THE RESPONSE OF THE AUSTRALIAN STATES TO A NATIONAL ECONOMIC SHOCK: A STATISTICAL ANALYSIS OF REGIONAL ECONOMIC RESILIENCE

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ABSTRACT: It is well known from the literature on regional business cycles in Australia that there are significant differences between the time-paths of economic activity of the Australian states. These differences must result from either differences in the response of the state economies to a common national shock and/or their response to state-specific shocks. The way in which a regional economy reacts to a national shock is closely related to the notion of regional economic resilience, a concept that has gained considerable popularity in the regional economics literature of the past decade or so. It has become common in that literature to distinguish between engineering resilience (the ability of a regional economy to return to the original equilibrium following a negative shock) and ecological resilience (the convergence of regional economies to new equilibria). The economic resilience of the Australian states is the focus of the research reported in this paper.

We analyse resilience within a vector-autoregressive (VAR)/vector-error-correction (VEC) model using monthly employment data for the states and the nation as a whole from the 2nd quarter 1978 to 1st quarter 2019. We find that employment growth rates are stationary so that, in terms of growth rates, the state economies are resilient in the engineering sense, although they may revert to equilibrium at different rates. The (log) levels of employment, however, are non-stationary but cointegrated, suggesting ecological resilience in employment levels since cointegration implies that the cointegrated variables return to (likely new) equilibria following a shock. We use a VEC model to identify a national shock, generate responses of the state employment levels to this shock and compare the resulting time-paths (the impulse response functions) to assess relative resilience. We find that Western Australia is the least sensitive of the states to a national shock and so the most resilient, while the economies of Tasmania and Victoria are the most sensitive to an adverse national shock and so the least resilient. The responses of the other states are all quite close to the national average response, indicating little difference in the resilience of New South Wales, Queensland and South Australia.

KEY WORDS: Regional economic resilience; regional employment; Australian states; national economic shocks

1. INTRODUCTION

While the disparities between the economic performance of Australia's state economies are not large by international standards, there is, nevertheless, frequent comparison of economic outcomes at the state level in the news media—wages growth, unemployment rates, rates of job growth, house prices and so on. For example, in 2018 the ratio of the per capita GDP for the poorest state in the US (Mississippi) to that for the nation is 0.75 while that for Australia (Tasmania) is 0.80. The comparable figure for the Canadian provinces is 0.76 for Prince Edward Island. Disparities are typically considerably higher for developing countries; thus, for example, for China the ratio GDP per capita of the poorest province (Gansu) to that for the whole country is 0.48. In the first decade of this century there was frequent talk of a 'two-speed economy' with the resource-rich states of Queensland and Western Australia growing for a considerable time at above the national average and the remainder of the country generally growing at below the Australian rate. More recently, this relativity has been substantially reversed, with Queensland's growth slowing significantly in the last decade and Western Australia's growth rate becoming negative with the winding down of the mining boom, bottoming out in 2017. Similar patterns are evident in the states' employment growth rates. Figures 1 and 2 display growth rates in output and employment for the states (and territories) and for the rest of the country (Australia *less* the state in question).

There are several important features of the data shown in the two figures. First, there are differences between the state/territory growth rates and the national growth rate. Second, the relationship between the national and state/territory growth rates varies considerably across state/territories. Loosely, the coherence between the national and state/territory output growth rates varies directly with the relative size of the state/territory. This is more or less borne out by the growth rates and the correlations in Table 1, although there, the low correlation for Western Australia is a surprise in light of Figures 1 and 2.

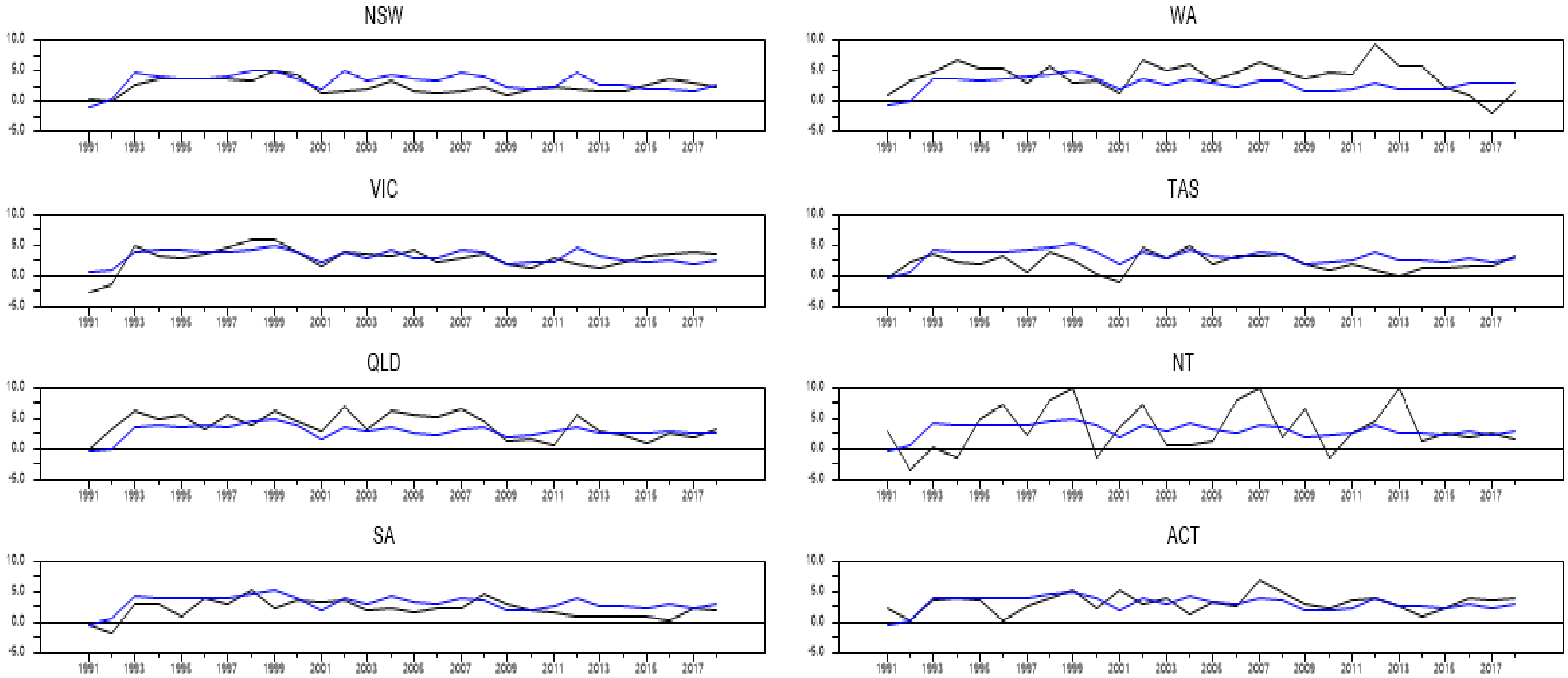

Figure 1. National and State Output Growth, Annual, 1991 to 2018. Note: Blue line = national, Black line = state. Output data are real Gross Domestic Product (GDP) for Australia and real Gross State Product (GSP) for the states and territories. Source: Author's calculations; Data sources are described below.

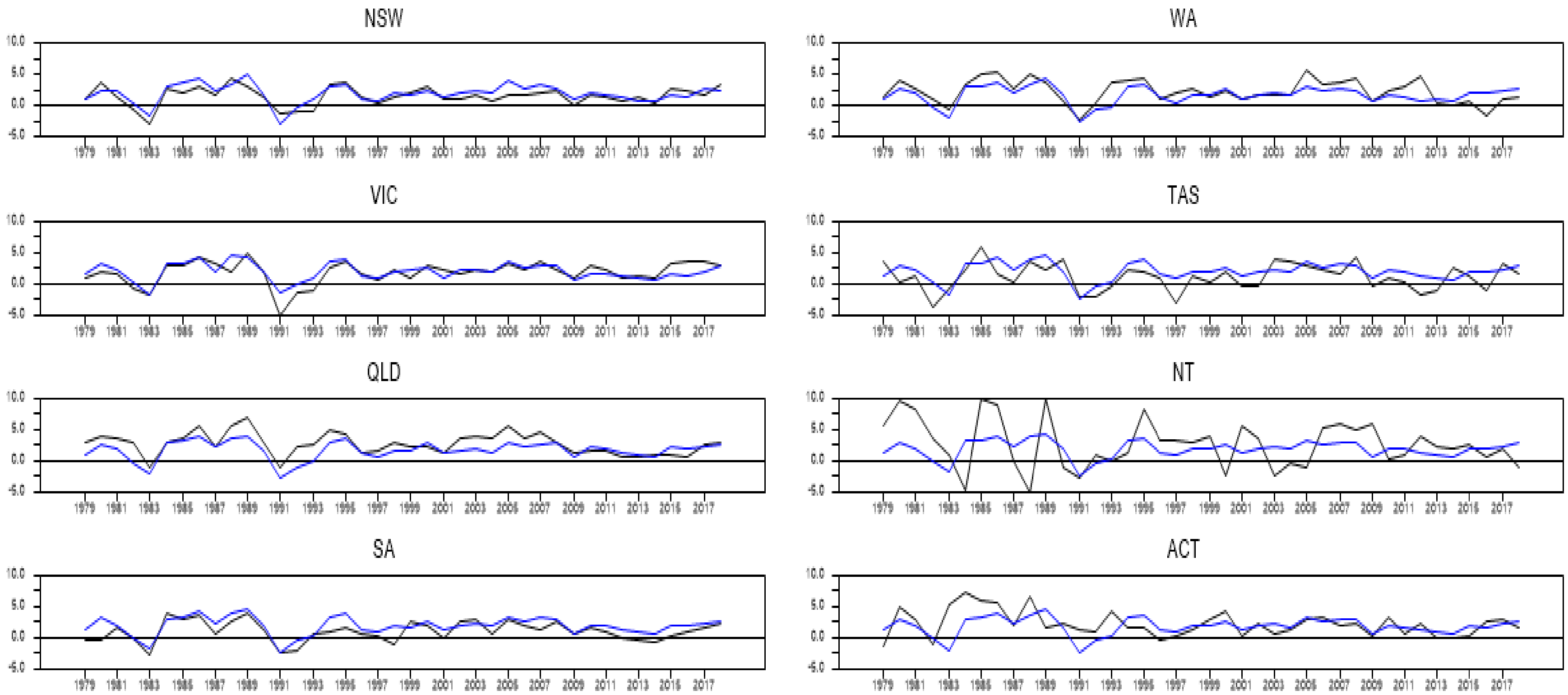

Figure 2. National and State Employment Growth, Annual, 1979 to 2018. Note: Blue line = national, Black line = state. The employment data are annual averages of monthly employed persons (seasonally adjusted) for the states, territories and Australia. Source: Author's calculations; Data sources are described below.

Table 1. Annual Real GDP/GSP Growth Rates, 1991-2018.

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST
1991-2018	2.6	2.9	3.9	2.1	4.3	2.0	3.5	3.2	3.1
1991-2000	3.2	3.0	4.4	2.3	4.2	2.0	3.1	2.8	3.3
2001-2010	2.0	2.8	4.4	2.7	4.8	2.6	3.9	3.6	3.1
2011-2018	2.6	2.8	2.5	1.3	3.7	1.4	3.7	3.1	2.7
Rho	0.76	0.87	0.76	0.64	0.49	0.49	0.31	0.35	1.00
Adj Rho	0.55	0.72	0.59	0.58	0.25	0.46	0.28	0.34	NA

Notes: figures in the first four rows are average annual real growth rates; figures in the ‘Rho’ row are correlations between the state and Australian growth rates over the period 1991-2018 and figures in the ‘Adj Rho’ row are correlations between growth rate of each of the states and the rest of the country. Source: Author’s calculations.

The employment data in Figure 2 and Table 2 tell a broadly similar story, with New South Wales, Victoria, and South Australia showing relatively strong similarity with the rest of the nation, followed by Queensland, Western Australia, Tasmania and, finally, the territories. This is substantially borne out by the employment correlations in the last row of Table 2.

These features of the data are consistent with the results of more in-depth studies of regional business cycles in Australia by Poon (2018), Dixon and Shepherd (2001; 2013) and Norman and Walker (2007), all of whom find inter-regional differences in state business cycles and, generally, greater business cycle coherence between the larger states of New South Wales, Victoria and Queensland.

Table 2. Annual Employment Growth Rates, 1979-2018.

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST
1979-2018	1.62	1.76	2.65	1.05	2.38	1.04	2.87	2.22	1.87
1979-1989	1.90	2.02	3.50	1.37	3.16	1.42	5.23	3.59	2.29
1990-1999	1.14	0.52	2.34	0.24	1.93	0.20	1.97	1.60	1.18
2000-2009	1.60	2.23	3.22	1.78	2.80	1.85	2.45	1.95	2.23
2010-2018	1.85	2.32	1.33	0.74	1.46	0.61	1.46	1.52	1.71
Rho	0.90	0.90	0.81	0.82	0.74	0.63	0.30	0.35	1.00
Adj Rho	0.79	0.80	0.72	0.78	0.67	0.61	0.27	0.33	NA

Notes: figures in the first four rows are average annual growth rates; figures in the ‘Rho’ row are correlations between the state and Australian growth rates over the period 1991-2018 and figures in the ‘Adj Rho’ row are correlations between growth rate of each of the states and the rest of the country. Source: Author’s calculations.

The differences in the business-cycle behaviour of the Australian states and territories beg many questions, some of which are addressed in the literature just cited. The question we focus on in this paper is prompted by the observation that the differences in regional economic fluctuations result either from differences in the state/territory responses to common (national) shocks or to regional responses to regional shocks. The way in which regions respond to national shocks is the subject of a rapidly expanding literature on regional economic resilience; see Martin and Sunley (2015) for a widely-cited explanatory paper, Bristow and Healy (2018) and Wolman *et al*., (2017) for recent book-length treatments and the *Annals of Regional Science* (2018) and *Regional Studies* (2018) for recent special journal issues on this topic. It is this literature that forms the basis of and the motivation for the analysis reported in this paper.

The notion of regional resilience applies to the way in which regions react to (usually adverse) shocks, with more resilient regions being ones which suffer less than others. The existing literature has included both a descriptive analysis of regional resilience in response to a shock as well as econometric investigations of the determinants of differences in resilience across regions.

It is not surprising that in a new, rapidly growing literature, the notion of regional economic resilience has not always been clearly defined and has been used in different ways. To clarify the discussion, we rely on Martin's (2012) widely-cited seminal article in which he has distinguished three types of resilience: engineering resilience, ecological resilience and adaptive resilience. They are defined in Table 1, p.5 of his paper as follows. Engineering resilience is used to refer to the "Ability of a system to return to, or resume, its assumed stable equilibrium state or configuration following a shock or disturbance." Ecological resilience, on the other hand, refers to "The scale of shock or disturbance a system can absorb before it is de-stabilised and moved to another stable state or configuration." Finally, adaptive resilience is used for "The ability of a system to undergo anticipatory or reactionary reorganisation of form and/or function so as to minimise the impact of a destabilising shock."

Most of the empirical literature has focussed on engineering resilience which assumes dynamic stability so that the region will return to its pre-shock state and the question of interest concerns the characteristics of the path along which the return is effected: the extent of the deviation from equilibrium and the time taken to return to equilibrium. Martin's definition of ecological resilience is more difficult to apply as it stands since it seems to require one to find the (maximum) size of a shock that "a system can absorb, before it is de-stabilised". Instead, in much of the literature, a system which is resilient in the ecological sense is taken to mean a system which is not resilient in the engineering sense but which will converge to a new equilibrium in response to a shock; see Angulo *et al*. (2018), Capello *et al*. (2015), Di Caro (2017), Diodato and Weterings (2015), Faggian *et al.* (2018), Fingleton *et al*. (2012), Fratesi and Rodriguez-Pose (2016), Kitsos and Bishop (2018) and Rizzi *et al.* (2018). This notion may be appropriate to economic systems which exhibit non-stationary but cointegrated behaviour so that when a shock disturbs the equilibrium, there is convergence but to a (likely) new equilibrium.

Within the framework of engineering resilience, we may distinguish, again following Martin (2012), between four phases in the process of return of the regions to their original state: (1) resistance: short-term reaction to shocks; (2) recovery: the speed with which the region bounces back from a shock; (3) reorientation: structural re-orientation for the region's output and employment; (4) renewal: resumption of pre-recession growth paths. Again, most of the empirical literature presumes engineering resilience and has focussed on the short- to medium-run reaction to the shock, although some papers have also considered recovery (see, e.g., Pudelko *et al.*, 2018; Fingleton *et al*., 2012; Brakman *et al*., 2015; Crescenzi *et al*., 2016; Giannakis and Bruggeman, 2017a; 2017b; Faggian, *et al*., 2018). Moreover, with some notable exceptions (see Fingleton *et al*. 2012; Cellini and Torrisi, 2014), the empirical analysis of resilience has focussed on the effects at the regional level of the demand-contraction emanating from the Global Financial Crisis (GFC). The presumption in this work has been that countries and regions will recover from the GFC to resume their pre-crisis state so the analysis falls in the engineering resilience category.

The empirical research usually proceeds in two stages: the first is to measure resilience and compare this measure across regions to answer the question: which regions are more resilient and which are less resilient? Within the context of the GFC, the measure of a region’s resilience has generally been the fall in regional output or employment in a number of years following the beginning of the GFC contraction. The second stage addresses the issue of why some regions are more resilient than others and typically takes the form of cross-section regression analysis where the measure of resilience computed in the first stage is regressed on a number of regional characteristics which might be expected to influence resilience.

While the research reported in the present paper is based on the notion of resilience, it does not strictly follow the pattern described above. In the first place, we do not focus on the reaction of Australia’s regional economies to a specific shock such as the GFC. Since the Australian economy suffered relatively little following this event, it makes little sense to talk of a national shock and makes it difficult to detect the effects on the regional economies. Rather, we use a time-series model to define a national shock and then derive general measures of resilience by generating the time-paths of the state economies in response to such a national shock and base our measure of resilience on the characteristics of this time-path. Second, since we have only six states, we do not have enough observations for cross-section econometric analysis of the determinants of the differences in resilience across states and restrict ourselves to informal discussion of the resilience differences.

In particular, we employ a VAR/VEC model in the employment for each of the six Australian states and Australia as a whole, use the model to identify a common national shock and then proceed to compute the impulse response functions which capture the dynamic effects of this shock on the state employment levels. We use the characteristics of these functions as the basis for our measure of resilience which we compare across states.

Two interesting alternative approaches to the VAR/VEC models (in addition to the unobserved components model in Norman and Walker, 2007, cited earlier) applied to Australian data are those by Stimson *et al.* (2016) and Drew and Dollery (2015). The first of these uses data for 134 'functional economic regions' and shift-share analysis to assess employment performance over the 2001 to 2011 period while the second uses intertemporal data envelopment analysis to analyse the efficiency of state economic performance over 2007-2012.

The VAR/VEC framework has been extensively used in empirical macroeconomic modelling but less so in regional economic research, although a paper by Rickman (2010) argues strongly for the more widespread application of empirical methods used in macroeconomics to regional analysis. There has, however, been a variety of regional applications of the VAR/VEC model. Thus, Blanchard and Katz (1992) applied the model to the analysis of labour markets in the US states, Carlino and De Fina (1998; 1999) have applied it to the effects of monetary policy in the US states, Beckworth (2010) has used it to model the effects of monetary shocks at the regional level in the US, as have both Weber (2006) and Fraser *et al.* (2014) for the Australian economy and Ridhwan *et al*. (2014) for Indonesia. Owyang and Zubairy (2013) used the VAR model for the analysis of the effects of fiscal policy on the US states. Moallemi and Melser (2019) set up a global VAR framework to model the inter-relationships between the state economies in Australia. Finally, a specific application to regional resilience is the paper by Fingleton *et al*. (2012)

which applied the VAR model to the analysis of regional resilience of regions in the UK.

The structure of the remainder of the paper is as follows. In section 2 we set out the VAR/VEC modelling framework which we use to generate the measure of resilience. In section 3 we briefly discuss the data used before turning, in section 4, to the presentation and discussion of the results. Conclusions are drawn in section 5.

2. THE MODELLING FRAMEWORK

We begin by testing the employment series for stationarity. If a particular regional variable (e.g., output, growth, employment, the unemployment rate) is stationary it is mean-reverting and we can conclude that the region is engineering-resilient in terms of that variable. If a set of regional variables is not stationary they may be cointegrated, in which case there is a long-run equilibrium relationship between them and, while they are unlikely to revert to the original equilibrium following a common shock, they will converge to a new equilibrium and so may be said to be resilient in the ecological sense.

The stationarity test we employ is the commonly used augmented Dickey-Fuller (ADF) test which is based on the equation:

$$y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{it} + \varepsilon_t, \qquad t = 1, 2, \ldots, \mathrm{T} \tag{1}$$

and we test the null hypothesis of non-stationarity, H_0: $\gamma = 0$.

If the whole set of regional variables is stationary, all regions will be resilient, but they will likely revert to equilibrium in different ways and a comparison of the time-paths to equilibrium across regions will tell us something about the relative strength of their resilience. For a set of stationary variables we can use a vector-autoregressive (VAR) model to define a national shock and to generate the time-paths for the regional variables following this shock. The VAR model takes the form (where intercepts have been omitted for simplicity):

$$B_0 y_t = B(L) y_t + \eta_t, \tag{2}$$

where y is a vector of the (n-1) regional values and the national value of a particular variable, B_0 is an (nxn) matrix of coefficients, $B(L) = B_1L + B_2L^2 + \ldots + B_pL^p$ is a matrix polynomial in the lag operator, L, with the coefficient matrices B_i also being (nxn). η is an n-vector of random error terms which are serially and mutually uncorrelated. The model is not identified as it stands and we make the common identification assumption (the 'Cholesky assumption') that the matrix B_0^{-1} is lower triangular when the variables are ordered from the smallest state to the largest state and, finally, the national value of the variable. This implies that a national shock is identified as one which will affect all state variables contemporaneously and state-level shocks affect only smaller states within the period of the shock. While this procedure is restrictive, it is commonly used in VAR-type models involving national and regional variables (see, e.g., Weber, 2006; Owyang and Zubairy, 2013; Ridhwan *et al*., 2014). In our application it is less restrictive than might appear since the order among the regional variables themselves does not matter for the simulations of interest.

To estimate the model, we convert it from the structural form (2) to the reduced form:

$$y_t = A(L)y_t + \varepsilon_t \quad (3)$$

where $A(L) = B_0^{-1}B(L)$ and $\varepsilon_t = B_0^{-1}\eta_t$. The reduced-form model can be validly estimated with ordinary least squares (OLS). The Cholesky restrictions on the B_0 matrix and the restrictions on the covariance matrix of the error vector allow us to retrieve the structural coefficients B_i from the estimated reduced-form coefficients, A_i, and allow us to shock the structural errors, the elements of η. The effects of the structural shocks on the set of variables in y is given by:

$$y_t = D(L)\eta_t \quad (4)$$

where $D(L) = [I - A(L)]^{-1}B_0^{-1}\ \eta_t$. The coefficients in the matrices in the $D(L)$ matrix polynomial contain the effects on each variable at each horizon of a unit shock to each of the structural errors. These are the impulse response functions (IRFs) of which there will be (*nxn*). For a stationary system the IRFs will converge to zero, reflecting the fact that all the variables will eventually return to their original equilibria but, as noted above, the path by which each variable returns to its previous state is likely to differ across regions. The IRFs of particular interest in our analysis are the set following a shock to the last element of η which is the national shock. We will compare these IRFs across regions to assess relative resilience of the regional economies.

The analysis above was predicated on the stationarity of the variables. If this is not the case, generally the variables will need to be differenced until they are stationary, and a stationary VAR model specified in the differenced variables before being analysed as above. An important exception is if the variables are cointegrated. Assuming (as will be the case for our data) that the variables are non-stationary in the levels but stationary when first-differenced (they are said to be I(1)), they are cointegrated if there exists at least one linear combination of them which is stationary. Cointegration can be tested using the Engle-Granger test that the error in the regression of one of the variables on the others is stationary using the ADF test. It is more common, however, to use the Johansen test (Johansen, 1991), a maximum likelihood test which can test for multiple cointegrating relationships within the framework of a vector-error-correction (VEC) model:

$$\Delta y_t = \Pi y_{t-1} + A(L)\Delta y_t + \varepsilon_t. \quad (5)$$

The question of cointegration revolves around the rank of the matrix Π: if its rank is zero (so that it is the zero matrix) the system simplifies to a VAR in the first differences, appropriate to a set of I(1) variables which are not cointegrated; if the rank is $k < n$ then the variables are cointegrated and there are k cointegrating vectors; if the Π has full rank, the variables must, in fact, be I(0). The Johansen tests are tests for the rank of Π and there are two forms of the test—the trace test and the eigenvalue test.

Note that the VEC model contains both levels and differences of y and can, therefore, be used to generate effects, of each of the shocks, on the levels of y, even though the variables are non-stationary. As in the case of the VAR model, the estimated VEC model can be used to generate IRFs:

$$y_t = D(L)\eta_t \quad (6)$$

where, in this case $D(L) = [(I - A(L))(I - L) - \Pi]^{-1}B_0^{-1}$. These will give the effects of shocks to the structural errors (which, again, will be identified using the Cholesky assumption) on the levels of the members of y. While the elements of y will converge, they will generally converge to a new equilibrium following a temporary shock, suggesting ecological resilience. The presence of non-stationary but cointegrated variables will, therefore, be taken as evidence of ecological resilience. Moreover, the IRFs will be compared across regions to assess their relative resilience in the face of a common national shock.

It is important to recognise at this juncture, before we proceed to the data and the results, a general limitation of the method used. We follow the approach used in the vast majority of empirical papers on economic resilience in that we use a single measure (employment in our case) and a simple model which is uniformly applied to all the states at once. The single-valued measure masks many underlying processes which are not captured in our analysis, such as the variability across time of the resilience measures and the underlying inequalities which make up the aggregate employment such as might be captured by a Gini coefficient. Moreover, the simple model structure imposes the same linear structure and the same lag structure on all states, even though an important part of the motivation for the research is the diversity in the state economies. Clearly, our analysis can be only a beginning of the exploration of this important area of the economic performance of the Australian state economies in the face of an adverse aggregate shock.

3. THE DATA

From the model set up in the previous section, it is clear that we need economic activity data for Australia and each of the states. The most common such measure is an output variable such as real gross domestic product (RGDP). Such data are available for Australia as a whole at a quarterly frequency, seasonally adjusted from 1959(3) onwards. However, for the states and territories, data for the equivalent measure (real gross state product, RGSP) are available only on an annual basis from 1990. An alternative measure which has been widely used in the resilience literature is employment and data for this variable are available for the country as a whole and for each of the states, seasonally adjusted on a monthly basis from 1978(2). Data for the two territories, the Northern Territory and the Australian Capital Territory, are also available for this period but not in seasonally-adjusted form.

While using RGDP/RGSP data is attractive because they are the most common measure of economic activity, there are two disadvantages in using these data—the frequency and the sample period. The use of RGSP requires an annual frequency which is a significant drawback for the way in which we distinguish between national and regional shocks—recall that a national shock is one which affects all regions contemporaneously but a regional shock does not affect the nation within the period of the shock. This is more likely to be a good approximation if the period is short, such as a month rather than as long as a year. Moreover, the use of RGDP/RGSP would shorten the sample period to start at 1990 which would exclude one of only two recessions that would be captured in the longer sample starting at 1978—the recession of the early 1980s—and leave just the milder recession of the early 1990s.

In view of these constraints on the data, we decided to use employment data, monthly, seasonally-adjusted for Australia and the six states. The states (in decreasing order of economic size) are New South Wales (NSW), Victoria (VIC), Queensland (QLD), Western Australia (WA), South Australia (SA) and Tasmania (TAS). We omit the territories (the Northern

Territory, NT, and the Australian Capital Territory, ACT) because the data for them are not seasonally-adjusted and it turns out that including them in the model has substantial and implausible effects on its dynamic behaviour which is puzzling, given that the territories are very small relative to the rest of the country (employment shares in 2019(2) were 1.8% for the Northern Territory and 1.0% for the Australian Capital Territory) and that the behaviour of their employment is very different to that of the rest of the country, as can be seen from Figure 2. The data were obtained from the website of the Australian Bureau of Statistics (ABS); in particular, employment data from Catalogue 6202.0, Table 12. 'Labour Force Status by Sex, State and Territory—Trend, Seasonally Adjusted and Original'.

4. RESULTS

We begin by testing the logs of the employment data for stationarity using the ADF test described in section 2. The results of this test are reported in Table 3. It is clear from the results reported in the table that the employment levels are non-stationary in their logs and stationary in their first-differenced logs, implying stationarity in the employment growth rates. The employment log-levels are thus all I(1). We can immediately conclude that regional employment in Australia is not resilient in the engineering sense but that the growth rates are resilient in this sense. Rather than proceed to the estimation and simulation of a VAR model in the growth rates, we first test for cointegration since, if the levels are cointegrated, a VAR in the growth rates is mis-specified since it ignores the long-run equilibrium relationship between the levels of the variables.

Table 3. Stationarity: Monthly Employment.

	(log) levels				(log) differences	
	Intercept, no trend		Intercept, trend		Intercept, no trend	
Region	lags	p-value	lags	p-value	lags	p-value
AUST	5	0.9486	5	0.1249	4	0.0000
NSW	1	0.9867	1	0.5207	0	0.0000
VIC	1	0.9997	1	0.9621	0	0.0000
QLD	5	0.3969	5	0.8640	4	0.0000
SA	2	0.9672	2	0.5660	1	0.0000
WA	1	0.5726	1	0.9717	0	0.0000
TAS	1	0.8301	1	0.3469	0	0.0000

Notes: lags were chosen on the basis of the SIC with a maximum number of lags of 17. Source: Author's calculations.

Recall that cointegration requires all the variables to be integrated of the same order, a condition which is satisfied in the present case since all (log) employment levels are I(1). We use the Johansen test as described in section 2 to test for cointegration. It is carried out in the framework of a VEC model which requires us to decide on the number of lags and the deterministic specification, a choice which needs to be made carefully since the number of cointegrating vectors and, ultimately, the IRFs are sensitive to this choice. Given that the variables are clearly I(1) and that this does not require the presence of a trend in the ADF equation for any of the states, we choose a deterministic specification without trend in either the cointegrating vector or the short-run adjustment (VAR) part of the VEC model. Moreover, the mean growth rates of employment are clearly positive for all regions which suggests the need for an intercept in the short-run VAR component of the VEC model. Thus, our deterministic specification is one with an intercept but no trend in both the cointegrating vector and the short-run VAR component of the VEC model. If a trend is included in the cointegrating vector, it is insignificant. Similarly, if one is included in the VAR part of the VEC model, it is generally insignificant. If the intercept is excluded from the VAR part of the model, the IRFs show divergent behaviour over all reasonable horizons; indeed, they take about 200 months to converge to their new long-run equilibria.

We then ran lag-exclusion tests, starting with 15 lags. A Wald test for the exclusion of the 15^{th}, 14^{th} and 13^{th} lags across all equations could not reject the restriction but this was not the case for the 12^{th} lag (p-value = 0.0000), showing that the 12^{th} lag is clearly necessary. We therefore chose a model with 12 lags. Within the framework of this specification, both the eigenvalue and the trace versions of the Johansen test indicated that the variables are cointegrated and that there is a single cointegrating vector.

The model was estimated and simulated to generate IRFs following a shock of -1 which we choose because we are interested in resilience in the face of an adverse shock which we normalise at -1 for ease of interpretation. The IRFs for the effects on each of the states of a national shock are shown in Figure 3 and summary information on them is reported in Table 4.

Table 4. IRFs in Response to a National Shock of -1.

	NSW	VIC	QLD	SA	WA	TAS	AUS
Impact	-1.09	-1.16	-0.82	-0.68	-0.77	-0.74	-1.00
Short run	-1.14	-1.01	-1.04	-0.93	-0.66	-0.53	-1.01
Medium run	-1.80	-1.94	-1.88	-1.85	-1.61	-1.96	-1.82
Long run	-1.93	-2.27	-2.01	-1.86	-1.72	-2.33	-2.00

Note: 'Impact', 'Short run', 'Medium run' and 'Long run' are at horizons of 1, 3, 12 and 24 months.
Source: Author's calculations.

In Figure 3 each of the state IRFs is shown separately, in each case together with the national IRF for comparison. Various features are worth mentioning. First, the effect of the shock on the country as a whole is that employment falls, initially by 1 (imposed) and then continues to fall gradually over time so that after about two years it has converged to its new equilibrium by which stage it has fallen by twice the amount of the initial shock. Estimates of demand multipliers vary widely but a multiplier of two is within the usual range; for recent surveys of fiscal-policy multipliers see Whalen and Reichling (2015) and Wierzbowska and Shibamoto (2018). Thus, as expected in a cointegrated system, a temporary shock has a permanent effect on the aggregate level of employment. Second, the employment levels of all the states also generally fall over time. Third, all states converge to a new long-run equilibrium so they can be said to be resilient in the ecological sense. Finally, while all states move to a new equilibrium, the equilibria as well as the paths to equilibrium differ across states and, in this sense, the extent of resilience differs from state to state. The differences in the long-run effects are quite clear. WA is the most resilient state and VIC and TAS are clearly the least resilient with SA falling a little less than the national average and QLD and NSW close to the value for Australia as a whole. Some of these might reasonably be expected but others not. Thus, NSW as Australia's largest state economy (32% of national GDP) is likely to track the national economy relatively closely and it is not surprising that TAS, the smallest of the state economies is relatively disconnected from national economic fluctuations. Similarly, WA has an economy larger than its population share and is relatively structurally and geographically distant from Australia as a whole. Two surprise results stand out. First, QLD is often grouped with WA as a relatively prosperous, resource-based economy and we would expect it to be similarly resilient.

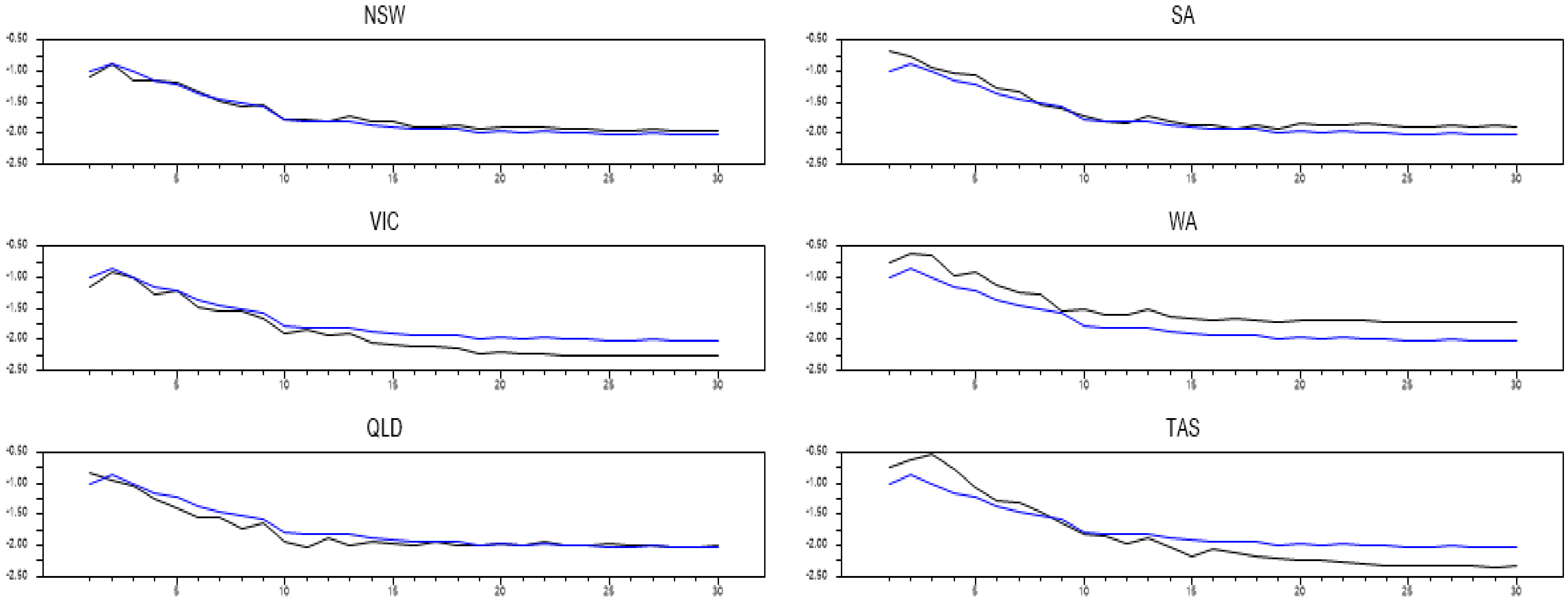

Figure 3. State and National IRFs Following a Shock of -1 to National Employment. Note: Blue line = national, Black line = state. Source: Author's calculations.

However, it must be pointed out that in 2018 QLD's share of national GDP was less than its population share, casting doubt on its relative prosperity and it is clearly more closely connected to the national economy than WA. Second, VIC, the second-largest state economy does not perform close to the national average as NSW does; indeed, its IRF falls consistently and significantly below the one for Australia as a whole. This is consistent with its GDP share being substantially below its population share and the common characterisation of the Victorian economy as the core of Australia's economic rust-belt. For example, recently the NSW Treasurer characterised Victoria as 'the rust belt manufacturing state' on the ABC News web-site; see ABC News (2018).

There ae also some differences in the paths to long-run equilibrium. Thus, VIC, WA, QLD and SA perform reasonably consistently over the entire time horizon but NSW is initially harder hit than average but eventually performs slightly above average. TAS is an enigmatic case with strong short-run resilience but by the time 12 months have elapsed since the shock, it lags the nation and this lag worsens steadily over the forecast horizon. Thus, initially TAS is little affected by the adverse shock but over time there are negative spill-overs which increasingly affect its economy.

These results are confirmed by the snap-shots of the IRFs in Table 4 at horizons of 1 (the impact), 3 (the short run), 12 (the medium run) and 24 (the long run). The most striking result again is that for TAS which has the best performance in the short run but the worst in the medium run and the long run. This underlines an obvious point that, not only does resilience differ across regions, but the measure of resilience depends on the time horizon over which regional responses are measured. Regions can be relatively resilient at one horizon and vulnerable at another.

The forecast-error variance decompositions (FEVDs) pictured in Figure 4 provide additional information, at various horizons, of the contribution of each of the shocks to each state's employment.

Here it is striking that NSW is heavily influenced by national shocks, underscoring the close relationship between NSW and the Australian economy as a whole. VIC is considerably less influenced by national shocks, as are QLD and SA. At the extreme, both WA and TAS are relatively little affected by shocks emanating from the national economy, in both cases making them relatively disconnected from the country as a whole, in the case of WA resulting in great resilience but in the case of TAS having the opposite result.

It should be emphasised that, as with all modelling, the results are model-specific. This is a particularly important qualification in the present case given the simplicity of the models (which omit many potentially relevant variables) and the strong identification restrictions to which the results may be sensitive.

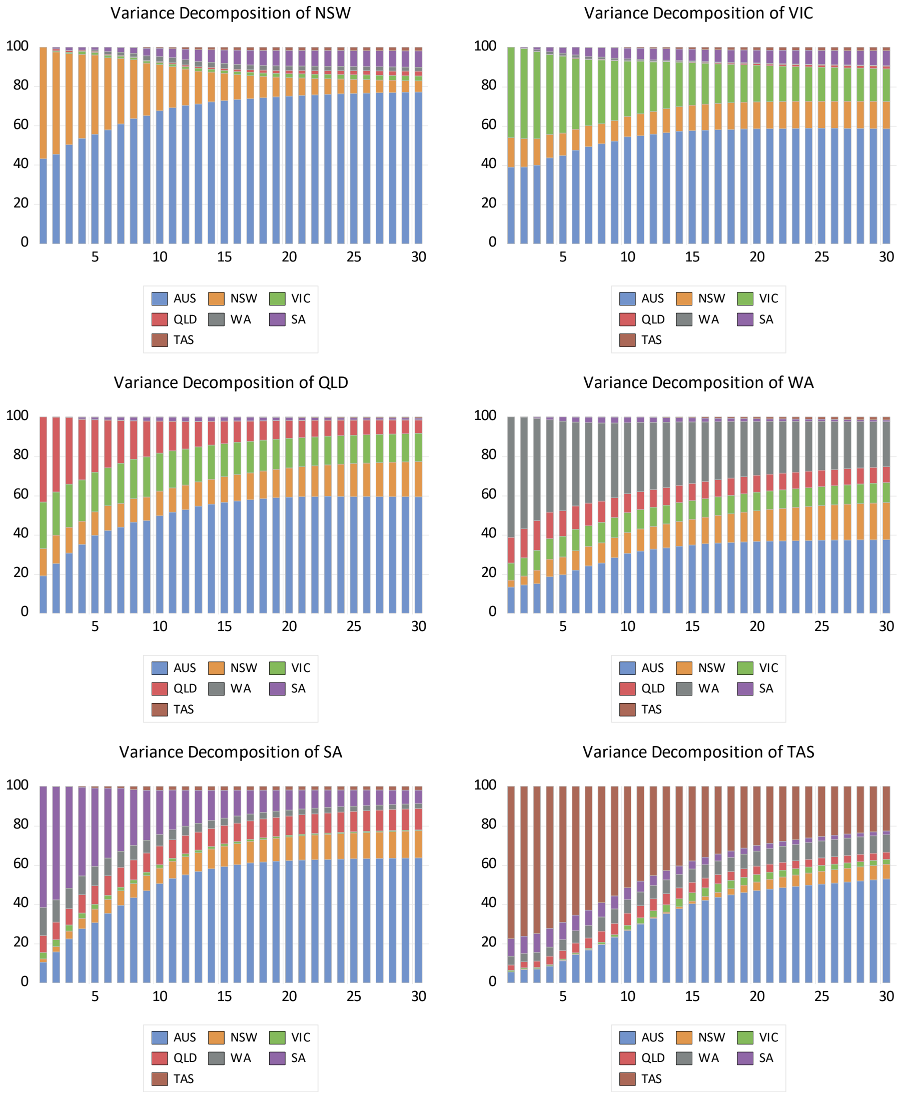

Figure 4. Forecast-Error Variance Decompositions Using Cholesky (d.f. adjusted) Factors. Source: Author's calculations.

5. CONCLUSIONS

This paper has reported an investigation of the economic resilience of the Australian states using monthly employment data for the period 1978(2)-2019(1). Using what have become standard definitions, we distinguished between engineering and ecological resilience which we related to the empirical characteristics of stationarity and cointegration. We tested the (log) employment levels and found them to be all non-stationary but cointegrated which satisfied the requirement of ecological resilience. Further, the employment growth rates were all stationary implying engineering resilience for all the Australian states.

We went on to assess the relative resilience of the state economies by using a VEC model in the state and national employment (log) levels to define a national shock and simulated the effect of such a shock on the state economies using impulse response functions. We found that a national shock resulting in a unit contraction in the national employment level led to a further reduction in employment over time and in the new long-run equilibrium employment contracted by about twice the impact reduction. All state employment levels also contracted in both the short and long runs but reacted differently both as to their long-run responses and as to the time path to the long-run equilibrium. In the long run we found the Western Australian economy to be the most resilient and the Tasmanian and Victorian economies to be the least resilient, with the remaining states moving closely in line with the national average. The time-path to equilibrium following the initial impact also differed across states with that for Tasmania being most dramatic—it suffered the smallest impact effect but the largest long-run effect. These results were generally borne out by the forecast-error variance decompositions which showed that Tasmania and Western Australia, in particular, had only a loose connection with the national economy.

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