# CO-MOVEMENT OF AUSTRALIAN STATE BUSINESS CYCLES

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## Abstract

We use a variety of techniques to examine the nature and degree of co-movement among Australian state business cycles. Our results indicate that these cycles move quite closely together, with particularly strong links between the cycles of the larger states. This finding is robust to a range of statistical measures. We also use an unobserved components model to attempt to distinguish the sources of this co-movement. An implication of our model is that the major source of cyclical fluctuation in state activity is shocks that are common to all states. Region-specific shocks appear to have a moderate influence on cyclical fluctuations, while spillovers of such shocks from one state to another seem to play only a minor role. These findings are consistent with the results of recent studies for the United States, Canada and Europe, where common shocks have also been found to dominate regional cyclical activity.



JEL Classification Numbers: C22, E32, R11

Keywords: business cycles, concordance, unobserved components

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## 1. Introduction

Are Australian state business cycles synchronised? While there is a wealth of literature addressing the issue of cyclical co-movement among countries, very little focus has been given to the issue at a state level, despite its importance for policy-makers. The extent of co-movement of state activity has implications for our understanding of the economy as a whole, and for the role of national policy instruments in smoothing business cycles. Furthermore, an understanding of the sources of cyclical co-movement could help policy-makers improve their response to economic shocks, given that purely regional shocks may involve a different adjustment of capital and labour than shocks affecting all states.

An examination of the growth of economic activity across Australian states, using state final demand as the measure of activity, suggests that economic cycles are quite closely synchronised (Figure 1).[1] This is particularly true of the three largest states, whose business cycles appear to have been very similar since the mid 1980s. The cycles of the three smaller states appear more disparate, but even these states share some cyclical similarities.

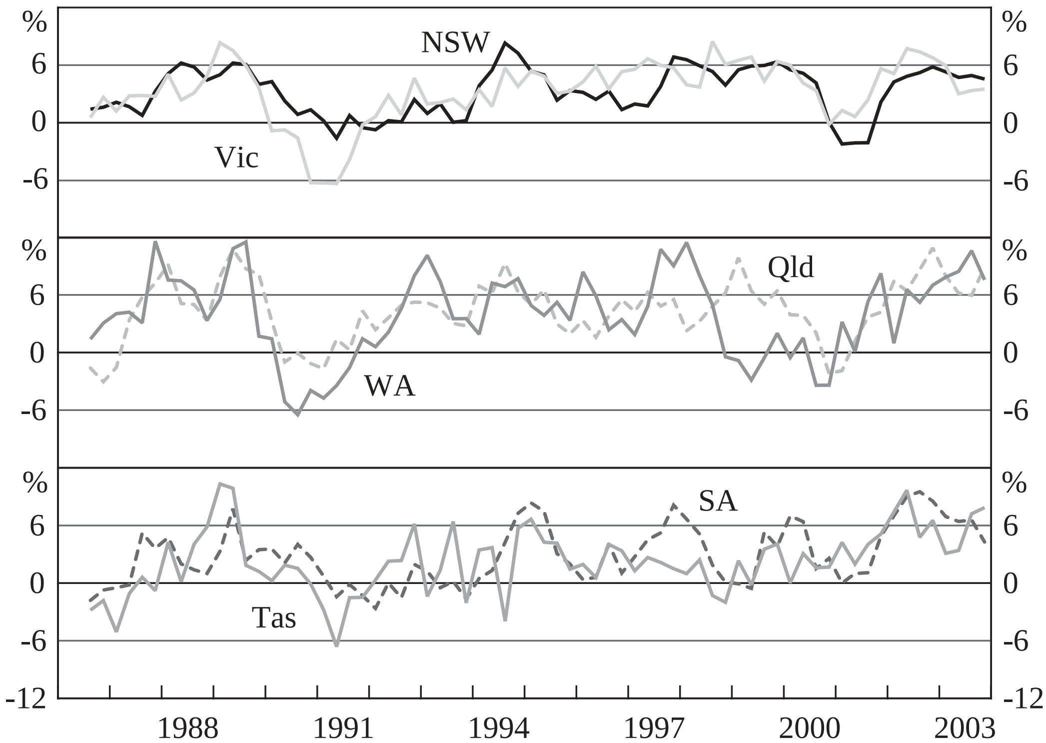
The aim of this paper is to identify the extent and sources of business cycle co-movement among Australian states. While there are a number of studies focusing on regional co-movement in other countries, there has been little research on this issue for Australia. A notable exception is Dixon and Shepherd's (2001) study of unemployment in Australian states, which found a high degree of correlation between state unemployment rates, along with evidence that cyclical activity in the

1 For reasons discussed shortly, we focus on state final demand as a measure of activity in this paper. We confine our analysis to the six states of Australia.

five largest states is driven by a common cycle.[2] Section 3 of our paper expands this research by focusing on more direct measures of the business cycle, and by looking at a range of alternative measures of co-movement. Consistent with Dixon and Shepherd, we also find that state cyclical activity is quite closely linked. Sections 4 and 5 then look at what may account for this co-movement, a question which, to the best of our knowledge, has not previously been addressed in Australia. In support of the findings in Section 3, our results indicate that Australian state activity is dominated by a common cycle, with region-specific fluctuations and spillovers of fluctuations between states making less substantial contributions.

**Figure 1: Cycles in State Economic Activity**

Year-ended growth in state final demand




2 There are other studies that look at synchronisation of state labour markets over a longer time frame than a cycle (for example, Debelle and Vickery 1999).

## 2. Previous Research and Data Issues

In contrast to the lack of previous work using Australian data, there are a number of studies suggesting that quite close linkages exist between US regions. Kouparitsas (2002) and Carlino and Sill (1997), for example, find that correlations of per capita personal income cycles among regions of the US range from 0.6 to 0.8, and Owyang, Piger and Wall (2003) find that turning points in the economic cycles of US states occur at broadly the same time as turning points nationally. Similar results have also been found for regions within European countries (Barrios and de Lucio 2003; Barrios *et al* 2003), and across country blocs (Artis, Kontolemis and Osborn 1997; Hall, Kim and Buckle 1998; Stock and Watson 2003).

Although the nomenclature used varies, the literature broadly identifies two types of shocks to economic activity that might account for this observed co-movement:[3]

- *common* shocks, which affect all regions simultaneously (examples of such shocks include changes in the exchange rate, monetary policy or world economic activity); and

- *idiosyncratic* shocks, which are specific to individual regions (examples of which include changes in regional fiscal policy, regional droughts or local bank failures).

Models using this framework also typically include a mechanism for idiosyncratic shocks to *spill over* from the region in which they originate to other regions, through trade and investment channels, for instance.

If regional cycles are driven to a large extent by idiosyncratic shocks, they will tend to display individual dynamics (i.e. they will not co-move) unless those shocks then spill over to other regions. In contrast, if regional cycles are heavily influenced by common shocks, they will tend to display similar dynamics. Consequently, common shocks and spillovers *create* co-movement, whilst idiosyncratic shocks *reduce* co-movement. The available research suggests that

[3] Several papers also include industry-level shocks, which could be assigned to either of these categories (depending on the degree of industrial similarity).

common shocks are a major source of cyclical co-movement between regions, although spillovers are also non-trivial (Kouparitsas 2002). Cross-country research has yielded similar results although, consistent with the smaller number of common shocks, spillovers play a greater role in cross-country dynamics (Norrbin and Schlagenhauf 1996; Clark and Shin 2000).

The difficulty with examining these issues at a sub-national level is the scarcity of comprehensive measures of economic activity. The most comprehensive measure of state economic activity, gross state product (GSP), is only consistently available for Australian states on an annual basis (from 1989–1990), which limits its usefulness in assessing business cycle synchronicity. We have therefore chosen to use two alternative proxies of economic activity in our analysis: state final demand (SFD) and hours worked. Both measures have limitations. SFD, which measures total domestic spending in each state and is akin to domestic final demand at a national level, excludes important components of economic activity, particularly external trade (both international and interstate). This deficiency has implications for our assessment of the importance of spillovers, given that trade is often seen as a primary avenue for the transmission of shocks from one state to another. In contrast, hours worked data should capture changing conditions in a state's external sector, but information from the labour market is only an indirect estimate of economic activity, and shocks might be observed with a lag. In what follows, we use both measures to try to mitigate these deficiencies.

# 3. Statistical Approaches

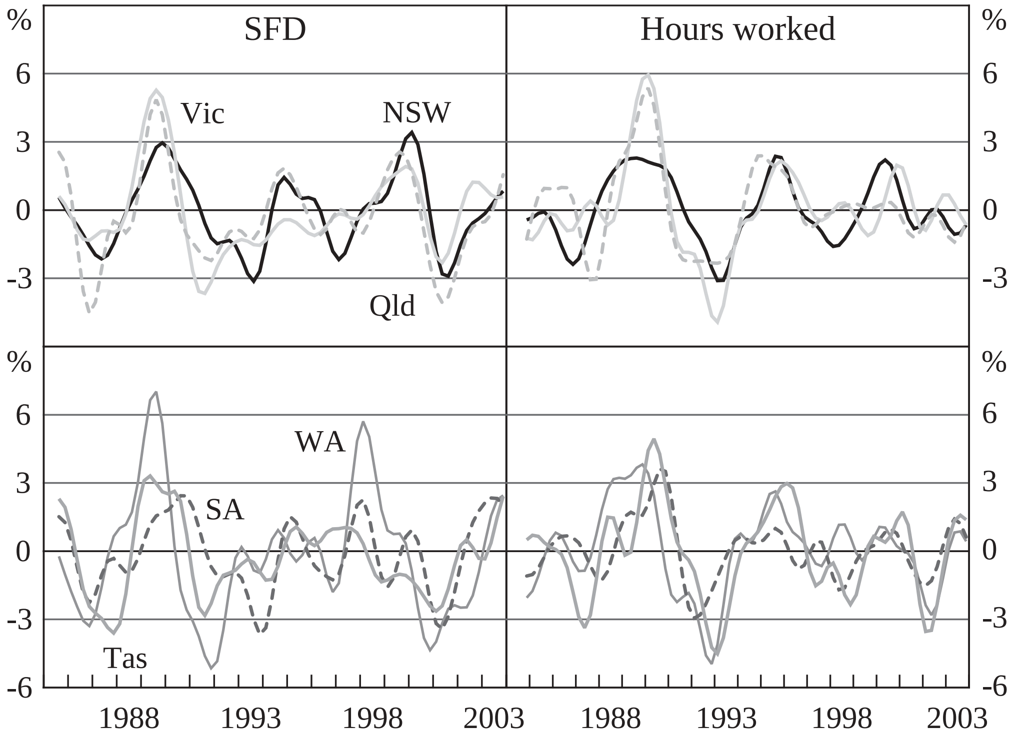
## 3.1 The Extent of Co-movement

In constructing a measure of 'the cycle', one must choose a method of removing high-frequency noise from the data. Our primary method follows the growth cycles literature, whereby trends and volatility are removed from the data using Baxter and King's (1999) band-pass filter.[4] This filter was chosen in preference to

[4] A band-pass filter is the difference between a low-pass filter (which removes all fluctuations with periodicity less than or equal to some threshold) and a high-pass filter (which removes all fluctuations with periodicity greater than or equal to some other threshold). We choose these thresholds to be 6 and 32 quarters, to match Burns and Mitchell's (1946) definition of a business cycle.

others such as the Hodrick-Prescott filter or first-differencing, because it more effectively removes high-frequency information, and has been shown to introduce less distortion than the Hodrick-Prescott filter when a series is autoregressive (Pedersen 2001). Figure 2 shows the resulting cycles. It is clear from this that there is a high degree of synchronicity, particularly among the larger states.[5]

**Figure 2: Band-pass Filtered State Cycles**




These visual observations can also be confirmed by examining the cross-state correlation of these band-pass filtered variables shown in Table 1. For our sample size, the correlation between two independent random walks will only exceed 0.29 in absolute value in 1 per cent of random draws.[6] All of the correlations exceed this

5 A 6,32 band-pass filter removes the first and last 12 observations. Given our short sample (1985:Q3–2003:Q4 for SFD and 1984:Q4–2003:Q4 for hours worked), we consider this an unacceptable data loss. To correct this, we used trends to extrapolate each series beyond their start and finish point, and allowed the band-pass filter to remove these observations. Consequently, the endpoints of our series are less reliable than their midpoints and should be interpreted with caution.

6 Our calculations are based on the approximate $z$-statistic for hypothesis tests of correlations described in Miller and Miller (1999, p 477). For a test against the null of zero correlation, the statistic $z = \left(\sqrt{n-3}/2\right)\ln\left[(1+r)/(1-r)\right]$ is approximately standard normal, where $r$ is the correlation coefficient and $n$ = 71 and 74 is the sample size for SFD and hours worked.

figure, so we can be reasonably confident that SFD and hours worked for all states are contemporaneously correlated at high levels of significance. The degree of synchronicity is greatest amongst the larger states, with average correlations between NSW, Vic and Qld of 0.73 using SFD and 0.70 using hours worked. Whilst correlations are lower among the smaller states (0.49 using SFD and 0.58 using hours worked), they also point to broadly synchronised cycles. Correlations across these two groups average 0.56 using SFD and 0.65 using hours worked.

**Table 1: Correlation of Band-pass Filtered Variables**

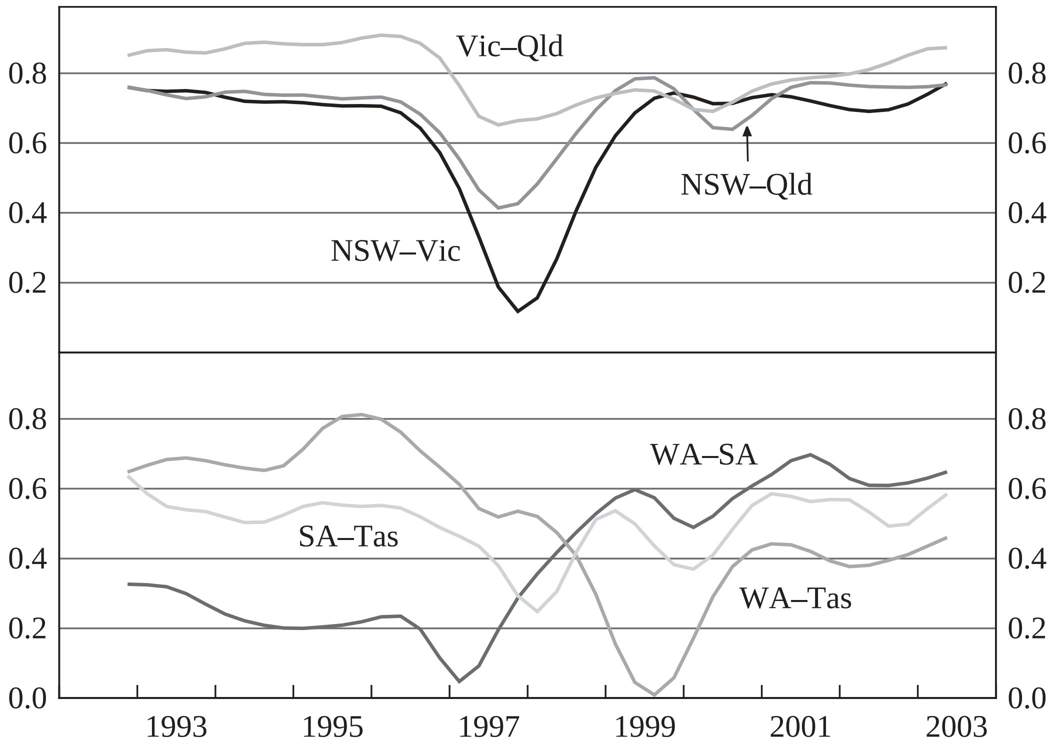
| | **State final demand** | | | | | |
|---|---|---|---|---|---|---|
| | NSW | Vic | Qld | WA | SA | Tas |
| NSW | 1.00 | | | | | |
| Vic | 0.68 | 1.00 | | | | |
| Qld | 0.74 | 0.77 | 1.00 | | | |
| WA | 0.43 | 0.70 | 0.67 | 1.00 | | |
| SA | 0.64 | 0.45 | 0.50 | 0.43 | 1.00 | |
| Tas | 0.44 | 0.64 | 0.63 | 0.56 | 0.57 | 1.00 |
| Australia | 0.88 | 0.90 | 0.90 | 0.74 | 0.66 | 0.66 |
| **Average** | **0.58** | **0.65** | **0.66** | **0.56** | **0.52** | **0.57** |
| | **Hours worked** | | | | | |
| | NSW | Vic | Qld | WA | SA | Tas |
| NSW | 1.00 | | | | | |
| Vic | 0.68 | 1.00 | | | | |
| Qld | 0.65 | 0.77 | 1.00 | | | |
| WA | 0.59 | 0.70 | 0.70 | 1.00 | | |
| SA | 0.53 | 0.65 | 0.61 | 0.53 | 1.00 | |
| Tas | 0.73 | 0.68 | 0.64 | 0.58 | 0.62 | 1.00 |
| Australia | 0.87 | 0.92 | 0.88 | 0.79 | 0.71 | 0.78 |
| **Average** | **0.64** | **0.70** | **0.67** | **0.62** | **0.59** | **0.65** |

Notes: Average correlations are calculated over state-state correlations, and exclude correlations with Australia. Data for ‘Australia’ are the band-pass filtered sum of all six states’ SFD or hours worked.

To assess whether the degree of synchronicity has changed substantially over our sample, we computed rolling correlations using a 30-quarter window. The results suggest that there has been no significant change in the degree of co-movement among the larger states, with the exception of the period around 1997–1998 (Figure 3, top panel). The declining correlation of state cycles in that period reflects the staggered entry into, and recovery from, the early 1990s recession across states, and the effect that this has on the rolling correlations as the recession period rolls out of our 7½ year window. The degree of synchronicity among the smaller states has been less stable (Figure 3, bottom panel), with the Western Australian and South Australian cycles increasingly correlated, but the Western Australian and Tasmanian economies increasingly divergent.

**Figure 3: Rolling Correlations**

Band-pass filtered state final demand




Note: Rolling correlations use 30-period windows, plotted relative to the sample end date.

An alternative way to assess co-movement is to consider *classical* business cycles, which are dated without removing trend growth. Although the literature since Burns and Mitchell's (1946) seminal paper has concentrated more on (detrended) *growth* cycles, some authors (for example, Harding and Pagan 2002) criticise this approach because it requires imposing a particular structure on the (unknown) trend. As shown by Canova (1998), changes in the trend specification can indeed produce significant differences in the characteristics of the resulting cycles.

A well-known method for dating classical cycles is that set out in Wecker (1979), that two quarterly declines in activity represents a recession, while two successive quarters of growth represents an expansion. On this basis, peaks in activity are defined as periods where $\{\Delta y_t>0, \Delta y_{t+1}<0, \Delta y_{t+2}<0\}$, while troughs are dated by reversing the inequalities. This algorithm corresponds to a minimum peak-to-peak cycle duration of five quarters, as generally assumed in the literature (Harding and Pagan 2002). It also ensures that an expansion will only be recorded if a series is increasing. However, it does not ensure that an expansion *will* be recorded if a series is generally increasing, as the series may not record two consecutive quarters of growth.[7] Consequently, for such periods, we supplement this algorithm with the Bry and Boschan (1971) method, now associated with the NBER, to ensure that the absence of two consecutive quarters of growth does not cause a period of generally rising activity to be characterised as an extended recession (nor a decreasing series as an expansion).[8] Applying this technique to Australian data shows that there was a relatively co-ordinated recession between 1989 and 1991. While downturns were observed on other occasions in the sample period in particular states, these were not concurrent across all states.

The degree of similarity between states' classical business cycles can be assessed using the statistical framework provided by Harding and Pagan (2002). They suggest examining the *degree of concordance* between two states' cycles, using the measure:

$$I_{j,k} = T^{-1}\sum_{t=1}^{T}\left\{S_{jt}S_{kt} - (1-S_{jt})(1-S_{kt})\right\} \tag{1}$$

where $S_{jt}$ represents the business cycle phase of state $j$ at time $t$ (1 represents expansion, 0 contraction). This measure ranges between 0 and 1, with 0 representing perfectly counter-cyclical business cycles, and 1 perfectly synchronous cycles. For two cycles described by random walks, the measure will be 0.5 in the limit.

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7 A series may be increasing, but not record consecutive quarterly growth, if the magnitude of the expansionary quarters outweighs the magnitude of the contractionary quarters.

8 In such situations, Bry and Boschan's algorithm, which dates peaks in activity as occurring when $\{y_t > y_{t\pm k}\}$, with $t$ = 1,2, allows such periods to be classified as expansions.

The degree of concordance between each cycle is shown in Table 2. At first glance, these results portray a quite high degree of synchronicity, with most values around 0.7 or above. However, some care must be taken in interpreting these figures. Expansions in each state are highly persistent because trend growth is positive. The expected value for each coefficient is therefore greater than 0.5 – in most cases, somewhat above 0.6.[9]

**Table 2: Degree of Concordance between Classical State Cycles**

State final demand

| | NSW | Vic | Qld | WA | SA | Tas |
|---|---|---|---|---|---|---|
| NSW | 1.00 | | | | | |
| Vic | 0.82 | 1.00 | | | | |
| Qld | 0.81 | 0.82 | 1.00 | | | |
| WA | 0.81 | 0.77 | 0.76 | 1.00 | | |
| SA | 0.74 | 0.68 | 0.64 | 0.69 | 1.00 | |
| Tas | 0.72 | 0.70 | 0.66 | 0.61 | 0.78 | 1.00 |
| Australia | 0.92 | 0.91 | 0.81 | 0.86 | 0.69 | 0.69 |
| **Average** | **0.78** | **0.76** | **0.74** | **0.73** | **0.71** | **0.69** |

Note: Average concordance is calculated over state-state concordances, excluding the concordance with Australia.

Furthermore, it is important to remember the statistical error associated with our estimates, particularly given the small sample size with which we are working. Using a test statistic proposed by McDermott and Scott (2000), we find that 11 of the 21 concordance measures in Table 2 are significant at the 5 per cent level, and 15 at 10 per cent.[10] Tests involving at least one of NSW, Vic and WA tend to be significant, while very few relationships involving SA are significant, even at the

9 The expected value is calculated by replacing $S_{jt}$ and $S_{kt}$ in Equation (1) with the proportion of time each series spends in expansion. Denoting this average proportion as $\bar{S}$, the expected value will equal $E(I_{j,k}) = \bar{S}_j \bar{S}_k + (1-\bar{S}_j)(1-\bar{S}_k)$ (Harding and Pagan 2002). The closer $\bar{S}_j$ and $\bar{S}_k$ are to 0.5, the closer the expected value will be to 0.5.

10 The test relies on the ratio of the drift of a series (i.e. its trend growth) to its standard error, as well as the sample size. McDermott and Scott (2000) present coefficient weightings for these variables based on Monte Carlo simulations.

10 per cent level.[11] We take these results to be quite strong evidence in favour of co-movement, given our small sample size.

### 3.2 Why State Cycles Might Co-move: Preliminary Observations

Following the framework described in Section 2, the considerable co-movement documented above could be the result of common shocks, spillovers of idiosyncratic shocks, or a combination of the two. To distinguish between the competing explanations, we use the identification assumption that is standard in the literature, that common shocks affect all states in the same quarter, while spillovers affect states with a lag. Given this assumption, a higher correlation between activity in one state and lagged activity in another (than between activity in these states contemporaneously) would therefore be evidence that spillovers are more important than common shocks. To judge whether this is the case, we plot correlations of SFD in Figure 4, where each dot represents a pair of states. The horizontal axis measures the contemporaneous correlation between these states, and the vertical axis measures the correlation when one state is lagged a quarter. Observations above the 45-degree line represent state pairs where the lagged correlation exceeds the corresponding contemporaneous correlation, suggesting that spillovers are important in explaining co-movement between these states.

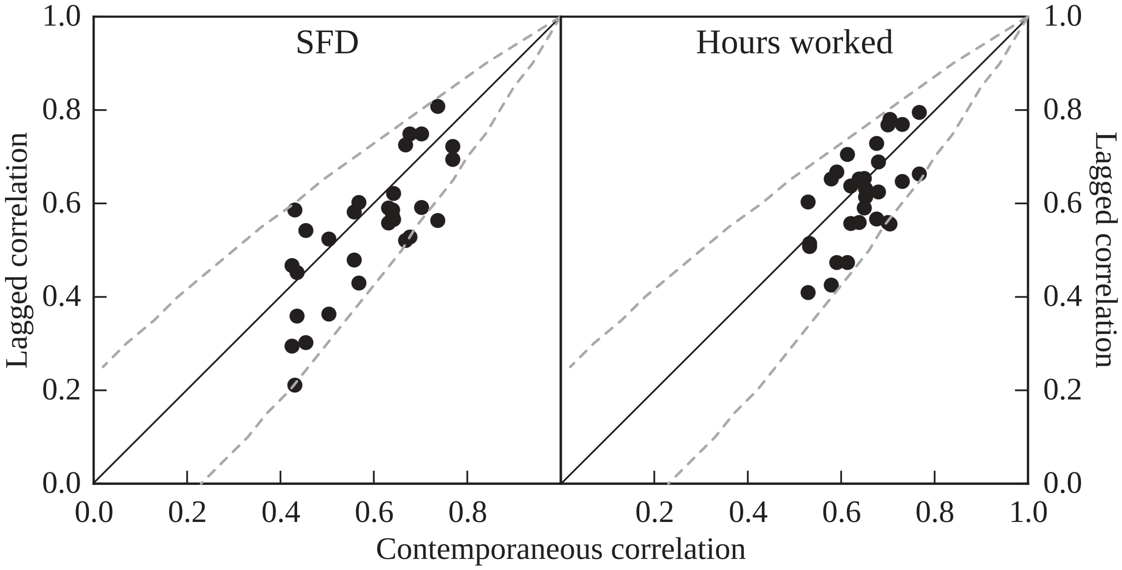
Conducting a formal test of whether each lagged correlation is significantly different from its corresponding contemporaneous correlation is not a straightforward task, since it involves making assumptions about the behaviour of the underlying data. As a rough guide, the dashed lines in Figure 4 depict the 95 per cent confidence bounds which would be obtained if (together with a number of other assumptions) the SFD data for each state pair came from a bivariate normal distribution with no serial correlation. This is clearly not a realistic assumption, because it implies no autocorrelation in state activity, but these confidence intervals do provide a very broad indication that few of the lagged correlations are likely to be significantly greater than the contemporaneous correlations. This suggests that common shocks may be more important in driving

[11] South Australia is included in all but two of the relationships that are insignificant at 10 per cent.

co-movement than spillovers. A possible exception to this is WA, whose lagged activity tends to be more highly correlated with contemporaneous activity in other states, indicating that WA's resource-based economy might tend to lead activity in other states. This might occur in several ways. Because of its openness, movements in exchange rates or the terms of trade may affect WA more quickly than other states. In addition, the capital-intensive nature of the mining sector in WA might result in demand-side shocks for WA's resources being transmitted to other states as the need for mining-related capital rises or falls.

**Figure 4: Correlations between State Pairs**

Band-pass filtered cycles




Note: Dashed lines are explained in text, and are included only as a rough guide to 95 per cent confidence intervals.

Granger causality tests are a second method that can provide guidance on the extent to which spillovers might drive co-movement. A finding that one state Granger-causes another (but not vice versa) would suggest that shocks from that state may indeed spill over to other states. Consequently, we tested for the presence of Granger causality between states, and between each state and the national cycle excluding that state. To account for the presence of unit roots in our series, both SFD and hours worked were first-differenced prior to testing.

Only 4 of the 30 state pairs using SFD, and 9 using hours worked, indicated Granger causality at the 5 per cent level of significance, with no evident pattern in the significant relationships. The higher number of significant relationships using hours worked may reflect that measure's inclusion of the traded sector. However, even taking the results using hours worked as more indicative of state interactions, these results suggest that spillovers play only a small role in driving co-movement, providing support to our earlier findings based on lagged correlations.

We also considered a role for industrial structure in creating cyclical co-movement, given the traditional assumption that it is important. However, comparing Krugman's (1991) industrial dissimilarity index for state pairs with correlations between state cycles, we found little evidence that industrial structure is important, consistent with other research (see, for example, Clark and Shin 2000); our results are presented in Appendix A. Consequently, we have chosen not to further explore industrial structure in our formal examination of the factors accounting for business cycle co-movement.

## 4. An Unobserved Components Model

### 4.1 Background

The results presented in the previous sections offer an insight into the patterns of cyclical activity in Australia, the degree of co-movement between state cycles, and the possible importance of different types of shocks. These simple measures may explain the extent to which economic activity in one state co-moves with activity in another, but they cannot determine how states respond to different types of shock, or where these shocks come from. They may also give an exaggerated impression of the economic *interdependence* of states, to the extent that state data contain a large component of activity common to all states and driven by external factors. Finally, the smoothness of the band-pass filtered data may lead to higher correlations than is plausible. In this section we introduce an unobserved components model, which attempts to disentangle the many sources of cyclical fluctuation, and determine how these fluctuations trace their way through the economy.[12]

Our approach is a variation on that used by Kouparitsas (2002), which in turn is based on work by Watson (1986). In his analysis of US regional activity, Kouparitsas studied quarterly per capita income from 1961:Q1 to 2000:Q4. Unfortunately, quarterly SFD for Australia is only available back to the mid 1980s, yielding around 70 observations. Given the number of parameters to be estimated, we reconfigure the model to use both SFD and hours worked simultaneously. The benefits of this adjustment are twofold. First, by restricting SFD and hours worked to respond (in the latter case with a lag) to the same common and state-specific cycles, we increase the degrees of freedom by doubling the number of observations while less than doubling the number of coefficients. Second, the augmented model produces extracted cycles which can be considered a compromise between the fluctuations in labour market and income-based measures of activity (with hours worked also capturing developments in the traded sector, which SFD excludes). This compromise is consistent with Burns and Mitchell's (1946) definition of business cycles as patterns observed across a range of economic data, and hopefully makes our results more robust.

Data on SFD and hours worked for the six states are available quarterly from 1985:Q4–2003:Q4. Growth in domestic final demand has its highest correlation with growth in total hours worked at a lag of two quarters, so we lag hours worked by two quarters in the model.[13] This reduces the sample to 1985:Q4–2003:Q2, or 71 observations.

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[12] VAR models are also often used in the literature to explore business cycle co-movement (see, for example, Labhard 2003), but consume too many degrees of freedom, and are unable to distinguish clearly between common and idiosyncratic shocks when the data are relatively smooth.

[13] A lag of roughly two quarters is also apparent from a visual comparison of the band-pass filtered cycles for SFD and hours worked (Figure 2).

## 4.2 Specification

This section outlines the methodology and basic structure of the model. It is an example of the class of general dynamic multiple-indicator, multiple-cause (DYMIMIC) models pioneered by Watson and Engle (1983), which characterise observed economic activity as a function of observed and unobserved variables. We assume the level of state activity (for either SFD or hours worked) can be specified as the sum of state-specific trend and cyclical components:

$$y_{it} = \tau_{it} + c_{it} \tag{2}$$

where $y_{it}$ is the log of either measure of activity in state $i$, and $\tau_{it}$ and $c_{it}$ are state-specific trend and cycle components. Following Beveridge and Nelson (1981), we assume that the trend level of activity is characterised by a random walk with drift, as shown in Equation (3):[14]

$$\tau_{it} = \delta_i + \tau_{it-1} + \mu_{it} \tag{3}$$

The drift parameter $\delta_i$ is state-specific, allowing states to grow at different trend rates. Although not shown in Equation (3), we add a structural break in the trend growth rate after 1994:Q4, to capture structural changes in the economy following the recession.[15] The cyclical component for state $i$ is assumed to be driven by two unobservable cycles: a common national cycle, $x_{nt}$, and an idiosyncratic cycle, $x_{it}$, as shown in Equation (4):

$$c_{it} = \gamma_i x_{nt} + x_{it} \tag{4}$$

[14] Tests indicated the presence of a unit root in all states for both SFD and hours worked. We therefore model activity as the sum of a non-stationary trend and a stationary cycle.

[15] We experimented with various locations for the trend break, and a break after the 1990 recession was found to be most successful in fitting the data and ensuring the estimated cycles were stationary. Our results are not sensitive to the exact location of the break, but we chose the end of 1994 as a point sufficiently past the end of the recession period yet close to the middle of our sample.

The parameter $\gamma_i$ governs the magnitude of the response of activity in state *i* to the common cycle, and is allowed to vary across states. This means that the amplitude of the common cycle effect on each state's activity may vary, but its shape and timing is identical for all states. The common cycle is assumed to be an AR(1) process:[16]

$$x_{nt} = \rho x_{nt-1} + \eta_t \tag{5}$$

where $\eta_t$, the common shock, is normally distributed with mean zero and variance $\sigma_\eta^2$. The idiosyncratic cycles are modelled as a VAR, with each idiosyncratic cycle specified as a function of the first lags of all six idiosyncratic cycles:

$$x_{it} = \left( \sum_{j=1}^{6} \phi_{ij} x_{jt-1} \right) + \varepsilon_{it} \tag{6}$$

where the $\varepsilon_{it}$, the state-specific (or *idiosyncratic*) shocks, are normally distributed with mean zero and variance $\sigma_i^2$. Idiosyncratic shocks in each period are assumed to be uncorrelated both across states and with the common shock. We assume that all shocks are uncorrelated across time.

Note that, in this framework, idiosyncratic and common shocks are distinguished by the fact that common shocks affect all states simultaneously, while idiosyncratic shocks affect only the state of origin in the quarter of the shock. However, idiosyncratic shocks may subsequently spill over to other states' cycles. Our framework therefore allows for three sources of cyclical disturbance to the level of state activity: common shocks, idiosyncratic shocks, and spillovers of shocks between states.

16 Cycles are generally modelled as AR(2) processes, including by Kouparitsas (2002). We found that allowing a common cycle to be AR(2) did not materially change our results, so we used a simpler AR(1) process for parsimony, given our small sample size. It may be that the inclusion of two observed series, one with a two-period lead, provides the second eigenvalue necessary for the observed cyclical behaviour.

Because all series are non-stationary, we model SFD and hours worked in first differences of the log levels.[17] The estimated equations (for each state *i*) are:

$$\begin{bmatrix} \Delta s_{it} \\ \Delta h_{it+2} \end{bmatrix} = \begin{bmatrix} \delta_i^s \\ \delta_i^h \end{bmatrix} + \begin{bmatrix} \gamma_i^s & 1 \\ \gamma_i^h & \theta_i \end{bmatrix} \begin{bmatrix} \Delta x_{nt} \\ \Delta x_{it} \end{bmatrix} + \begin{bmatrix} \mu_{it}^s \\ \mu_{it}^h \end{bmatrix} \tag{7}$$

where the superscripts *s* and *h* denote coefficients pertaining to SFD and hours worked. In state-space form, this can be represented by the measurement equations:

$$\begin{bmatrix} \Delta s_{t} \\ \Delta h_{t+2} \end{bmatrix} = \begin{bmatrix} \delta_1^s & \delta_2^s \\ \delta_1^h & \delta_2^h \end{bmatrix} \begin{bmatrix} D_t^{85:4,94:4} \\ D_t^{95:1,03:2} \end{bmatrix} + \begin{bmatrix} \gamma^s & I_6 \\ \gamma^h & \Theta \end{bmatrix} \begin{bmatrix} \Delta x_{nt} \\ \Delta X_{t} \end{bmatrix} + \begin{bmatrix} \mu_{t}^s \\ \mu_{t}^h \end{bmatrix} \tag{8}$$

and transition equations:

$$\begin{bmatrix} x_{nt} \\ X_{t} \end{bmatrix} = \begin{bmatrix} \rho & 0 \\ 0 & \Phi \end{bmatrix} \begin{bmatrix} x_{nt-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} \eta_t \\ \varepsilon_t \end{bmatrix} \tag{9}$$

where $\Theta$ is a 6x1 vector of the $\theta_i$ coefficients, and $\Phi$ is a 6x6 vector of the $\phi_{ij}$ response coefficients. Note that SFD and hours worked respond to the same common and idiosyncratic cycles, but hours worked responds with a two-quarter lag.[18] The variables $\mu_{it}$ are error terms, containing the trend innovations and noise (such as measurement error) not captured by the common or idiosyncratic cycles. These errors are assumed to be normal with zero mean and constant variance. All error terms in the model are assumed to be independent across time, states and

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17 The Kalman filter requires all dependent variables to be stationary. It would also be feasible to use as the dependent variable a detrended series, such as band-pass filtered SFD, or a year-ended growth rate. We use the first difference here because it produces a well-behaved error term, obviating the need for a more complicated specification.

18 The parameters $\gamma_i$ and $\theta_i$ allow SFD and hours worked for each state to respond with different amplitudes to the common and their own idiosyncratic cycles. For identification purposes, SFD is assumed to respond one-for-one to its idiosyncratic cycle, and $\gamma_1^s$ (the responsiveness of NSW SFD to the common cycle) is set equal to one.

equations. We estimate the system of Equations (8) and (9) as a Kalman filter, using Watson and Engle's (1983) two-step EM algorithm.[19]

## 5. Model Results

It is important to emphasise that our model results must be interpreted with caution, given the limited amount of data available and the well-known sensitivity of Kalman filters to assumptions and initial conditions. Thus our focus here is on the patterns of behaviour of the common, idiosyncratic and spillover components, and the stylised facts arising from these, rather than on the precise coefficient estimates and quantitative implications of the model. While we believe the model provides a fair representation of the data, there is simply not enough historical information on Australian state activity to draw reliable quantitative conclusions. Bearing this caveat in mind, however, the model results support the findings we reported in Section 3, providing evidence that common shocks, rather than spillovers of lagged shocks between states, are primarily responsible for the observed co-movement of state cycles. We focus here on the results for SFD; the results for hours worked are quite similar and are provided in Appendix B.

The estimates for $\delta$, in the first two columns of Table 3, suggest that trend growth in SFD picked up in all states during the 1990s, in some cases substantially.[20] This accords with our priors: the period since the recession has seen higher average productivity growth nationally, and stronger growth in every state.

We begin our analysis of the estimated cycles with the common cycle, which influences activity in all states. Recall that the extent to which SFD in state $i$ responds to the common cycle is governed by the parameter $\gamma_i^s$, so the magnitude of the common cycle effect varies across states. Figure 5 shows the estimated

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19 We impose a convergence criterion of $1\times10^{-4}$ on the sum of squared deviations of the parameters *and* unobserved components from their previous iteration levels. We found the results to be insensitive to the exact criterion and starting points used. See Hamilton (1994) for more information on this methodology.

20 In contrast, the estimated post-break trend growth rates for hours worked are all lower than the pre-break estimates. This suggests productivity growth in all states must have increased substantially during the 1990s, to reconcile the slowing of growth in hours worked with the increased trend growth rates of SFD.

common cycle multiplied by the weighted average of the parameters $\gamma_i^s$, where the weights are the states' shares of total SFD. This can be thought of as the common cycle of all states combined, or the common component of domestic final demand, excluding final demand in the two territories.

**Table 3: Estimated Parameters for SFD**

| **State** | **Trend parameter, $\delta_i^s$** | | **Common cycle response parameter, $\gamma_i^s$** |
|---|---|---|---|
| | 1985:Q4–1994:Q4 | 1995:Q1–2003:Q2 | |
| NSW | 2.59 | 3.61 | 1 |
| Vic | 1.68 | 4.76 | 1.06 |
| Qld | 3.81 | 4.47 | 1.19 |
| WA | 3.18 | 4.16 | 1.36 |
| SA | 1.59 | 3.63 | 1.15 |
| Tas | 1.43 | 2.33 | 1.19 |
| **National average** | **2.51** | **4.09** | **1.10** |

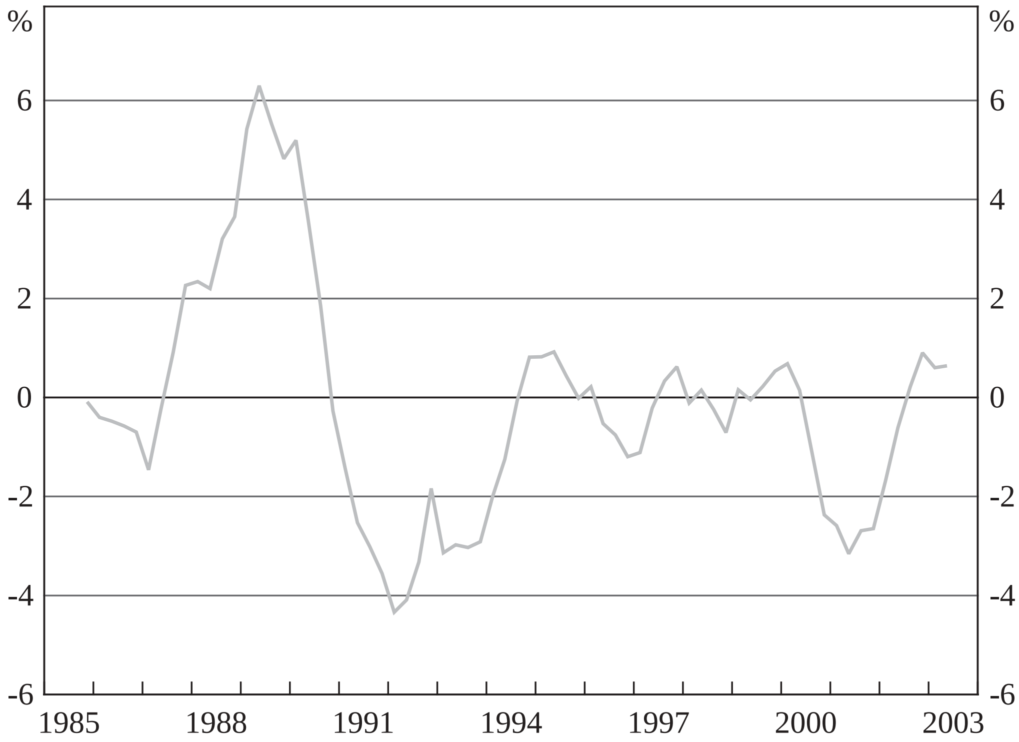
Notes: Trend parameter estimates can be interpreted as average annualised percentage trend growth rates. The national cycle response parameter for NSW is normalised to be 1. The 'national average' figures are calculated as the average of the state figures, weighted by their share of total SFD.

Although the estimated common cycle should be interpreted with our earlier caveat in mind, it matches many of the stylised facts about the Australian business cycle over the past 20 years.[21] The property and investment boom in Australia in the late 1980s and the subsequent recession are reflected in the estimated cycle peaking in June 1989 at 6 per cent above trend, before falling to levels indicating below-trend activity.[22] The cycle remains negative until mid 1994, before settling around zero over the remainder of the 1990s. (Note that this near-zero level does not imply weak growth, but rather less volatile growth at a stronger trend rate.) The final major feature is a dip below trend in late 2000, consistent with the swings in housing construction associated with the introduction of the GST in July 2000. Recent conditions indicated by the model can be characterised as around trend.

[21] The estimated cycle has a correlation of 0.85 with Hodrick-Prescott filtered domestic final demand.

[22] This coincides with the peak in the dated Australian SFD cycle discussed earlier.

**Figure 5: Weighted Average Common Cycle**




Note: Graph depicts the *weighted average* common cycle for SFD across states, where the average is calculated using states' shares of total SFD as the weights.

Estimates of the responsiveness of states to the common cycle for SFD, $\gamma_i^s$, are presented in the last column of Table 3.[23] The degree of responsiveness of different states to the common cycle generally accords with our priors and with previous research. The estimated response coefficients are similar for all states, suggesting that the common cycle has quite a uniform impact. Nevertheless, there appears to be a tentative relationship between openness and degree of sensitivity to the common cycle. Western Australia, which has the most open economy and is therefore most exposed to exchange rate shocks (Weber 2003, p 2), also has the strongest response. The two least open states, NSW and Vic, are the least responsive, consistent with the idea that fluctuations in the exchange rate and the terms of trade are major types of common shock for a small open economy. Regions with greater openness would be expected to be more sensitive to these shocks than less open regions.

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23 The estimated coefficients for hours worked are around half the size, with an average coefficient of 0.52, compared with an average of 1.10 for SFD.

In addition to the effect of the common cycle, the *overall* cycle in each state is partly driven by fluctuations specific to that state, which are captured in its idiosyncratic cycle, as shown in Equation (4).[24] One way of determining the relative importance of common and idiosyncratic shocks to state cyclical activity is to compare the contributions of the two terms on the right-hand side of Equation (4) to each state's overall cycle, $c_{it}$.

Figure 6 shows each state's overall cycle, graphed as a line, with the bars representing the common and idiosyncratic contributions to the overall cycle. In all states, the common cyclical component tends to be more important than the idiosyncratic component. Table 4 summarises the contributions of these components to the variance of the overall cycles. For the larger states (NSW, Vic and Qld), the common cycle makes a greater contribution than the idiosyncratic cycle, which suggests that state-specific shocks are less important for these states. For the smaller states (SA, WA and Tas), the contributions of both components are quite similar. This similarity may, however, partly reflect the model's identification assumptions; some shocks we think of as common (such as exchange rate movements) may affect states with different lags and thus be partly attributed to each state's idiosyncratic cycle. The greater volatility of activity in the smaller states may also show up in a larger idiosyncratic component. Indeed, it is interesting to note that common shocks still have a larger influence on these states' cycles than on those of the larger states.

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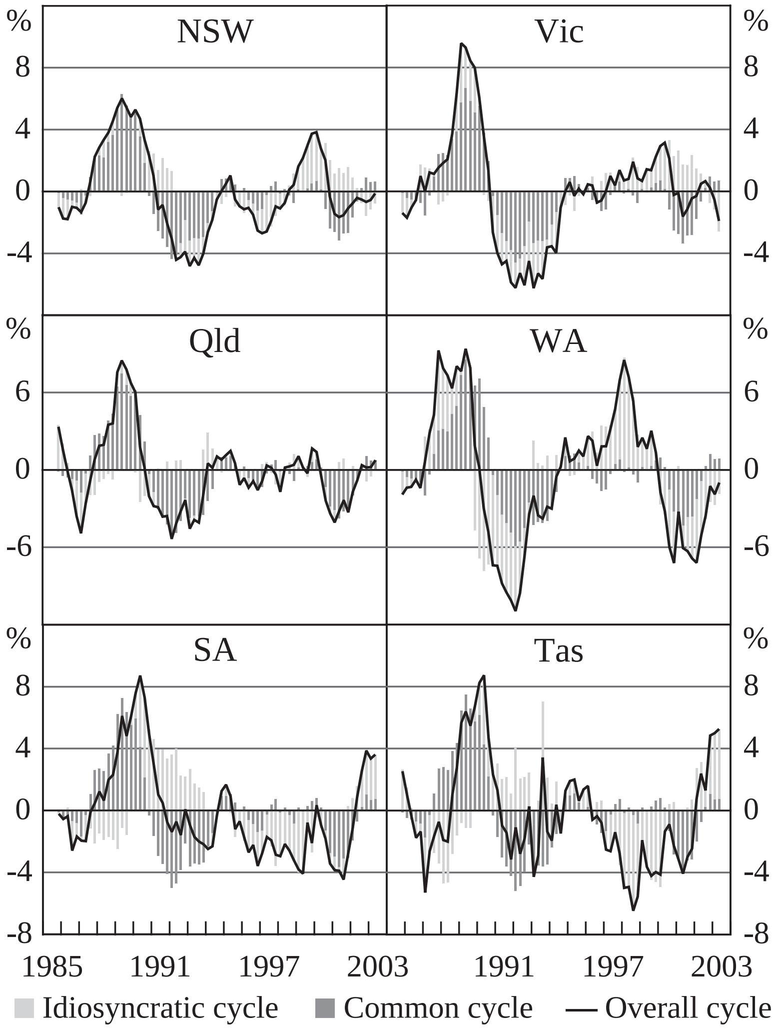
[24] Each state's SFD is assumed to respond one-to-one to its idiosyncratic cycle. As with the common cycle, we constrain hours worked to respond to the same idiosyncratic cycle as SFD, but allow the magnitude of response to vary by scaling parameters $\theta_i$. These fluctuations are permitted to be contemporaneously correlated with shocks in other states. We separate the idiosyncratic cycle from the common cycle by defining the latter as affecting *all* states simultaneously. Hence a regional shock covering more than one state would be picked up in those states' idiosyncratic cycles rather than in the common cycle.

## Figure 6: State Cycle Decomposition

State final demand




## Table 4: Variance of Cyclical Components

State final demand

| State | Common cycle component – ppt | Idiosyncratic cycle – ppt | Overall cycle |
|---|---|---|---|
| NSW | 5.5 | 2.1 | 7.4 |
| Vic | 6.1 | 2.9 | 12.2 |
| Qld | 7.7 | 1.5 | 8.8 |
| WA | 10.0 | 13.8 | 27.1 |
| SA | 7.2 | 5.3 | 9.1 |
| Tas | 7.7 | 7.8 | 11.6 |

Note: The sum of a state's common and idiosyncratic cycle variances need not equal the overall cycle variance because they may have a non-zero covariance.

These results suggest that common shocks are the primary contributors to cycles in state activity, although idiosyncratic shocks also play an important role. The fact that idiosyncratic shocks appear to make a larger contribution to activity in the smaller states could reflect behavioural differences, but we feel it is more likely to be explained by differences in the timing of states' responses to shocks such as exchange rate fluctuations.

Finally, we turn to spillovers as a third source of fluctuations in state activity. To assess the role and behaviour of spillovers in the model, we examine the impulse response functions implied by Equation (6), which trace the effects over time of a 1 per cent shock to one state's idiosyncratic cycle on the cycles of the other states. These impulse response functions are presented in Figure B1 of Appendix B. Unfortunately the functions are not well-behaved, primarily because the estimated response coefficients for WA and, to a lesser extent, Qld cause them to respond with implausible strength to shocks in other states. For example, positive shocks to NSW have a negative and destabilising influence on WA's activity, with a 1 percentage point shock to NSW's cycle reducing activity in WA by 4.7 per cent in the first year alone. The other states' responses are also then contaminated, to some extent, through flow-on effects. (We could find no outliers in the data to explain these large coefficients; as discussed before, they may arise in part from differences in the timing of state responses to shocks like fluctuations in the exchange rate.) These problems appear to stem from the small sample available and the complexity of the model, which make it especially difficult to accurately estimate the large number of parameters describing the interaction effects between state idiosyncratic cycles. To mitigate the problem somewhat, we also calculate impulse responses from the estimated coefficients, but with the response coefficients for WA and Qld set to zero. This is equivalent to 'disconnecting' these two states from the system, so they do not respond to shocks in other states. The resulting impulse response functions (Figure B2) are much more sensible. However, they are generally quite small and unlikely to be statistically significant.

To avoid some of these problems, we can instead focus on the longer-term *cumulative* effects of cyclical shocks on activity. Table 5 shows the cumulative gain in SFD for each state (analogous to a 'change in wealth' measure) in the eight quarters following a temporary 1 per cent shock to one state's idiosyncratic cycle.

In the last column of Table 5, we present the cumulative responses of state activity following a corresponding shock to the common cycle.

**Table 5: Cumulative Responses to Shocks**

State final demand

| State | Cumulative effect after eight quarters of a shock to: | | | | | | |
|---|---|---|---|---|---|---|---|
| | NSW | Vic | Qld | WA | SA | Tas | **National** |
| NSW | **4.5** | –1.0 | –1.1 | –0.6 | –1.1 | –1.2 | 5.9 |
| Vic | 1.1 | **1.8** | –1.0 | 0.1 | –2.8 | –0.6 | 6.3 |
| Qld | 1.7 | 0.3 | **2.5** | 1.6 | 1.3 | 1.1 | 7.1 |
| WA | –8.6 | –2.7 | –1.8 | **2.2** | –2.7 | –0.8 | 8.0 |
| SA | 1.8 | 1.0 | 0.7 | –1.3 | **3.8** | 0.5 | 6.8 |
| Tas | 2.2 | 2.4 | 2.4 | –0.4 | 3.3 | **3.1** | 7.1 |

Notes: The cumulative response is effectively the integral between the shocked level of SFD and the no-shock counterfactual level from the shock quarter to the eighth quarter following the shock. The shocks to state idiosyncratic cycles are all 1.0 per cent. The shock to the common cycle is 0.91 per cent, which corresponds to an increase in *aggregate* final demand of 1 per cent in the shock quarter. (The shock applied is less than 1 per cent because the average state response to the common cycle is greater than one – see Table 3.) All shocks last one quarter, but the model dynamics imply a sustained decay path in each case.

As with the impulse responses, the results for WA seem unrealistic. Aside from these, however, the most striking features are the cumulative effects of common shocks on activity, and the uniformity of these effects across states. The effect of a 1 per cent shock to the common cycle accumulates to an increase of between 5.9 and 8 percentage points in the level of SFD in each state over the shock quarter and the subsequent eight quarters. The size of this effect is due to the strong persistence of the common cycle, implying that common shocks provide repeated gains (or losses) in activity over a long period.

The bold diagonal elements in Table 5, measuring the long-term effect of idiosyncratic shocks on the state of origin, are also quite large (well above the initial shock of 1 per cent), although significantly smaller than the common shock effects. The off-diagonal elements, which characterise spillovers of shocks between states, are generally smaller than the corresponding own-state effects and in some cases have the opposite sign.[25] These results broadly support our earlier findings: common shocks appear the most important to activity, followed by idiosyncratic shocks, with spillovers playing a relatively minor role.

As a final robustness check, we tried replacing SFD with our own constructed estimates of quarterly gross state product (GSP). Full details are given in Appendix C. We found that making this change produced qualitatively very similar results to those from the SFD-hours worked model, even though the GSP estimates are a broader measure of activity.

## 6. Conclusion

Our goal in this paper has been to disentangle the common and idiosyncratic fluctuations which drive state cyclical activity in Australia, and to trace their paths through the economy. We have used a variety of statistical techniques to achieve this. A number of common conclusions arise from the different techniques. State business cycles tend to co-move quite strongly, particularly those of the larger states (NSW, Vic and Qld). This is perhaps not surprising, given all states share a common monetary policy and exchange rate. Correlations between state business cycles (using SFD as a measure of activity) are similar to those found in regional studies of other countries, and suggest the presence of a significant contemporaneous relationship. Concordance measures and comparisons of recession periods both support these findings.

A more detailed analysis suggests that this co-movement arises mainly from a pronounced common cycle, which affects all states simultaneously. This common cycle is presumably driven by macroeconomic shocks such as fluctuations in the exchange rate or the terms of trade. Spillovers of idiosyncratic shocks from one state to another through trade and investment linkages appear less important in explaining co-movement. Lagged correlations between state cycles are generally not larger than contemporaneous correlations, and there is only modest evidence that cyclical activity in one state Granger-causes activity in other states.

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[25] The exceptions are: the figures for WA (which, as already discussed, we regard as unreliable); those for Tas (which may reflect its relatively small size); and the response of Vic to SA, which also appears to be an outlier.

Using an unobserved components model, we find evidence that common shocks play the major role in shaping state activity, followed by idiosyncratic shocks, with spillovers of shocks between states the least important. Idiosyncratic shocks may play a relatively greater role in shaping the cycles of the smaller states, but simulations of shock responses suggest that the cumulative impact of a common shock is larger (even in these states) than an idiosyncratic shock of comparable size. Overall, while the lack of a long time series of state data makes it difficult to be definitive, our various approaches all suggest that state business cycles move quite closely together in Australia, and that common shocks are the most important source of fluctuations in state economic activity.

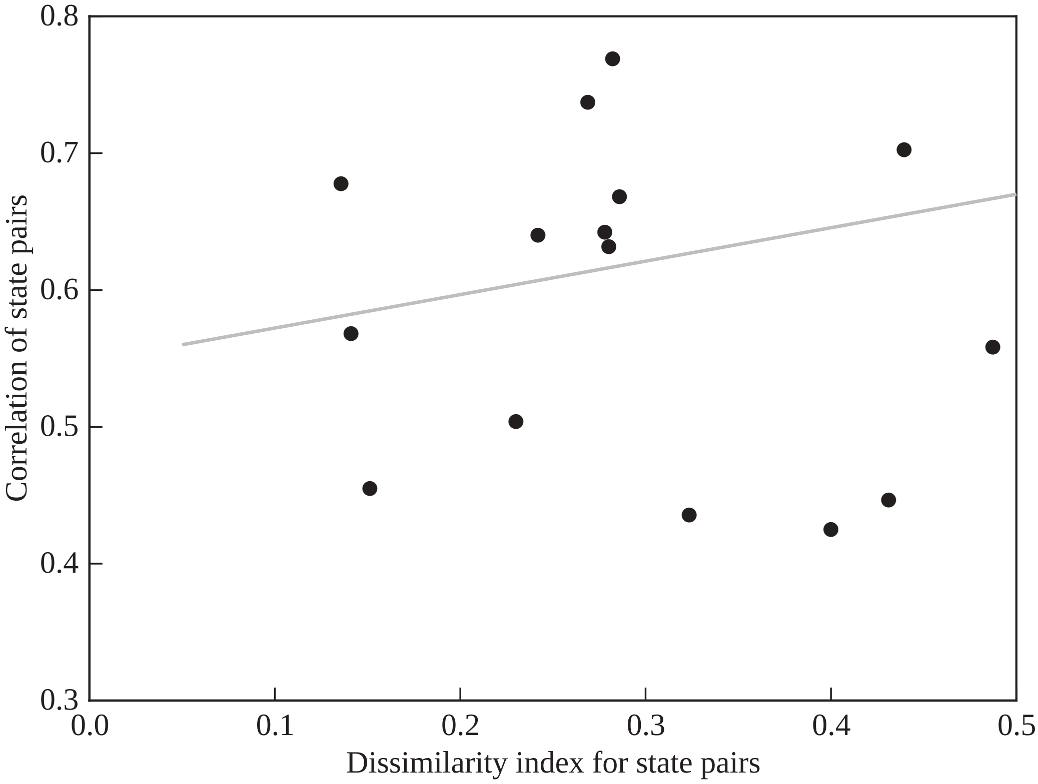
## Appendix A: Industrial Structure and Cyclical Co-movement

Whilst it has traditionally been assumed that industry structure is an important determinant of cyclical co-movement, recent research has tended to suggest otherwise (Altonji and Ham 1990; Clark and Shin 2000). A simple test of the importance of industry structure for cyclical co-movement is to construct a measure of the industrial similarity of state pairs, and compare this with the correlation of their cyclical activity. We use Krugman's (1991) index of industrial dissimilarity, as shown in Equation (A1), which increases from 0 to a maximum value of 2 as two economies become less similar.

$$DISS_{ij} = \sum_m S_m^i - S_m^j \tag{A1}$$

Here, $S_m^i$ and $S_m^j$ represent industry $m$'s share of total factor income in states $i$ and $j$ respectively. A scatter-plot of this index against correlations in band-pass filtered SFD is presented in Figure A1.

**Figure A1: Industrial Dissimilarity and Correlations of SFD**




Note: Trend line calculated excluding WA observations, as dissimilarity indices involving WA significantly exceed those among other states.

The results show that there is little relationship between the two, as indicated by the poor fit of the trend line. Furthermore, the trend line is actually positively sloped, counter-intuitively indicating that co-movement actually increases with differences in industrial structure, rather than with similarity. This simple exercise suggests that there is little role for industrial structure in explaining co-movement among state business cycles.

# Appendix B: Further Unobserved Components Model Results

**Table B1: Estimated Parameters for Hours Worked**

| **State** | **Trend parameter, $\delta^h$** | | **Common cycle response parameter, $\gamma^h$** |
|---|---|---|---|
| | 1985:Q4–1994:Q4 | 1995:Q1–2003:Q2 | |
| NSW | 1.86 | 1.35 | 0.51 |
| Vic | 1.22 | 1.12 | 0.59 |
| Qld | 3.40 | 2.03 | 0.48 |
| WA | 2.69 | 1.66 | 0.54 |
| SA | 0.84 | 0.72 | 0.40 |
| Tas | 0.77 | 0.30 | 0.65 |
| **National average** | **1.92** | **1.38** | **0.52** |

Notes: Trend parameter estimates can be interpreted as average annualised percentage growth rates. The ‘national average’ figures are calculated as the average of the state figures, weighted by their share of total hours worked.

**Table B2: Estimated $\rho$ and $\theta$ Parameters**

| | |
|---|---|
| National cycle coefficient, $\rho$ | 0.94 |
| National cycle error variance, $\sigma_\eta^2$ | $6.4 \times 10^{-5}$ |
| **State** | **Idiosyncratic cycle response coefficient, $\theta_i$ (for hours worked)** |
| NSW | 0.61 |
| Vic | 0.43 |
| Qld | 0.54 |
| WA | 0.18 |
| SA | 0.25 |
| Tas | 0.21 |

Notes: Sample is 1985:Q3–2003:Q2, yielding 71 observations. Idiosyncratic response coefficients for SFD are constrained to equal 1.

**Table B3: Idiosyncratic Cycle Equation Coefficients, Φ**

| State | NSW | Vic | Qld | WA | SA | Tas |
|---|---|---|---|---|---|---|
| NSW | **0.83** | –0.08 | –0.10 | –0.07 | –0.07 | –0.11 |
| Vic | 0.20 | **0.58** | –0.11 | –0.02 | –0.35 | 0.05 |
| Qld | 0.69 | 0.41 | **0.95** | 0.65 | 0.59 | 0.45 |
| WA | –0.63 | –0.53 | –0.52 | **0.46** | –0.61 | –0.14 |
| SA | –0.10 | –0.08 | –0.11 | –0.25 | **0.56** | 0.00 |
| Tas | –0.34 | 0.14 | 0.27 | –0.28 | 0.32 | **0.37** |

**Table B4: Cumulative Responses to Shocks**

Hours worked

| **State** | **Cumulative effect after eight quarters of a shock to:** | | | | | | |
|---|---|---|---|---|---|---|---|
| | NSW | Vic | Qld | WA | SA | Tas | **National** |
| NSW | **2.7** | –0.6 | –0.7 | –0.4 | –0.7 | –0.8 | 3.0 |
| Vic | 0.5 | **0.8** | –0.4 | 0.1 | –1.2 | –0.2 | 3.5 |
| Qld | 0.9 | 0.1 | **1.3** | 0.9 | 0.7 | 0.6 | 2.8 |
| WA | –1.6 | –0.5 | –0.3 | **0.4** | –0.5 | –0.2 | 3.2 |
| SA | 0.5 | 0.2 | 0.2 | –0.3 | **0.9** | 0.1 | 2.4 |
| Tas | 0.5 | 0.5 | 0.5 | –0.1 | 0.7 | **0.7** | 3.9 |

Notes: The cumulative response is effectively the integral between the shocked level of hours worked and the no-shock counterfactual level from the shock quarter to the eighth quarter following the shock. The shocks to state idiosyncratic cycles are scaled to increase SFD in the shock state by 1 per cent in the first quarter; the shock to the common cycle is similarly scaled and is 1.95 per cent (see notes to Table 5). All shocks last one quarter, but the model dynamics imply a sustained decay path in each case.

**Figure B1: Idiosyncratic Cycle Impulse Response Functions**

SFD and hours worked model

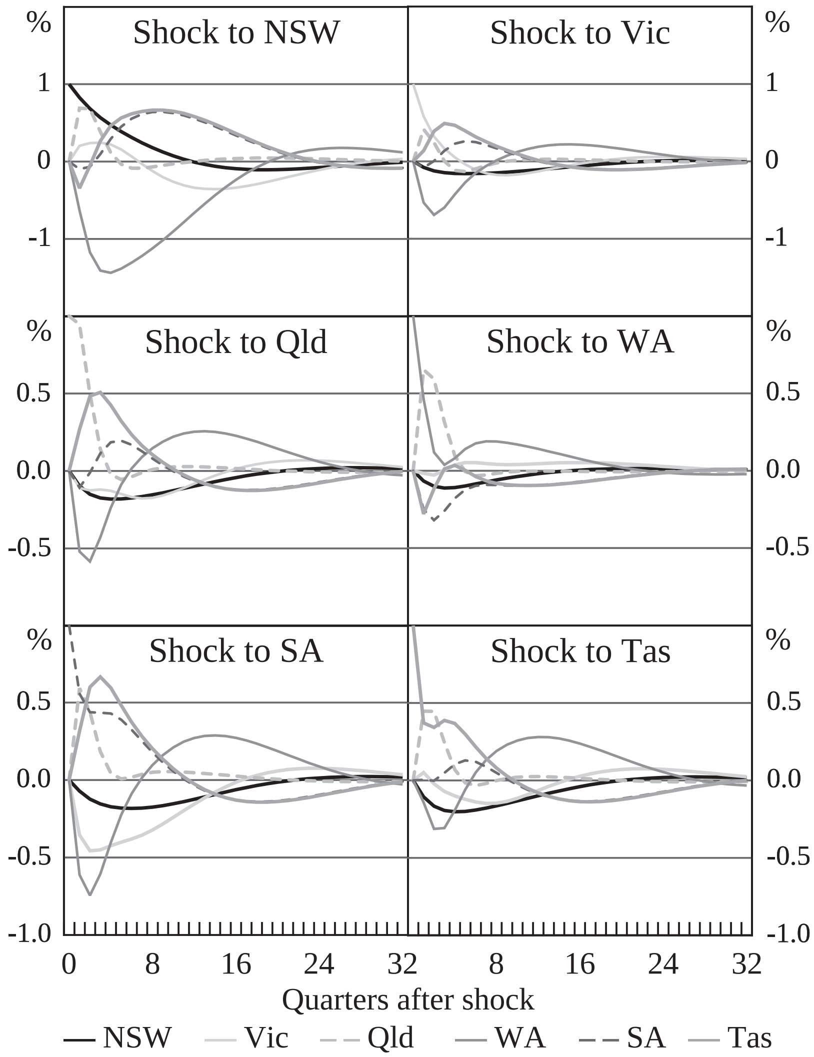
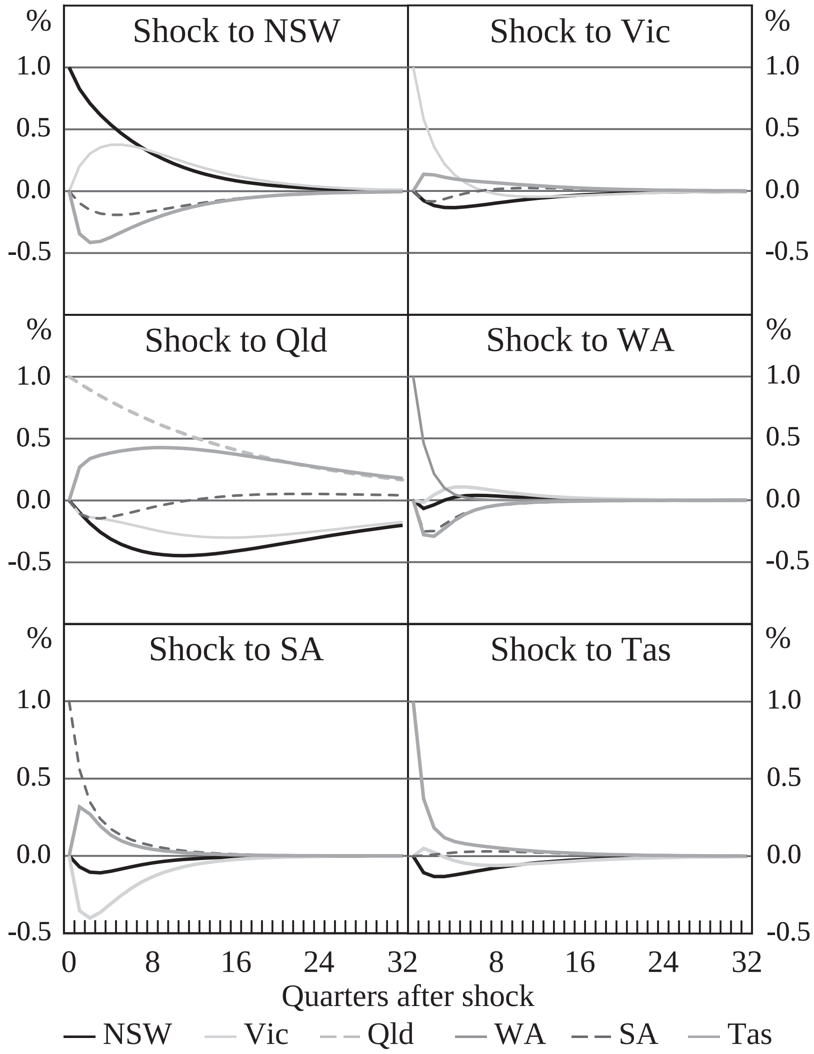


**Figure B2: Idiosyncratic Cycle Impulse Response Functions**

SFD and hours worked model – suppressing interstate responses of WA and Qld



## Appendix C: Gross State Product and Hours Worked

In our modelling we used SFD as a proxy for state output. As discussed in Section 2, SFD effectively excludes trade and changes in inventories, yet trade flows might be expected to capture the bulk of spillover effects between states. It would be preferable to use a measure of gross state product (GSP) which captures these effects. Since the ABS ceased calculating and reporting quarterly GSP estimates in June 1997, we construct our own estimates of quarterly GSP from annual data, to assess whether including trade increases the role given to spillovers in the model.

We apply the ordinary least squares method detailed in Chow and Lin (1971), using the quarterly profile of SFD to interpolate quarterly GSP estimates from the ABS's annual GSP series.[26] Compared with the ABS quarterly series available over the period 1985:Q3–1997:Q2, the constructed series matches medium-term movements in GSP moderately well (year-ended growth rates of the two sets of estimates have correlations of about 0.7), but quarterly growth rates only marginally (correlations of around 0.3). Since the ABS emphasised the experimental nature of its constant price quarterly GSP estimates, there is no absolutely reliable benchmark, but we feel it is worth examining the effects of using our constructed measure of GSP in place of SFD in the model.

Full results are presented below. The main point to note is that most of the results for this specification are very similar to those from the model using SFD and hours worked. The estimated common cycles of the two models are almost identical, and the trend and common cycle response parameter estimates for GSP (Table C2) are much the same as those for SFD. On the whole, the change does not appear to alter the main characteristics of the model. This may be due in part to the fact that the quarterly profiles of the constructed GSP series and SFD are by definition very similar.

[26] This method involves estimating a simple linear regression of annual GSP on annual SFD, allowing for serial correlation in the error term. We then use the estimated coefficients to generate quarterly estimates of GSP from the quarterly SFD data. Finally, in order to satisfy an annual adding-up constraint, the serial correlation relationship is used to generate quarterly predictions of the error terms, which are added to the quarterly GSP predictions. Further details can be found in Chow and Lin (1971).

The cumulative state responses to common and idiosyncratic shocks for the GSP-hours worked model are presented in Table C1. Using GSP does not substantially alter our assessment of the importance of spillovers. The response of WA to NSW is much more reasonable than in Table 5, but its response to the national cycle is larger. Most of the other responses remain broadly the same size. The off-diagonal elements are larger than in Table 5, but not significantly larger. Except for Tasmania's response to NSW and WA's response to Tas, all of the off-diagonals are smaller than their diagonal counterparts. Once again, this suggests that spillovers are less important than idiosyncratic shocks, but may nevertheless be of some significance in determining activity.

**Table C1: Cumulative Responses to Shocks**

Gross state product

| State | Cumulative effect after eight quarters of a shock to: | | | | | | |
|---|---|---|---|---|---|---|---|
| | NSW | Vic | Qld | WA | SA | Tas | **National** |
| NSW | **3.5** | –0.2 | –1.2 | –0.6 | –1.1 | –0.6 | 5.5 |
| Vic | 1.7 | **3.0** | 0.0 | 0.0 | –1.5 | –0.8 | 5.6 |
| Qld | 0.6 | 0.6 | **2.8** | 1.5 | 0.7 | 1.4 | 7.2 |
| WA | 1.4 | 2.8 | 2.9 | **3.7** | 2.4 | 4.2 | 9.6 |
| SA | –2.6 | –1.9 | –1.6 | –1.5 | **2.1** | –2.3 | 5.6 |
| Tas | –3.9 | –2.7 | –1.2 | –1.3 | 0.0 | **1.3** | 4.4 |

Notes: The cumulative response is effectively the integral between the shocked level of GSP and the no-shock counterfactual level from the shock quarter to the eighth quarter following the shock. The shocks to state idiosyncratic cycles are all 1.0 per cent; the shock to the common cycle is 0.89 per cent (see notes to Table 5). All shocks last one quarter, but the model dynamics imply a sustained decay path in each case.

On the whole, using an approximate measure of GSP in place of SFD in our model does not appear to change our earlier conclusions. Gauging the precise details of the effects of spillovers remains very difficult given the approximate nature of our GSP estimates and the small sample size.

**Table C2: Estimated Parameters for Gross State Product**

| State | Trend parameter, $\delta^g$ | | Common cycle response parameter, $\gamma^g$ |
|---|---|---|---|
| | 1985:Q4–1994:Q4 | 1995:Q1–2003:Q2 | |
| NSW | 2.54 | 3.68 | 1 |
| Vic | 1.88 | 4.02 | 1.01 |
| Qld | 4.36 | 4.57 | 1.31 |
| WA | 4.67 | 3.55 | 1.76 |
| SA | 1.45 | 2.75 | 1.03 |
| Tas | 0.95 | 1.56 | 0.81 |
| **National average** | **2.76** | **3.80** | **1.13** |

Notes: Trend parameter estimates can be interpreted as average annualised percentage growth rates. The national cycle response parameter for NSW is normalised to be 1. The 'national average' figures are calculated as the average of the state figures, weighted by their share of total GSP.

**Table C3: Estimated $\rho$ and $\theta$ Parameters**

| | |
|---|---|
| Common cycle coefficient, $\rho$ | 0.93 |
| Common cycle error variance, $\sigma_\eta^2$ | $5.8\times10^{-5}$ |
| **State** | **Idiosyncratic cycle response coefficient, $\theta_i$ (for hours worked)** |
| NSW | 0.41 |
| Vic | 0.41 |
| Qld | 0.22 |
| WA | 0.07 |
| SA | 0.18 |
| Tas | 0.48 |

Notes: Sample is 1985:Q3–2003:Q2, yielding 71 observations. Idiosyncratic response coefficients for GSP are constrained to equal 1.

**Table C4: Idiosyncratic Cycle Equation Coefficients, $\Phi$**

| State | NSW | Vic | Qld | WA | SA | Tas |
|---|---|---|---|---|---|---|
| NSW | **0.67** | –0.07 | –0.22 | –0.06 | –0.14 | –0.07 |
| Vic | –0.04 | **0.49** | –0.13 | –0.12 | –0.27 | –0.23 |
| Qld | –0.17 | –0.29 | **0.24** | 0.15 | –0.20 | –0.17 |
| WA | 1.03 | 1.29 | 1.35 | **1.11** | 0.94 | 1.15 |
| SA | –0.41 | –0.32 | –0.34 | –0.24 | **0.49** | –0.28 |
| Tas | –0.50 | –0.42 | –0.32 | –0.22 | –0.16 | **0.45** |

## Appendix D: Data Sources

### State final demand

Data are seasonally adjusted, in chain volume terms, 2001/02 prices, from Australian Bureau of Statistics (ABS), Australian National Accounts: National Income, Expenditure and Product, Cat No 5206.0 (various tables), December 2003.

### Hours worked

Data are total hours worked per state, in the reference week for the relevant quarter, obtained from ABS, Labour Force, Australia, Cat No 6202.0, Tables LHQI-103, -203, -303, -403, -503 and -603, April 2004.

### Gross state product

*Annual*
Data in chain volume terms, 2001/02 prices, from ABS, Australian State Accounts, Cat No 5220.0 (Table 1), June 2003.

*Quarterly*
Data are seasonally adjusted, in constant price terms, 1989/90 prices. Obtained from ABS, Australian National Accounts: State Accounts, Cat No 5242.0, using the latest data for each quarter as reported in the December 1992 to June 1997 publications. Adjustments to 2001/02 prices were made using state final demand deflators from 5206.0.

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