed in Mining	2.38	2.99	1.30	0.49	2.21
% employed in Manufacturing	6.90	6.82	6.60	4.24	6.65
% employed in Electricity, Gas, Water and Waste Services	1.02	1.19	1.06	0.89	1.08
% employed in Construction **	**7.43**	**8.95**	**7.15**	**6.59**	7.83
% employed in Wholesale Trade **	**2.57**	**2.87**	2.42	**1.60**	2.58
% employed in Retail Trade	10.99	10.78	10.77	10.25	10.82
% employed in Accommodation and Food Services **	**7.36**	**6.60**	**8.29**	**13.37**	7.66
% employed in Transport, Postal and Warehousing	4.15	4.67	4.33	3.56	4.34
% employed in Information Media and Telecommunications	0.97	0.99	1.05	1.59	1.03
% employed in Financial and Insurance Services **	**1.85**	**1.72**	**1.92**	**4.05**	1.94
% employed in Rental, Hiring and Real Estate Services **	**1.63**	**1.50**	**1.67**	**2.48**	1.64
% employed in Professional, Scientific and Technical Services **	**5.24**	**4.87**	**5.21**	**7.61**	5.23
% employed in Administrative and Support Services **	**2.83**	**2.78**	**3.02**	**4.03**	2.93
% employed in Public Administration and Safety	6.01	6.68	6.23	6.10	6.30
% employed in Education and Training **	**10.21**	**9.82**	9.21	**7.72**	9.69
% employed in Health Care and Social Assistance **	**13.97**	**11.82**	**13.79**	11.89	13.08
% employed in Arts and Recreation Services **	**1.65**	**1.35**	**1.74**	**2.68**	1.63
% low income jobs	20.2	19.6	20.6	19.5	20.1
% part-time jobs **	**35.7**	**33.1**	**36.4**	36.7	35.1
Unemployment rate of sub-region	6.7	6.8	6.6	7.3	6.8
% employed persons with low education **	35.9	**37.2**	36.0	**33.7**	36.2

**= Significant at 0.05

In contrast to Clusters A and C, the two groups that recorded the more extreme levels of high and low regional employment resilience (Cluster B and D) recorded widely varying employment characteristics. Of the 23 variables included in the analysis, ten were significant when the results of the multi-comparison tests are considered. The direct comparison of cluster

Table 4. Results for Multi-comparison Tests. Source: the Authors.

	Cluster A compared to	Cluster B compared to	Cluster C compared to	Cluster D compared to
Cluster A		-Construction - Accommodation - Health Care - part-time	- Accommodation (+) - Administrative (+)	-Wholesale Trade - Accommodation - Financial - Real Estate -Professional - Administrative - Education - Arts
Cluster B	-Construction - Accommodation - Health Care - part-time		-Construction - Accommodation - Administrative - Health Care - Arts - part-time	-Construction (-) -Wholesale Trade (-) - Accommodation (+) - Financial (+) - Real Estate (+) -Professional (+) - Administrative (+) - Education (-) - Arts (+) -low education (-)
Cluster C	- Accommodation (-) - Administrative (-)	-Construction - Accommodation - Administrative - Health Care - Arts - part-time		- Accommodation - Financial - Real Estate -Professional - Arts
Cluster D	-Wholesale Trade - Accommodation - Financial - Real Estate - Professional - Administrative - Education - Arts	-Construction (+) -Wholesale Trade (+) - Accommodation (-) - Financial (-) - Real Estate (-) -Professional (-) - Administrative (-) - Education (+) - Arts (-) - low education (+)	- Accommodation - Financial - Real Estate -Professional - Arts	

B to cluster D shows that higher employment resilience is associated with higher employment in Construction, Wholesale Trade, and Education and Training and higher proportions of employees with low education attainment. In contrast, the lower employment resilience of Cluster D is associated with higher proportions of employment in Accommodation and Food Services, Financial and Insurance Services, Rental, Hiring and Real Estate Services, Professional, Scientific and Technical Services, Administrative and Support Services, and Arts and Recreation Services.

4. CONCLUSION AND DISCUSSION

This paper has analysed regional employment resilience across Australia during the early stages of the nationwide COVID-19 lock-down. The strict lockdown, which lasted several weeks, had almost immediate impacts on employment, resulting in varying levels of employment resilience. The paper had three primary aims—two empirical aims related to contributing to an understanding of regional employment resilience. A further methodological purpose was related to using the Australian Bureau of Statistics payroll jobs index as an indicator of regional employment resilience.

What did the analysis suggest about regional employment resilience in the early period of the COVID-19 economic shutdown in Australia? The paper has shown that a distinct pattern of regional employment resistance and resilience existed during the COVID-19 lockdown, with some regions being characterised as resilient and others as lagging. While the patterns are complex in a comparative sense, it is clear that regional employment resilience is driven to some extent by the presence of employment in industries deemed ‘essential’, while negative or low resilience is driven by an employment structure with heavier reliance on either non-essential industries or in industry's that are reliant heavily on face-to-face interactions, or the ability of people to travel. Given that the economic geography of industry and employment characteristics are well understood, it is little wonder that the patterns identified here have emerged. Inner cities where agglomeration economies have resulted in the concentration of certain businesses - finance, real estate, administrative support services – have seen employment suffer due to the government-imposed national shutdown. Similarly, regional tourist zones reliant on international and intra-national travel have also had their employment resilience tested.

The mythological aim follows directly from these empirical aims. The analysis results suggest that the Payroll Jobs Index series is potentially a

useful indicator for considering both short and long-run transitions and changes in regional employment. The space-time nature of the dataset means that research questions involving regional resilience and recovery can be considered in some detail. Being able to undertake these kinds of analyses has been hampered in the past due to the availability of appropriate data sets. Often researchers are reduced to using census data collected at two distinct and often lengthy periods which may not capture short-run changes and transitions or allow a comprehensive understanding of periods of decline and recovery. When properly applied, such data should provide a robust evidence base with which to design and appraise policy measures aimed at building and repairing regional economies.

The analysis presented in this paper does carry with it several caveats. In terms of analysis, the paper has only focused on a single period. As such it has not attempted to provide a comparison of regional employment resilience during the period of economic slowdown with a comparative 'normal' period. Although this would provide significant analytical rigour, the payroll data did not exist prior to 2020, therefore negating the possibility of a pre-COVID comparison. Moreover, it is reasonable to argue that at the time of writing, the Australian economy had not returned to a 'normal' state and hence analysis of a later set of data may not provide useful comparisons.

Methodology, the clustering process used is open to debate and possible criticism depending on the type of clustering method used. Here we used longitudinal K means clustering. Others have suggested that a more robust result may be obtained using a clustering algorithm such as Latent Class Growth Models or GMM (Den Teuling *et al.*, 2020). Whether the use of such approaches results in an improvement or modification of the results identified here is an interesting question that will be tested in future papers. Another important caveat relates to the choice of cluster numbers. The choice made here was driven by both the statistical testing regime and also more qualitative approaches. There is no denying that cluster number choice impacts the outcomes just as the choice of clustering approach does. As there is generally no universally agreed or best approach to cluster number selection, it is prudent to consider the choice method when reviewing the analysis and discussion presented here.

Finally, there are questions about the choice of spatial units. In this paper, we have chosen to use Statistical Area 3 regions. However, the payroll jobs index series is also available at the next highest level of aggregation (SA4s). The areas chosen will impact the outcome and interpretation- the Modifiable Area Problem- resulting in an often-vexed choice between

detail and interpretability. This is not to say that one level of aggregation is right and the other is wrong, but instead that the potential for issues needs to be kept in mind when considering the analysis and discussion presented here.

At the time of writing, it is clear that the full impacts of COVID-19 are still being played out. This paper has conducted an exploratory analysis of regional economic resilience during the first phase of national public-health lockdowns. Future research of this ilk informed by the significant regional science literature on regional economic performance will be required to understand the impacts of COVID-19 on regional economies fully, not only in Australia but elsewhere.

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