

# **THE DECLINE IN AUSTRALIAN OUTPUT VOLATILITY**

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## **Abstract**

There has been a large decline in the volatility of Australian output over the past 40 years. This paper looks at the causes of this decline. Accounting for part of the change have been substantial changes in the inventories cycle. Abstracting from changes in the inventories cycle there have also been significant declines in underlying output volatility. This paper focuses on the underlying structural factors for the reduction in volatility. It finds that the principal cause of the decline has been a decline in the shocks hitting the economy rather than an increase in structural stability. Furthermore, the primary explanation seems to lie in a reduction in the volatility of supply or ‘productivity’ shocks. The ultimate source of these productivity shocks is left as an open question.

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## 1. Introduction

The 1990s have been a period of generally strong growth and extended expansion throughout much of the world. In the US the expansion beginning in March 1991 has set a record as the longest post-war expansion. The expansion in Australia from the June quarter of 1991 has also been long by historical standards. When combined with low inflation, this robust growth has led to economic conditions unlike any seen since the 1960s. This paper aims to shed more light on the sources of the recent output growth experience and thereby, indirectly, on the prospects for the future.

The most obvious feature of the recent growth experience is that output growth has been much smoother than in previous periods. Table 1 shows the facts on output variability over the past forty years. It shows the variance of output growth over the four cycles that generally cover the 1960s, 1970s, 1980s and 1990s.<sup>1</sup>

It is clear that there has been a significant decline in GDP(E) volatility. Much of this change in volatility can be traced to a change in the volatility of the inventories cycle. It is not clear whether this is a statistical artefact, given that it is so large compared to other output measures, or a real effect. To remove the influence of the inventories cycle and focus on more fundamental forces, I will concentrate on the growth of output minus inventories. A detailed examination of the inventories cycle in Australia will be left for another paper.

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<sup>1</sup> The cycles are defined from trough to trough. The cycle of the '1960s' is defined as 1961:Q4 to 1974:Q2, the cycle of the '1970s' as 1974:Q3 to 1983:Q2, the cycle of the '1980s' as 1983:Q3 to 1991:Q2 and the expansion of the '1990s' by 1991:Q3 to the present, 2000:Q4. Including the early 1990s recession in the '1990s' sample, and similarly adjusting earlier samples, does not unduly affect the results.

**Table 1: Variance of GDP(E)<sup>2</sup>**

1960s	14.60
1970s	3.34
1980s	1.75
1990s	0.63

Note: Calculated as the variance of quarterly GDP(E) growth, gross national expenditure plus net exports, over the periods identified in footnote 1.

Removing the influence of inventories from the data there is still a significant decline in output volatility. Table 2 shows the variance of domestic final demand plus net exports.<sup>3</sup>

**Table 2: Variance of Domestic Final Demand Plus Net Exports**

1960s	1.23
1970s	1.57
1980s	1.73
1990s	0.81

Note: The variances for the 1970s and 1980s are affected by one outlier in each case. Deletion of the outlier leads to a variance of 1.31 for the 1970s and 1.16 for the 1980s. The sample periods are those identified in footnote 1.

We can see that the volatility of output in the 1990s (abstracting from the inventories cycle) is still the lowest it has been since the start of the quarterly national accounts data – the volatility of the 1990s is less than half that of the 1970s or 1980s. The pattern is also slightly different, suggesting that the 1980s were a time of relative volatility and that the 1960s, despite the picture given from the GDP(E) data, were a time of relatively smooth expenditure growth.

The volatility of output growth is important in assessing the prospects for economic growth. Quite apart from the confidence that smooth, consistent growth

<sup>2</sup> The high volatility in the 1960s and 1970s is not present in the series for GDP(A). The divergence comes from (a) the statistical discrepancy and (b) the process of chain linking the real GDP series. These seem to lead to much greater volatility in earlier observations. Nonetheless, the same pattern is present in the GDP(A) series. These results are presented to provide a consistent basis for comparison with the results of Table 2. For comparison, the variances of GDP(A) in the 1960s, 1970s, 1980s and 1990s are 2.41, 1.15, 0.91 and 0.35.

<sup>3</sup> This measure is essentially GDP(E) less inventories but the use of chain-linked series creates some minor differences in earlier periods.

engenders, there is an effect on the potential length of expansions. With high volatility it is much easier for random shocks to cause the economy to contract and start a recession. The work of Hamilton (1989) seems to suggest that recessions, once begun, have different dynamics from expansions. Thus, to the extent that recessions are not merely a continuation of previous dynamics, their initiation is worth avoiding.

There is also a literature that looks at the correlation between output growth and its volatility (see Kormandi and Meguire (1985) for example). The initial finding was that higher volatility is correlated with higher growth. This was rationalised as an application of asset-market ideas about risk and return trade-offs; higher growth (return) should be accompanied by higher volatility (risk). However, this has been questioned by some more recent papers (Ramey and Ramey (1995), Martin and Rogers (2000)). It would be interesting to see how the recent run of data, including the substantially improved output performance in the US over the past few years, affects this story.

These factors should provide adequate reason to look at the sources of output volatility. Hopefully, a better understanding of their causes will allow for better understanding of any shocks that occur and provide a better foundation for forecasts of output growth. The rest of this paper looks at the nature of volatility in Australian output growth and how it has changed over the past decades. It identifies whether the reduced output volatility is primarily due to shocks or the improved stability of the economy. The paper also considers some potential explanations for the reduced variability of shocks. Section 2 conducts a brief literature review to place this work in the context of previous research. Section 3 then discusses the distinction between shocks and structure in more detail. Section 4 presents the technical details of the structural VAR model that will be used to separate the influences of shocks and structure and Section 5 presents the results. Section 6 speculates on causes of the decline in the supply (or productivity) shocks identified in Section 5. Section 7 concludes. Details of the data used are contained in Appendix A.

## 2. Literature Review

A decline in the volatility of output has been noted in a number of recent papers in a number of countries. Gruen and Stevens (2000) note the decline in Australian output volatility. Without conducting a detailed analysis they suggest that smaller shocks may provide the best explanation for the recent smoothness of output growth. Overseas studies have also focused on the reduction in output volatility. McConnell and Quiros (2000) find compelling evidence of a structural break in US output growth volatility in 1984. Decomposing output to find the source of the volatility decline, they attribute it to a change in the behaviour of durable goods production and associated inventories behaviour. Simon (2000) also documents the decline in volatility of US output growth and decomposes the sources using a structural VAR methodology. This decomposition finds that the primary source of the better performance is the reduction in the shocks hitting the economy rather than improved structural stability. Furthermore, the primary reduction has been in demand shocks and a much smoother profile for household consumption. The data show that households are now behaving much more in line with the predictions of the permanent income hypothesis and smoothing temporary income shocks much more than they did in the 1960s.

In a related area, there was a vigorous debate within the field of economic history about declines in US output volatility pre- and post-WWII. Results from this research on stabilisation are equivocal. There are many technical data questions resulting from the lack of good quality data for earlier time periods. The initial consensus in the literature was that stabilisation, in the form of reduced economic volatility, had occurred in the post-WWII period. This was formalised in DeLong and Summers (1986). This view was challenged by Christina Romer in a number of papers questioning the validity of the early data (see, for example, Romer (1986)). This contention has, itself, been challenged by Weir (1986) and Balke and Gordon (1989) among others.

Work on the duration dependence of business cycles attempts to understand stability without becoming bogged down with data issues by concentrating on less equivocal data – generally business cycle lengths. Longer expansions are seen as a closely related consequence of lower volatility, indeed it is generally the longer expansions that have brought the issue of lower volatility into the picture. Despite

hopes that the analysis would not be affected to the same degree by data problems, the findings are not clear. Diebold and Rudebusch (1990) find some evidence for duration dependence in whole cycles since the turn of the century, but no evidence in post-WWII expansions. Addressing the issue of post-WWII stabilisation, Diebold and Rudebusch (1992) find that the average length of an expansion is at least 9 months longer post-WWII than pre-WWII.

Many papers confined themselves to establishing that stabilisation has occurred; fewer concerned themselves with explaining why this has occurred. In a paper analysing 19<sup>th</sup> century US data, James (1993) finds increased volatility after the US Civil War and provides a possible reason. He finds the increased volatility was a result of the changed structure of the economy rather than the result of an increase in the size of shocks hitting the economy. On the basis of a structural VAR, he attributes the increased volatility after the Civil War to the increased influence of monetary shocks. This separation of structure (propagation mechanism) from shocks will also be used in this paper.

The structural VAR methods that will be used in this paper are very much in the tradition of Blanchard and Quah (1989) and Gali (1992). Similar work in the Australian context has been conducted by Otto (1995, 1999). Otto (1995) tried to identify the effect of terms of trade shocks on Australian output. He found that output could be best explained by productivity shocks with other shocks having a relatively minor effect.

### **3. Structure or Shocks?**

I consider two possible explanations for stabilisation. The first is that the shocks hitting the economy have changed; the second is that the structure of the economy has changed. The structural explanation focuses on changes in the propagation of shocks through the economy rather than the shocks themselves. Within the explanation based on shocks I focus on the different kinds of shocks that could affect the economy.



### 3.1 Shocks

Following on from the distinctions made in Blanchard and Watson (1986) we can separate shocks into large, identifiable shocks and small, noise shocks. Large, identifiable shocks include exogenous events such as the OPEC oil shocks of the 1970s as well as policy shocks such as the disinflation of the late 1980s. The periods of focus in this paper have been chosen around the major shocks. Periods of investigation are chosen around the four cycles that have occurred over, approximately, the 1960s, 1970s, 1980s and 1990s in Australia. The rationale for this is the research that finds that recessions are times of accelerated reorganisation. If there is any structural change in the economy it is most likely to show up around recessions. Thus, the 1970s is defined by the economy's reaction to the OPEC I oil shock and wage breakout, the 1980s by reaction to OPEC II and by the Accord and deregulation and the 1990s by low inflation. In line with the findings of Blanchard and Watson (1986), that an accumulation of small shocks does not lead to significant economic change, I assume that the economy is relatively stable within periods.

Turning attention to smaller, within episode, shocks we can divide these on the basis of their source. Following the seminal work of Blanchard and Quah (1989) we can think of demand and supply shocks as the most basic shocks to hit an economy. Simply put, supply shocks are those that have a permanent effect on output while demand shocks are those that have no permanent effect on output. I shall use the terms 'supply shock' and 'productivity shock' interchangeably. These can most easily be thought of as fluctuations around some trend rate of growth depending on how production innovations arrive and affect output.

In the context of an open economy we might also want to think about shocks to world prices and the competitiveness of the export sector through exchange rate changes. It is possible to conceive of these as being quite long-lived. Nonetheless, it is hard to think of shocks that could have permanent effects as these sorts of shocks are, at heart, just a change in prices. Thus, another sort of temporary shocks to consider are relative export and import price changes. In this paper I will focus on the terms of trade as the appropriate measure of these influences.

## 3.2 Structure

Structure is the way given shocks propagate through the economy. Thus, productivity shocks may have little initial effect on output, but when investment decisions respond and embody the new technology, output may change substantially in the medium and long run. If the pattern of the impulse response to given shocks changes, this is an example of structural change. For example, if a given shock causes overshooting and oscillation in one economy yet has a smooth damped effect in another we would characterise the first as being less structurally stable.

A more concrete example of structural change would be a change in the openness of an economy. Changes in an economy's trading relationships and the importance of trade in overall GDP could have an effect on how trade-related shocks were transmitted to the economy. One might expect that economies are now more sensitive to movements in their terms of trade than they used to be due to the greater international integration that has occurred in the past decades. A countervailing influence would be the stabilisation benefits of floating exchange rates. Until the results are generated it is difficult to guess which of these might be more important.

To separate structure from shocks I will make use of a VAR. Estimates of the structural VAR parameters will be used to capture the structure of the system while the structural residuals will, clearly, be the shocks. The following section deals with the estimation of the VAR and how I will use it to identify shocks and structure.

## 4. The Structural VAR

I use three variables in the VAR: output growth, the unemployment rate and the terms of trade (TOT). These variables are chosen to use the same variables as Blanchard and Quah (1989) augmented with the TOT to reflect the fact that Australia is a much more open economy than the US. I will not be imposing any restrictions on the model above those required to achieve identification. As such

the details of the individual equations are relatively unimportant. The VAR methodology specifically allows the data to suggest the best model.

Underlying the VAR we can think of three orthogonal structural shocks  $\varepsilon^s, \varepsilon^d, \varepsilon^{\text{TOT}}$ . These are i.i.d. shocks to supply (productivity), demand and the TOT.  $\varepsilon^s$  is a productivity shock that may have permanent effects on output while  $\varepsilon^d$  is a demand shock that is constrained to have no long-run effect on output.  $\varepsilon^{\text{TOT}}$  is a shock to the level of the TOT which is also constrained to have no long-run effect on output.

The exact variables used (i.e. whether in levels or differences) are discussed in the next section. For the time being I will just describe the relation between output, unemployment and the terms of trade. Suppose that the relation between  $\mathbf{x} = (y, ue, TOT)'$  can be characterised by the structural equations:

$$\mathbf{B}_0 \mathbf{x}_t = \mathbf{k} + \mathbf{B}_1 \mathbf{x}_{t-1} + \mathbf{B}_2 \mathbf{x}_{t-2} + \dots + \mathbf{B}_p \mathbf{x}_{t-p} + \boldsymbol{\varepsilon}_t \quad (1)$$

where:

$$\begin{aligned} \boldsymbol{\varepsilon}_t &= (\varepsilon_t^s, \varepsilon_t^d, \varepsilon_t^{\text{TOT}})' \\ \mathbf{B}_0 &= \begin{bmatrix} 1 & -\beta_{12}^{(0)} & -\beta_{13}^{(0)} \\ -\beta_{21}^{(0)} & 1 & -\beta_{23}^{(0)} \\ -\beta_{31}^{(0)} & -\beta_{32}^{(0)} & 1 \end{bmatrix} \\ \mathbf{k} &= (k_1, k_2, k_3)' \end{aligned} \quad (2)$$

and  $\mathbf{B}_s$  is a general (3x3) matrix. This can be rewritten in more standard VAR form by premultiplying both sides by  $\mathbf{B}_0^{-1}$ .

$$\mathbf{x}_t = \mathbf{c} + \boldsymbol{\Phi}_1 \mathbf{x}_{t-1} + \boldsymbol{\Phi}_2 \mathbf{x}_{t-2} + \dots + \boldsymbol{\Phi}_p \mathbf{x}_{t-p} + \mathbf{u}_t \quad (3)$$

where:

$$\begin{aligned}
\mathbf{c} &= \mathbf{B}_0^{-1}\mathbf{k} \\
\Phi_s &= \mathbf{B}_0^{-1}\mathbf{B}_s \\
\mathbf{u}_t &= \mathbf{B}_0^{-1}\boldsymbol{\varepsilon}_t
\end{aligned} \tag{4}$$

Identification of the structural parameters requires identification of the parameters of  $\mathbf{B}_0$ . Given knowledge of  $\mathbf{B}_0$  the remaining  $\mathbf{B}_s$  can be identified from the reduced form VAR parameters. There are six free parameters in  $\mathbf{B}_0$  so six restrictions are needed to identify them. The first three restrictions come from assuming that the underlying shocks are mutually orthogonal and, thus, that their covariances are zero. This is implemented through a number of nonlinear restrictions on  $\mathbf{B}_0$ . In particular:

$$\begin{aligned}
u_t u_t' &= \mathbf{B}_0^{-1} \boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t' \mathbf{B}_0^{-1'} \\
\Rightarrow E(u_t u_t') &= E(\mathbf{B}_0^{-1} \boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t' \mathbf{B}_0^{-1'}) \\
\Rightarrow \boldsymbol{\Sigma} &= \mathbf{B}_0^{-1} E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') \mathbf{B}_0^{-1'} \\
\Rightarrow \mathbf{B}_0 \boldsymbol{\Sigma} \mathbf{B}_0' &= \boldsymbol{\Omega} = E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t')
\end{aligned} \tag{5}$$

and we require that  $\boldsymbol{\Omega}_{ij}=0$  for  $i \neq j$ . A consistent estimate of  $\boldsymbol{\Sigma}$  is obtained from the reduced form VAR residuals.

The remaining three restrictions are generated from economic argument in the manner of Blanchard and Quah (1989). The first two are that demand shocks and terms of trade shocks have no long-run effect on the level or growth rate of output.

The long-run restrictions are now widely used but still controversial. Much of the justification for their use has already been given previously (see, for example, Blanchard and Quah (1989)). Notwithstanding this, I present some reasons why terms of trade and demand shocks may not have any long-run effect on output. As argued in Blanchard and Quah (1989) there may be reasons to think that demand shocks can have long-run effects on output. However, the size of these effects is likely to be very small compared to that of supply disturbances. As such, the identification that demand shocks have no long-run effects is ‘almost correct’.

It is possible to imagine two forces driving the terms of trade: long-term structural changes in the composition of imports and exports and fluctuations in the prices of a relatively stable basket of imports and exports. In the latter case there should be no significant long-run effect on output. In the former case you might well expect these changes to affect output. However, in these cases the shocks are more reflective of output and demand changes than terms of trade fluctuations. These shocks will appear in the terms of trade but are probably better identified with domestic factors such as demand or supply. The identification strategy used explicitly rules out long-run effect from the terms of trade and thereby focuses on the short to medium-term price fluctuations in the terms of trade. The longer-term changes are associated with supply shocks. I will return to this consideration when the final results are interpreted. Notwithstanding this, it is possible to change the identifying assumptions and relax the assumption that terms of trade shocks have no long-run effect. This is done at the end of the section.

The long-run restrictions are implemented as follows:

It is possible to write the reduced form VAR in MA( $\infty$ ) form

$$\begin{aligned} \mathbf{x}_t &= \boldsymbol{\mu} + \mathbf{u}_t + \boldsymbol{\Psi}_1 \mathbf{u}_{t-1} + \boldsymbol{\Psi}_2 \mathbf{u}_{t-2} + \dots \\ \Rightarrow \mathbf{x}_t &= \boldsymbol{\mu} + \mathbf{B}_0^{-1} \boldsymbol{\varepsilon}_t + \boldsymbol{\Psi}_1 \mathbf{B}_0^{-1} \boldsymbol{\varepsilon}_{t-1} + \boldsymbol{\Psi}_2 \mathbf{B}_0^{-1} \boldsymbol{\varepsilon}_{t-2} + \dots \end{aligned} \quad (6)$$

If  $\mathbf{x}^i$  is included in the VAR in differences then the long-run effect of a shock in  $\boldsymbol{\varepsilon}^j$  on the level of  $\mathbf{x}^i$  is the row  $i$ , column  $j$  element of

$$\sum_{i=0}^{\infty} \boldsymbol{\Psi}_i \mathbf{B}_0^{-1} \quad (7)$$

where  $\boldsymbol{\Psi}_0 = \mathbf{I}$ .<sup>4</sup> Thus, the two long-run restrictions are imposed as:

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<sup>4</sup> This will be the case in the implementation of this paper. In the event that the variables were entered into the VAR in levels the appropriate restriction is that the row  $i$ , column  $j$  element of  $\boldsymbol{\Psi}_\infty \mathbf{B}_0^{-1}$  is zero.

$$\sum_{i=0}^{\infty} \Psi_i \mathbf{B}_0^{-1} = \begin{bmatrix} \cdot & 0 & 0 \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{bmatrix} \quad (8)$$

In practice, we can use the VAR representation to impose the long-run restriction. If, for example, we have estimated a VAR(3) model, the long-run cumulative effect of an innovation in  $\mathbf{u}_t$  on  $\mathbf{x}_t$  is given by  $[\mathbf{I} - \Phi_1 - \Phi_2 - \Phi_3]^{-1}$ .<sup>5</sup> That is,  $[\mathbf{I} - \Phi_1 - \Phi_2 - \Phi_3]^{-1} = \sum_{i=0}^{\infty} \Psi_i$ . Thus, the long-run restriction on the effect of  $\boldsymbol{\varepsilon}^j$  on  $\mathbf{x}_t$  can be imposed as:

$$[\mathbf{I} - \Phi_1 - \Phi_2 - \Phi_3]^{-1} \mathbf{B}_0^{-1} = \begin{bmatrix} \cdot & 0 & 0 \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{bmatrix} \quad (9)$$

The remaining restriction imposed is that the terms of trade has no contemporaneous effect on unemployment. This captures the fact that there are lags in the effect of the terms of trade on the economy. This is the simplest to implement as it amounts to requiring that:<sup>6</sup>

$$\mathbf{B}_0^{-1} = \begin{bmatrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot \end{bmatrix} \quad (10)$$

Thus, these restrictions guarantee identification of the structural model from the reduced form estimation.

The robustness of these results was tested by varying the set of restrictions among a wider set of alternatives. The results are relatively insensitive to the particular restrictions chosen. When alternative contemporaneous restrictions are imposed the results are generally the same. Restricting the TOT to have no contemporaneous

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<sup>5</sup> See Hamilton (1994, p 20) for the presentation of the univariate case. The vector case is a simple generalisation of this.

<sup>6</sup> It makes no difference whether the variable is expressed in levels or differences for this restriction.

effect on output or restricting the TOT to have no contemporaneous response to productivity or demand shocks did not alter the results. Furthermore, there was little change in the results from allowing the TOT to have some long-run effect on output.<sup>7</sup> In this case the estimated long-run effect on output was very close to zero. This suggests that long-run changes in the composition of imports and exports that would have long-run effects on the terms of trade and output are better captured by the model as supply shocks than terms of trade shocks.

#### 4.1 Separating Structure and Shocks

Identifying whether the reduction in output volatility is due to the structure of the economy or the shocks hitting it is a central objective of this paper. This section outlines the strategy that will be used to make this identification.

Following the discussion in Section 3, structural change is identified as a change in the coefficients of the structural VAR while a change in shocks is a change in the variance of the structural errors. Thus, changes in  $\mathbf{\Omega}$  are changes in shocks and changes in  $\mathbf{B}_0, \dots, \mathbf{B}_p$  are structural changes or, more correctly, changes in the propagation mechanism.

For example, volatility in output could emerge due to an increase in the size of demand shocks or through a change in the propagation of those same demand shocks through the economy. In practice many changes are occurring at once. Policy rules change as well as interest rate shocks. Demand shocks change at the same time as supply shocks. The propagation of demand shocks through the economy, perhaps through greater economic integration, may be more or less damped.

Structurally similar models (those with similar parameters  $\mathbf{B}_0, \dots, \mathbf{B}_p$ ) should react similarly to given shocks while there should be a different response when the same shocks are applied to structurally dissimilar models. A useful metric for evaluating the volatility of a model is the forecast error variance (FEV) of output at some

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<sup>7</sup> To ensure identification, another contemporaneous restriction on the TOT or unemployment is used instead. For example, one set tested consisted of the restrictions: demand shocks have no long-run effect on output, the terms of trade shock has no contemporaneous effect on unemployment and the terms of trade shock has no contemporaneous effect on output.

given horizon. In the tables below I will consider separately the effect of the structure on the FEV and the size of the structural shocks. The second is easy to see as it is just given by the matrix  $\mathbf{\Omega}$ . Thus, we can see what has happened to the individual shocks, whether their variance has risen or fallen. The first is slightly more complicated. Nonetheless, identifying the effect of the structure on the FEV requires only a simple modification of the information contained in standard variance decompositions.

The formula for the contribution of the  $j^{\text{th}}$  orthogonalised innovation to the mean squared error (MSE) of the  $s$ -period forecast is:

$$\text{Var}(\varepsilon_{jt}) \cdot [\mathbf{a}_j \mathbf{a}'_j + \mathbf{\Psi}_1 \mathbf{a}_j \mathbf{a}'_j \mathbf{\Psi}'_1 + \dots + \mathbf{\Psi}_{s-1} \mathbf{a}_j \mathbf{a}'_j \mathbf{\Psi}'_{s-1}] \quad (11)$$

where  $\mathbf{a}_j$  is the  $j^{\text{th}}$  column of the matrix  $\mathbf{A} = \mathbf{B}_0^{-1}$  and  $\text{Var}(\varepsilon_{jt})$  is the variance of the  $j^{\text{th}}$  structural shock. In a variance decomposition this is normally divided by the total MSE to give the relative contribution of each orthogonal component. Instead I will focus on the portion in brackets – the structural part. I look at the relative sensitivity of each model to a unit variance structural shock.<sup>8</sup> Of themselves these responses are not informative, however, by looking at them relative to other periods we can see whether one model is more or less sensitive to particular shocks. Thus, if a given shock in one model leads to a higher overall MSE then we would say that that model is more sensitive to that particular structural shock. If a particular structure is more sensitive to all shocks we can clearly say that it is a less stable structure. Unfortunately, we are unlikely to get a complete ordering of structures on the basis of this observation. What we will get, however, is an indication of which shocks a particular period is most sensitive to.

If a more complete ranking is desired a natural one to consider is given by the following procedure. Consider subjecting one system to the shocks from another system. If the overall FEV is higher in the second system we might conclude that it is less resilient to the kind of shocks that occur in the first system. This uses the relative variances of shocks as the method of weighting the model sensitivities. While still arbitrary, this method provides an easily interpretable result.

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<sup>8</sup> Although any size would do, as all that is necessary is that  $\text{Var}(\varepsilon_{jt})$  be equal for all the structures being evaluated.



Specifically, it can tell how well the 1990s, say, would have reacted to the shocks experienced in the 1970s. If the overall FEV is lower in the 1990s when subjected to the shocks of the 1970s we would say that the 1990s were a more stable system.

## 5. Data and Results

Before presenting the main results I consider the appropriate way to include the variables in the VAR. This decision is driven by the results of ADF tests presented in Table A1 in the appendix. Output is unquestionably non-stationary while its growth rate is stationary so it is included in the VAR in growth rates. The evidence for unemployment and the terms of trade is more mixed. Over some samples they appear stationary and over others it is not possible to reject the null of integration. As there is not much to be gained one way or the other I include these variables in levels. Ultimately, the choice does not have a strong effect on the results.

The table below shows the variances of the structural shocks across the four samples considered in this paper. Clearly the shocks were much smaller in the 1990s than in any other period.

	<b>Productivity</b>	<b>Demand</b>	<b>TOT</b>
1960s	1.36	0.027	26.96
1970s	0.81	0.045	3.84
1980s	1.24	0.079	4.80
1990s	0.70	0.024	1.50

It is worth reminding the reader at this point that the ‘1970s’ in this table applies to the expansion from 1974:Q3 to 1983:Q2. Thus, the first OPEC oil shock actually falls right at the end of the ‘1960s’ sample. This is part of the explanation for the relatively low TOT structural variance in the ‘1970s’ and the high variance in the ‘1960s’.<sup>9</sup> With regard to the interpretation of the structural variance of the

<sup>9</sup> The other part of the explanation is that quarter-to-quarter volatility in the 1960s was very high whereas the quarter-to-quarter volatility was less in the 1970s despite the overall range for the TOT being larger in the 1970s. These variances are residuals from an estimation and so do not necessarily match standard deviations of the series over the various samples.

productivity shocks this is not as much of an issue. Output was highly volatile in the 1960s even in the absence of any effect from the large OPEC oil shock. Table 4 below presents the sensitivity of each system to the different structural shocks at a horizon of one year. The results are all normalised so that the sensitivity of the 1990s equals one and so cannot be directly compared across columns.

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**Table 4: Sensitivity to Structural Shocks**

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	<b>Productivity</b>	<b>Demand</b>	<b>TOT</b>
1960s	0.84	1.35	0.06
1970s	1.27	2.40	0.45
1980s	1.12	1.56	0.42
1990s	1.00	1.00	1.00

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Note: The numbers are the sensitivity term identified in Equation (11) normalised by the sensitivity of the 1990s. The numbers represent the sensitivity to each kind of shock at a horizon of four quarters. The samples are those identified in footnote 1.

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We see that the 1990s were more sensitive to TOT shocks than in previous periods while there has been a reduction in the sensitivity to demand shocks. Nonetheless, the changes in sensitivity to demand and TOT shocks are significantly smaller than the changes in the structural variances.

The finding that output growth is more sensitive to TOT shocks in the 1990s is, at first glance, counterintuitive. Standard international economics theory suggests that a floating exchange rate should insulate the economy from TOT shocks more than a fixed-rate regime. We might then expect that output would be less responsive to TOT shocks in the 1990s. Unfortunately it is difficult to make a direct connection between the theory and the empirical results here. Part of the difference stems from the fact that appropriate dynamic responses are not well understood in these circumstances. Furthermore, the results reported above are for output growth rather than the level of output which is what is commonly included in the theory. Looking at the results for the *level* of output suggests that there has been little change in the sensitivity of output to TOT shocks. This may suggest that the moving peg that prevailed before the float of the dollar may have provided the same level of insulation as the float. This is, however, moving a little far from the focus of this paper and I will leave further investigation to other work.

The decline in the sensitivity of the economy to demand shocks provides some evidence that structural changes have helped reduce the volatility of output. Specifically, the economy is now somewhat more resistant to temporary shocks. The particular structural changes may include the microeconomic reform of the 1980s as well as the introduction of the medium-term inflation target in the 1990s.

Overall, however, Tables 3 and 4 suggest that the primary reason for the decline in output volatility in the 1990s was a decline in the volatility of the underlying shocks. The final piece of information required is to look at a variance decomposition to see which shocks are the most important in explaining overall output variability. Table 5 shows this decomposition at a one year horizon. Results are similar for longer horizons.

**Table 5: Variance Decomposition of Output Growth**

	<b>Productivity</b>	<b>Demand</b>	<b>TOT</b>
1960s	83	5	12
1970s	72	15	13
1980s	75	13	11
1990s	78	5	17

Note: Numbers represent the percentage of forecast error variance that can be attributed to each kind of structural shock at a horizon of one year. Samples are those identified in footnote 1.

The dominance of productivity shocks in all periods leads to the strong conclusion that the decline in the volatility of productivity shocks was the most important single factor in the decline in output volatility in Australia in the 1990s. More precisely, given the identification strategy, the decline in the volatility of permanent shocks is the most important single factor explaining the decline in output volatility in Australia – and these permanent shocks are best thought of as productivity shocks. Demand and TOT shocks are relatively insignificant. Nonetheless, they both have parts to play in the decline.

The increased sensitivity of the 1990s to TOT shocks shows up in a larger contribution to the forecast error variance (FEV) for TOT shocks despite the lower variance of TOT shocks during the 1990s. This suggests that an important area to watch in terms of output volatility is the terms of trade. Relatively minor fluctuations in the TOT (from a historical perspective) could have a significant effect on output volatility. For example, volatility in the TOT similar to that of the

1980s could raise the volatility of output by almost 50 per cent.<sup>10</sup> The reduction in demand shocks' weight in the variance decomposition is a reflection that demand shocks and the structural sensitivity of the economy to demand shocks have reduced by significantly more than the average.

These results are broadly in line with previous work on Australia by Glenn Otto (1995, 1999). He found that TOT shocks were relatively insignificant and that productivity shocks explained much of the forecast error variance in his models. Nonetheless, it is interesting to see that the predominant influence on Australian output volatility comes from the shocks hitting the economy rather than the structural responses to those shocks.

Thinking about the various shocks identified raises some substantial questions. While it is fairly easy to identify causes of fluctuations in Australia's terms of trade, it is more difficult to think about causes of fluctuations in productivity. The next section speculates on possible interpretations of the results.

## **6. The Source of the Volatility**

The facts detailed in this paper fall into a much larger worldwide picture. In most industrialised countries the volatility of output growth has been falling fairly consistently.<sup>11</sup> The figure below shows this pattern in the US, UK, Canada and Australia by way of illustration.<sup>12</sup> This suggests that there is a common force affecting industrialised nations or, perhaps additionally, that the observed patterns have an overseas source. In the case that there is a common force affecting nations it is unsurprising that TOT shocks have a limited role in Australia. Other countries have experienced a similar decline in output volatility despite widely varying sensitivity to TOT shocks.

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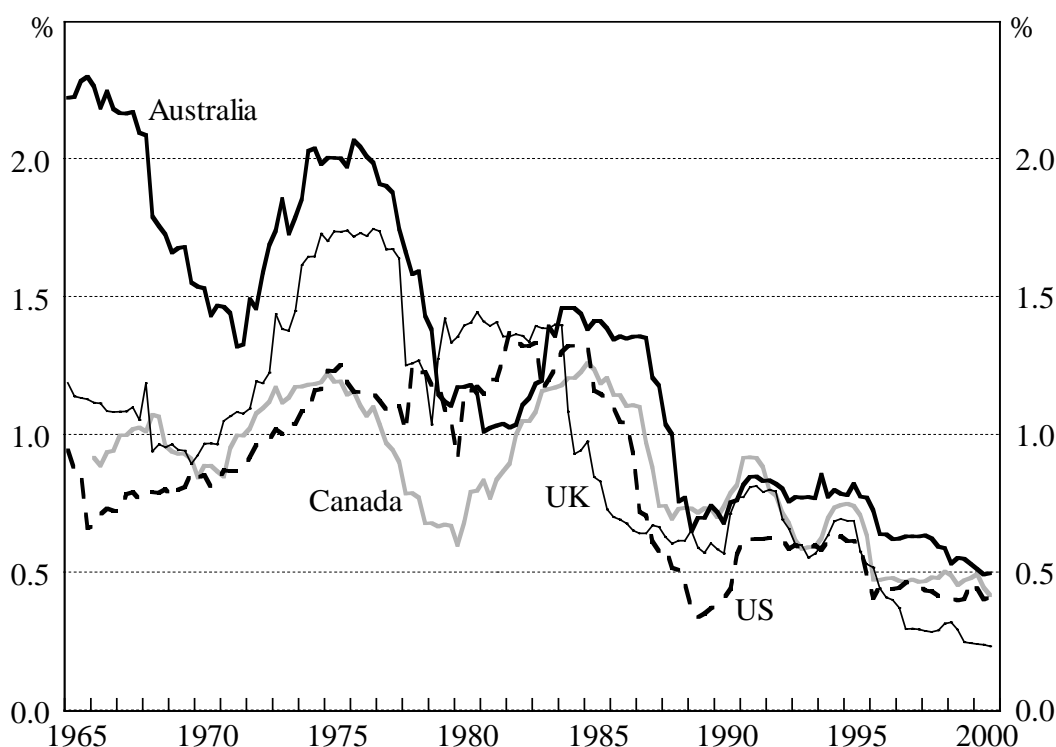
<sup>10</sup> This is calculated by looking at the FEV of output one year out if the economy was subjected to productivity and demand shocks of the same size as in the 1990s but TOT shocks from the 1980s.

<sup>11</sup> See Blanchard and Simon (2001) for a discussion of the G7.

<sup>12</sup> The line for Australia is based on GDP rather than the series used in this paper to ease the comparison across countries, hence, the data broadly match those mentioned in footnote 2.

**Figure 1: Output Volatility**

5-year-moving standard deviation of quarterly output growth



Panel data regressions run by Blanchard and Simon (2001) on the G7 minus Japan reveal that output volatility is well characterised by a steady downward trend that is interrupted in the 1970s and 1980s when inflation volatility was high. That is, a regression with a time trend and inflation volatility provides a good fit for output growth volatility in the G7 less Japan. Interestingly, the level of inflation is not found to be significant while the volatility of inflation is highly significant. This fact suggests that inflation volatility is capturing the effect of general uncertainty rather than an effect specifically related to the rate of inflation.

These additional findings suggest the following explanation for the specific results found in this paper. Temporary demand shocks had a larger role in explaining output volatility in the 1970s and 1980s when inflation volatility was also higher (see Table 5). This coincidence suggests that the demand shocks identified in Australia are related to economic uncertainty of the sort associated with high and variable inflation. With inflation having been brought under control, this particular source of shocks makes very little contribution to overall volatility in the 1990s. This also suggests that monetary policy may play a useful role in the reduction of

general economic uncertainty and thereby achieve simultaneous reductions in output and inflation volatility. Previous theoretical research has suggested that monetary policy may involve a trade-off between the two. However, the simultaneous reduction in output and inflation volatility is a robust characteristic of the data. It is hoped that further research can reconcile the theoretical and empirical findings.

The supply or productivity shocks seem more closely linked with the trend component of the decline in output volatility. The causes of the trend decline worldwide have yet to be identified but several suspects present themselves. General structural change in output towards services production, which is generally smoother, can explain some, but certainly not all, of the pattern. A potentially larger force is the effect of this trend on individual incomes in combination with the increased skill of the workforce. In addition to moving towards services production, the workforces of the industrialised world have become more highly skilled over the past decades. Australia has been no exception. Skilled workers generally experience smoother income paths than unskilled workers. They also have better employment prospects in the event that they lose their current job. Thus, a general compositional shift towards more skilled workers in combination with a shift towards services may result in a smoother overall profile for earnings, employment, consumption and, finally, output. The verification of this hypothesis requires the analysis of micro data on individual earnings. This is the next natural step in this research program.

An additional suspect is the increased financial sophistication and development that has occurred around the world over the past decades. A greater ability of consumers to borrow and smooth their consumption could have a large effect on the overall volatility of demand and, consequently, total output. One specific manifestation of this would be a reduction in the number of credit-constrained consumers. Research on the permanent income hypothesis and consumption smoothing has found some support for the idea that less consumers are credit-constrained now than in the past. One beneficial consequence of this financial development could then be reduced output volatility.

Finally, a comment on the low contribution of the terms of trade to overall output volatility. If the Australian pattern of output, and in particular exports, is moving

towards products whose output is less volatile this could show up in either the terms of trade or the productivity shocks. By making the identification assumption that the terms of trade shocks have no long-term effects the sustained shifts in the pattern of production and trade would be excluded. Thus, the terms of trade shocks may capture those shocks to the pattern of production that are separate from the general, and permanent, trend towards less volatile products. Given the large presumed size of the trend in production this could lead to most of the shocks being identified as productivity rather than terms of trade shocks. Furthermore, given that the shocks are very much a product of domestic changes they should not necessarily be identified with terms of trade shocks. Only if Australian domestic production remained in volatile industries while our exports shifted towards smoother industries would these effects be identified with terms of trade shocks.

## **7. Conclusion**

Australia's output growth has shown a marked smoothing in the 1990s compared to previous decades. Part of this smoothing can be attributed to a moderation of the inventories cycle. Nonetheless, after removing the inventories cycle from the data a significant smoothing remains. The source of this smoothing was traced to a reduction in the volatility of productivity shocks. Importantly there does not seem to be a significant role for changes in the propagation mechanism.

The relative influence of shocks found in this paper is in line with previous Australian findings. Otto (1995), in a study that did not look for structural changes, found that terms of trade shocks were relatively insignificant in explaining output volatility and that productivity shocks were the primary factor.

The finding that the reason for reduced volatility is not changes in the structure of the economy is also similar to the findings on the US economy in Simon (2000). Nonetheless, there are some contrasts to the results from the US. There, the prime cause of the fall in volatility is found to be in demand shocks. Nonetheless, productivity shocks also play some role in the observed decline in US volatility, just as demand shocks play a role in Australia. The difference is in the relative importance of the shocks in the two countries; productivity and demand shocks

both declined in the 1990s in the two countries. As such the findings are more easily reconciled.

There is also evidence from the US that inventories have some part to play in the reduction of overall volatility. Nonetheless, it is not clear whether inventories are a causal factor or are merely responding to lower volatility in other areas of the economy. Hopefully, future research will clarify this question.

More practically, the results suggest that terms of trade shocks can have a much greater effect on output volatility than in the past. Furthermore, future research is needed to identify the nature of productivity shocks hitting Australia to provide a basis for more confident forecasts and understanding of future output fluctuations. Section 6 provides some speculation as to potential explanations for the findings so far. If the primary cause of the reduction in output volatility is the combination of sectoral shifts and changing skills of the workforce we should expect that output volatility will continue to remain low in the future. Continued low output volatility should enhance the prospect that the business cycle will be milder than in earlier periods. Similarly, provided there is no deterioration in the financial system, it seems likely that consumers' ability to smooth their consumption should remain. It is hoped that further research can answer the questions raised in this paper and confirm (or refute) the ideas of Section 6.



## Appendix A: Data

The data used are quarterly domestic final demand plus net exports, the unemployment rate, and the terms of trade on goods and services. The output data are measured in constant chain-linked prices while the terms of trade is an index and the unemployment rate is in percentage points. The unemployment rate for a quarter is calculated as the average of the three monthly observations in that quarter. While it is not strictly necessary for the correct estimation of the VAR that the variables be stationary it is useful to have an idea of their general properties. The following table presents the results from ADF tests on the order of integration of the variables across the samples used and across the entire sample period.  $y$  is the log of output and  $\Delta y$  is the change in the log.

**Table A1: ADF Test Statistics**

	Full sample	1960s	1970s	1980s	1990s
$y$	2.73	0.72	2.97	0.90	2.43
$\Delta y$	7.48 <sup>***</sup>	11.13 <sup>***</sup>	6.01 <sup>***</sup>	5.82 <sup>***</sup>	7.69 <sup>***</sup>
$ue$	2.82	3.64 <sup>***</sup>	3.25 <sup>*</sup>	-1.01	2.18
$\Delta ue$	7.23 <sup>***</sup>	8.33 <sup>***</sup>	2.63	1.69	3.41 <sup>*</sup>
TOT	5.57 <sup>***</sup>	4.63 <sup>***</sup>	2.21	2.93	1.84
$\Delta TOT$	11.97 <sup>***</sup>	6.87 <sup>***</sup>	6.64 <sup>***</sup>	2.12	4.04 <sup>**</sup>

Notes: The tests are conducted by regressing the variable ( $x$ ) on its own lag ( $x_{t-1}$ ), a time trend and constant, and enough lags of  $\Delta x$  to remove autocorrelation. The statistics reported are  $(1-\rho)/\sigma$  where  $\rho$  is the coefficient on the lagged dependent variable and  $\sigma$  is the standard deviation of the estimate. Critical values are found in Table B.6 in the back of Hamilton (1994).

\*, \*\*, and \*\*\* indicate significance at the 10%, 5% and 1% levels.

So we see that while output growth is unquestionably stationary the unemployment rate and terms of trade seem non-stationary. Indeed, if we took these results at face value, it suggests that unemployment is I(2) in the seventies and eighties and the terms of trade is I(2) in the eighties. This is sufficiently beyond the realms of possibility that I discount these findings. The results for unemployment and the terms of trade are most likely a result of the small sample sizes involved in these decade long samples and the low overall power of the tests. Over samples including the 1960s and 1970s, and 1980s and 1990s the terms of trade is found to be stationary, however, it is still not possible to reject the null of integration for unemployment. I appeal to common sense to argue that the terms of trade and

unemployment rate, while persistent, are unlikely to be integrated. The terms of trade should be stationary if even a weak form of purchasing power parity holds while the unemployment rate is bounded by definition. As such, I include them in the VAR in levels rather than differences. There is little change in the results if the change in the unemployment rate is included instead of the level, however, results change more if the change in the terms of trade is used.

## References

**Balke NS and RJ Gordon (1989)**, ‘The Estimation of Prewar Gross National Product: Methodology and New Evidence’, *Journal of Political Economy*, 97(1), pp 38–92.

**Blanchard OJ and D Quah (1989)**, ‘The Dynamic Effects of Aggregate Demand and Supply Disturbances’, *American Economic Review*, 79(4), pp 655–673.

**Blanchard OJ and J Simon (2001)**, ‘The Long and Large Decline in U.S. Output Volatility’, *Brookings Papers on Economic Activity*, 1, forthcoming.

**Blanchard OJ and MW Watson (1986)**, ‘Are Business Cycles All Alike?’, in RJ Gordon (ed), *The American Business Cycle: Continuity and Change*, University of Chicago Press, Chicago, pp 123–179.

**DeLong JB and LH Summers (1986)**, ‘The Changing Cyclical Variability of Economic Activity in the United States’, in RJ Gordon (ed), *The American Business Cycle: Continuity and Change*, University of Chicago Press, Chicago, pp 679–719.

**Diebold FX and GD Rudebusch (1990)**, ‘A Nonparametric Investigation of Duration Dependence in the American Business Cycle’, *Journal of Political Economy*, 98(3), pp 596–616.

**Diebold FX and GD Rudebusch (1992)**, ‘Have Postwar Economic Fluctuations Been Stabilized?’, *American Economic Review*, 82(4), pp 993–1005.

**Gali J (1992)**, ‘How Well Does the IS-LM Model Fit Postwar U.S. Data?’, *Quarterly Journal of Economics*, 107(2), pp 709–738.

**Gruen D and G Stevens (2000)**, ‘Australian Macroeconomic Performance and Policies in the 1990s’, in Gruen D and S Shrestha (eds), *The Australian Economy in the 1990s*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 32–72.

**Hamilton JD (1989)**, ‘A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle’, *Econometrica*, 57(2), pp 357–384.

**Hamilton JD (1994)**, *Time Series Analysis*, Princeton University Press, Princeton, New Jersey.

**James JA (1993)**, ‘Changes in Economic Instability in 19<sup>th</sup>-Century America’, *American Economic Review*, 83(4), pp 710–731.

**Kormandi RC and PG Meguire (1985)**, ‘Macroeconomic Determinants of Growth: Cross-Country Evidence’, *Journal of Monetary Economics*, 16(2), pp 141–163.

**Martin P and CA Rogers (2000)**, ‘Long-term growth and short-term economic instability’, *European Economic Review*, 44(2), pp 359–381.

**McConnell MM and GP Quiros (2000)**, ‘Output Fluctuations in the United States: What Has Changed Since the Early 1980s?’, *American Economic Review*, 90(5), pp 1464–1476.

**Otto G (1995)**, ‘Terms of Trade Shocks and the Australian Economy’, University of New South Wales, School of Economics Discussion Paper No 95/23.

**Otto G (1999)**, ‘The Solow Residual for Australia: Technology Shocks or Factor Utilization?’, *Economic Inquiry*, 37(1), pp 136–153.

**Ramey G and VA Ramey (1995)**, ‘Cross-Country Evidence on the Link Between Volatility and Growth’, *American Economic Review*, 85(5), pp 1138–1151.

**Romer CD (1986)**, ‘Is the Stabilization of the Postwar Economy a Figment of the Data?’, *American Economic Review*, 76(3), pp 314–334.

**Simon J (2000)**, ‘The Long Boom’, in *Essays in Empirical Macroeconomics*, PhD thesis, MIT, Cambridge, pp 5–34.

**Weir DR (1986)**, ‘The Reliability of Historical Macroeconomic Data for Comparing Cyclical Stability’, *Journal of Economic History*, 46(2), pp 353–365.