Identifying aggregate demand and supply shocks in a small open economy

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Abstract

The standard Blanchard-Quah (BQ) decomposition forces aggregate demand and supply shocks to be orthogonal. However, for a variety of reasons, this assumption may be problematic. For example, policy actions may cause positive correlation between demand and supply shocks. This paper employs a modification of the BQ procedure that allows for correlated shifts in aggregate supply and demand. The method is demonstrated using Australian data. It is found that shocks to Australian aggregate demand and supply are highly correlated. The estimated shifts in the aggregate demand and supply curves are then used to measure the effects of inflation targeting on the Australian inflation rate and level of GDP.

Keywords
Structural VAR, Decomposition, Supply and Demand Shocks, Inflation Targeting

JEL Classification E3, C32

1 Introduction

Blanchard and Quah (1989), hereafter BQ, use a structural vector autoregression (VAR) to decompose the movements in real output growth and unemployment into the effects of aggregate supply shocks and aggregate demand shocks. One reason why the BQ methodology has been so widely adopted is that the assumptions necessary for the exact identification of the shocks seem to be innocuous.[1] Specifically, these assumptions are as follows: aggregate demand and aggregate supply shocks are normalized to have unit variance; the structural shocks are uncorrelated; and the demand shock has no long-run effect on output. The literature, however, has questioned this seemingly weak set of assumptions. In the influential collection by Mankiw and Romer (1991), New Keynesian economists argue that money shocks need not be neutral and even in New Classical models money is not 'super-neutral' since changes in the rate of money growth can have permanent effects on the level of output. More recently, Waggoner and Zha (2003) and Hamilton *et al.* (2004) show that different normalizations can have important consequences for statistical inferences in a structural VAR. It is not the aim of this paper, however, to debate these points. It is sufficient merely to point out that plausible arguments have been raised about some of the assumptions underlying the standard BQ methodology. The central contribution of this work is to examine the the consequences for identification of allowing aggregate demand and supply shifts to be correlated by extending the approach of Cover *et al.* (2005) to the case of a structural VAR for a small open economy.

The rest of the paper is organized as follows. Section 2 reviews the indentification of structural shocks in the standard BQ framework. In Section 3 a modified version of the decomposition is developed, following Cover *et al.* (2005). This decomposition allows movements in aggregate demand and

[1] At the time of writing the B-Q paper had 604 citations listed on *Google Scholar*.

supply to be contemporaneously correlated. Sections 4 and 5 use Australian data for the period 1980:1 to 2003:4 to compare the results obtained from the standard BQ and our decompositions respectively. One of the key results obtained is that the correlation between the structural demand and supply shocks in Australia is about 0.73. Section 6 describes how the alternative decomposition can be used to analyze the costs and benefits of inflation targeting in Australia. Section 7 is a brief conclusion.

2 The Blanchard-Quah methodology

Consider a restricted VAR given by

$$\begin{aligned} \Delta y_t^* &= \sum_{j=1}^{k} a_{11j}\Delta y_{t-j}^* + e_{1t} \\ \Delta y_t &= \sum_{j=0}^{k} a_{21j}\Delta y_{t-j}^* + \sum_{j=1}^{k} a_{22j}\Delta y_{t-j} + \sum_{j=1}^{k} a_{23j}\Delta \pi_{t-j} + e_{2t} \qquad (1) \\ \Delta \pi_t &= \sum_{j=0}^{k} a_{31j}\Delta y_{t-j}^* + \sum_{j=1}^{k} a_{32j}\Delta y_{t-j} + \sum_{j=1}^{k} a_{33j}\Delta \pi_{j-i} + e_{3t} \ . \end{aligned}$$

in which y_t^* and y_t, respectively, measure real foreign and domestic output, and π_t is the domestic inflation rate and the constant terms are supressed for notational convenience.[2] Equation (1) is intended to be used for a small open economy such as Australia (see, for example, Dungey and Pagan, 2000). Unlike a traditional VAR, the structure of the system is such that the real value of foreign output evolves independently of the other variables. Hence, the foreign output equation does include current or lagged values of the other variables. Moreover, the small-country assumption means that domestic output and inflation are allowed to depend on the current and lagged values of foreign output.

The regression residuals, e_{1t}, e_{2t} and e_{3t}, are assumed to be related to each other through three different types of shocks: a foreign productivity

[2] Variables are differenced sufficiently to achieve stationarity. This is discussed in more detail in Section 4.

shock, υ_t, measures the current innovation in foreign output; a domestic demand shock, η_t; and a domestic supply shock, ε_t. Since υ_t, η_t and ε_t are not observed, a critical task is to identify these three shocks from the VAR residuals. Let the relationship between the VAR residuals and the innovations be given by

$$\begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{bmatrix} \begin{bmatrix} \upsilon_t \\ \varepsilon_t \\ \eta_t \end{bmatrix}. \tag{2}$$

In this setup there are fifteen unknowns to identify. There are nine elements, g_{ij}, of the matrix G linking the VAR residuals and structural innovations, three variances σ_υ, σ_ε, σ_η, and three covariances $\sigma_{\upsilon\varepsilon}$, $\sigma_{\upsilon\eta}$, $\sigma_{\eta\varepsilon}$ in the variance-covariance matrix, Σ_s, of the structural innovations.

The identification proceeds as follows. From equation (2) the variance-covariance matrix of the VAR residuals, Σ_e, is given by

$$\Sigma_e = G \Sigma_s G'. \tag{3}$$

The distinct elements of Σ_e therefore provide six of the fifteen restrictions requried for exact identification. The standard BQ method now makes the following additional assumptions. All variances are unity, $\sigma_\upsilon = \sigma_\varepsilon = \sigma_\eta = 1$. All covariances are zero $\sigma_{\upsilon\varepsilon} = \sigma_{\upsilon\eta} = \sigma_{\eta\varepsilon} = 0$. The domestic shocks, η_t and ε_t, have no effects in the large country, $g_{12} = g_{13} = 0$. Finally, demand shocks have no long-run effect on domestic output

$$g_{23}\left[1 - \sum_{i=1}^{k} a_{33j}\right] + g_{33}\left[1 - \sum_{i=1}^{k} a_{23j}\right] = 0. \tag{4}$$

These restrictions seem innocuous at first glance, but it is now recognised that normalization can have affect statistical inference in a structural VAR, particularly on the confidence intervals for impulse responses (Waggoner and Zha, 2003; Hamilton *et al.*, 2004). Of central concern in this paper, however, is the assumed orthogonality of the structural shocks. Consider a standard AD–AS model which is peturbed by a supply shock ε_t that causes a shift in the aggregate supply schedule. What is observed at the macroeconomic level is a change in the equilibrium levels of output and prices which any decomposition must then decompose into constituent parts. As illustrated in Fig. 1, suppose that a supply shock results in the movement depicted by a shift from point A to point C, where equilibrium output has increased but inflation has remained constant. In terms of the BQ assumptions this movement can be attributed to a supply shock that shifts the aggregate supply schedule from AS to AS′. As shown in Panel a of Fig. 1, it must therefore be the case that the aggregate demand curve is highly elastic.

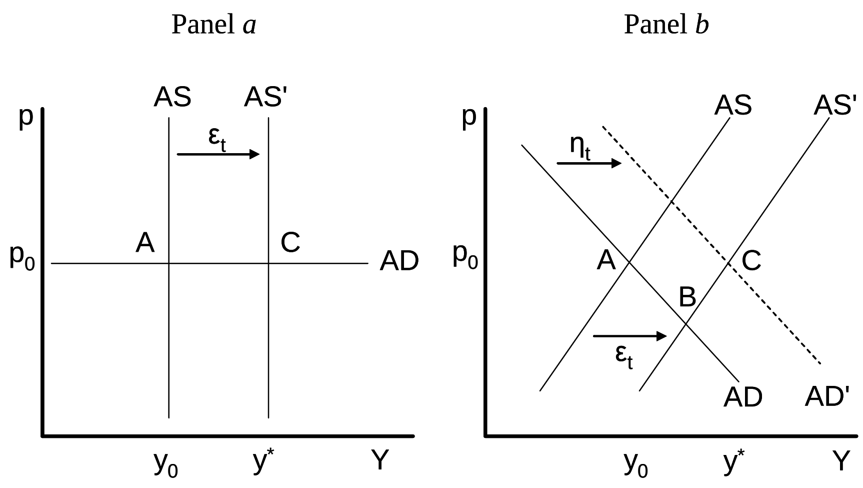

Fig. 1 Two views of shifts in the aggregate supply curve

If the assumption that shifts in the aggregate demand and aggregate supply schedules are orthogonal is relaxed, there is an alternative decomposition of the movement from A to C which is shown in Panel b of Fig. 1. The supply shock ε_t shifts the aggregate supply schedule to AS′ and the equilibrium from point A to point B. However, if supply and demand shocks are correlated, perhaps due to a policy intervention, the situation may arise where a demand shock η_t shifts the aggregate demand schedule to AD′. The resultant equilibrium at C is identical to that depicted in Panel a but the decomposition of the change is entirely different.

As hinted above, the rationale for contemporaneous correlation in the structural disturbances may be due to policy. For example, in Australia where there is an explicit inflation target, a positive aggregate supply shock would require a policy response in order to prevent the price level from declining. Similarly, if there is a negative aggregate supply shock, inflation targeting requires a decrease in aggregate demand. This response may not necessarily be in terms of a formal feedback rule. As a practical matter, policymakers may be able to act more quickly than the time span of the data. If, for example, it takes less than three months for the central bank to react to current economic circumstances, quarterly data may reveal a contemporaneous correlation between the innovations in demand and supply.

It could be argued that the orthogonality of the structural disturbances in face of policy intervention could still be maintained by increasing the dimension of the VAR to include, say, an endogenous policy instrument such as the interest rate.[3] There are, however, both theoretical and practical reasons for not pursuing this avenue of research in the current paper. From the theoretical perspective, it may be argued that policy intervention is not the only source of contemporaneous correlation in the structural disturbances. For example, in an intertemporal optimizing model, a temporary increase in demand will lead to a positive supply response as agents react to a temporary increase in real wages. New Keynesian models also suggest reasons to believe that demand and supply shocks are correlated as some firms increase output (rather than price) in response to a positive demand shock. Moreover, the nature of policy intervention may change over the course of the sample so that incorrect inference is drawn for periods in which the chosen endogenous policy instrument is inappropriate. From the purely practical point of view, the more equations included in the VAR the more degrees of freedom are lost, but perhaps more importantly, the more equations, the

[3] We are indebted to a referee for pointing this out.

more restrictions that need to be imposed in order to achieve identification. In practice, the restrictions become increasingly *ad hoc* as more equations are added to the system.

3 The alternative decompostion

The alternative decomposition proposed in this paper is a straightforward modification of the AD-AS model presented in Cover *et al.* (2005). However, the method is not intended to be model-specific but can be employed using a wide variety of macroeconomic models. Consider the simple model

$$\begin{aligned} \Delta y_t^s &= E_{t-1}\Delta y_t + \alpha\left(\Delta\pi_t - E_{t-1}\Delta\pi_t\right) + \varepsilon_t + \gamma\upsilon_t \\ \Delta y_t^d + \Delta\pi_t &= E_{t-1}\left(\Delta y_t^d + \Delta\pi_t\right) + \eta_t \\ y_t^s &= y_t^d \end{aligned} \tag{5}$$

In this model, $E_{t-1}\Delta y_t$ and $E_{t-1}\Delta\pi_t$ are the expected changes in domestic output and inflation given the information available at the end of period $t-1$. The superscripts s and d represent supply and demand, respectively. The first equation represents a Lucas (1972) aggregate supply curve in that output increases in response to unexpected increases in inflation and positive realizations of the foreign supply shock and the pure domestic supply shock ε_t. The second equation is the aggregate demand relationship; aggregate demand equals its expected value plus the random demand disturbance, η_t.

If agents form their expectations based on a VAR, it is straightforward to see how the AD-AS model is consistent with the VAR. Clearly, $E_{t-1}\Delta y_t$ and $E_{t-1}\Delta\pi_t$ are determined by lagging equation (1) by one period and taking conditional expectations. The point is that the structure of the AD-AS model places restrictions on the relationships between the regression residuals and the innovations which are manifest in the structure of the matrix, G, in equation (3). The elements of this matrix are now functions of the parameters of the macroeconomic model. In this particular case the matrix is

$$G = \begin{bmatrix} g_{11} & 0 & 0 \\ \gamma/(1+\alpha) & 1/(1+\alpha) & \alpha/(1+\alpha) \\ -\gamma/(1+\alpha) & -1/(1+\alpha) & 1/(1+\alpha) \end{bmatrix}. \tag{6}$$

As before, the estimated variance-covariance matrix of the VAR, Σ_e, contains six independent elements that can be used in the identification of g_{11}, γ, α, the three variances σ_υ^2, σ_ε^2, σ_η^2; and the three covariances $\sigma_{\upsilon\varepsilon}$, $\sigma_{\varepsilon\eta}$, and $\sigma_{\upsilon\eta}$. To identify the system, three additional restrictions are used, namely $g_{11} = 1$, $\sigma_{\upsilon\varepsilon} = 0$ and the long-run neutrality restriction in equation (4).

Notice that there are two distinct differences between this decomposition and the standard BQ decomposition. *First*, it is not necessary to employ the normalization that the variances are all equal to unity. Instead, the normalizations seem quite natural. A one-unit foreign supply shock, υ_t, has a one-unit effect on foreign output; a one-unit domestic supply shock, ε_t, has a one-unit effect on domestic supply; and a one-unit demand shock, η_t, has a one-unit effect on demand. *Second*, the restriction that the idiosyncratic innovation in domestic supply is orthogonal to the global shock, $\sigma_{\upsilon\varepsilon} = 0$ is consistent with the small country assumption in that movements in aggregate supply that are correlated with foreign output are attributed to the global shock. It is important to note that no restrictions on the contemporaneous correlation in aggregate demand and foreign and/or domestic supply shocks are imposed. As such, the correlation between the shocks to aggregate demand and the shocks to aggregate supply can be estimated.

4 Results for the Blanchard-Quah decomposition

Quarterly data for US and Australian real GDP and Australian inflation for the period 1980:1 to 2003:4 are used to implement the ideas outlined in Sections 2 and 3 above. The starting date of 1980 is consistent with other macroeconometric time-series studies of the Australian economy (see, for example, Dungey and Pagan, 2000; Dungey, Fry and Martin, 2003) and is due to the desire to avoid modelling structural breaks in the data[4]. Most empirical models of Australia use United States' variables as proxies for the entire external sector. The exception to this general rule is Dungey and Fry (2001) who introduce Japanese variables into a VAR and show small, but statistically significant, effects. Since it is not the aim of the paper to isolate the source of Australia's shocks, we follow the conventional approach and use U.S. real GDP as the measure of foreign output.

[**Figure 2 about here**]

The Australian data for real GDP growth and annualized inflation as measured by the GDP deflator are shown in Panels *a* and *b* respectively of Fig. 2. Notice that inflation in the 1980s was generally much higher than inflation in the rest of the sample period. Part of the decline is the move to explicit inflation targeting beginning in 1993:1. However, even before 1993:1, there is evidence that the Reserve Bank of Australia (RBA) acted to stabilize the inflation rate. Nevertheless, part of the rationale of this paper is to ascertain the effects of demand shocks on the inflation rate. It is also important to note that Australia instituted a general sales tax (GST) in 2000:3. One effect of the GST was to induce a sharp shift in the level of inflation.

Standard Dickey-Fuller tests of the logarithms of U.S. real GDP and Australian GDP indicated that both are difference stationary. Even with the inclusion of level and impulse dummy variables for the GST, the log of the Australian GDP deflator had to be differenced twice to become stationary. As is standard in this literature, we found no statistical evidence of a cointegrating vector among the three variables in the system. Hence, the variables employed in the VAR are the log-first differences of U.S. and Australian real GDP levels and the first-difference of Australia's inflation rate as

[4]National Accounts data in Aunstralia underwent serious reivsion at this date and the entire wage-bargaining process experienced substantial change in the late 1970s.

measured by the GDP deflator.[5] Sims' (1980) cross-equation log likelihood ratio indicated that seasonal dummy variables were unnecessary, and that the optimal lag length for all three equations was found to be two. The results of the seemingly unrelated regressions (SUR) estimation of equation (1) are reported in Table 1.

[**Table 1 about here**]

The standard Blanchard-Quah decomposition results in a reasonably complete separation between the determinants of output and the determinants of inflation. The forecast-error variances reported in Table 2 indicate that at demand shocks have almost no influence on output at any forecasting horizon. Beyond a 2-step horizon, U.S. and Australian supply shocks (i.e., υ_t and ε_t shocks) respectively account for approximately 30% and 70% of the forecast-error error variance in Δy_t. On the other hand, demand shocks account for about 96% of the forecast-error variance in inflation.

[**Table 2 about here**]

As shown in Fig. 3, the impulse response functions tell a similar story. Note that the solid lines depict the actual impulse responses and the dashed lines represent a 90% confidence interval obtained using 1000 bootstrapped impulse response functions. Specifically, we used the residual-based bootstrapping method described in Breitung, Brüggemann, and Lütkepohl (2004) and formed confidence intervals using the percentile method. We maintained the structure of the contemporaneous correlations among the VAR residuals by randomly sampling the same time index across all three equations. Panel *a* indicates that a one standard deviation υ_t shock shifts Δy_t by almost 0.33 standard deviations, Δy_{t+1} by about 0.26 standard deviations, and Δy_{t+2} by

[5] Whether or not inflation is stationary is a source of debate in many countries, including US and Australia. While there are solid theoretical reasons for believing that inflation is stationary, the change in inflation is used in the VAR following the results of the ADF tests. This has the desirable side effect of making the results directly comparable to previous work using the alternative decomposition for the US (see, Cover et al., 2005). In any event the results are not much changed when inflation is used.

Note that all estimations and bootstrapping results were obtained using RATS 6.02.

about *0.44* standard deviations. Thereafter, the successive values of Δy_{t+i} steadily decline toward zero. Panel *b* shows that the effects of a one standard deviation ε_t shock on Δy_t are almost immediate since the effects after period *t+1* are almost zero. In contrast, Panel *c* indicates that a one standard deviation η_t shock has no discernable effect on the Australian output series. Panels *d* and *e* show that $\Delta\pi_t$ exhibits little effect from υ_t and ε_t shocks. However, as shown in Panel *f*, a one-standard deviation increase in η_t sharply increases $\Delta\pi_t$. In the following period $\Delta\pi_{t+1}$ is negative. The suggestion is there is 'overshooting' in that the initial effect of the demand shock on the change in inflation is, somehow, partially offset.

[**Figure 3 about here**]

5 Results for the alternative decomposition

The alternative decomposition allows aggregate demand to change in response to aggregate supply so that it is possible to estimate the non-orthogonal variables υ_t, ε_t and η_t. When this this alternative decomposition is used, the estimated variances and correlation coefficients are

$$\begin{array}{lll} \sigma_\upsilon^2 = 4.20e-05 & \sigma_\varepsilon^2 = 4.17e-05 & \sigma_\eta^2 = 7.12e-05 \\ \rho_{\eta\varepsilon} = 0.736 & \rho_{\upsilon\varepsilon} = 0.000 & \rho_{\eta\upsilon} = -0.038 \end{array},$$

where ρ_{ij} is the correlation coefficient between shocks i and j. Notice that the variance of the of the U.S. supply shock, υ_t, is approximately equal to that of the Australian supply shock, ε_t, but the variance of the domestic demand shock η_t is nearly twice as large. Since the estimated value of γ is 0.00162, the estimated value of $\sum_j a_{21j} = 0.324$, and $\sigma_{\upsilon\varepsilon} = 0$, the conditional variance of the aggregate supply curve is:

$$\sigma_\varepsilon^2 + \left[\gamma + \sum_{j=1}^{k} a_{21j}\right]^2 \sigma_\upsilon^2 = 4.64e-05$$

Hence, the aggregate demand curve is far more volatile than the aggregate supply curve. Of critical importance to the current work is that the correlation coefficient between η_t and ε_t is 0.736. While much smaller in size, there is also a correlation between η_t and υ_t is almost zero, implying that the response of the aggregate demand schedule to contemporaneous shocks in domestic supply is much higher than the response to a foreign supply shock. Given, however, that η_t is correlated with both ε_t and υ_t, a number of different scenarios may be explored.

5.1 Supply shocks shift the demand curve

Let δ_{1t}, δ_{2t} and δ_{3t} be three *i.i.d.* and mutually uncorrelated shocks. Consider the following relationships between these shocks and the structural innovations υ_t, ε_t and η_t,

$$\begin{aligned} \upsilon_t &= \delta_{1t} \\ \varepsilon_t &= \delta_{2t} \\ \eta_t &= c_1\upsilon_t + c_2\varepsilon_t + \delta_{3t} \end{aligned} \tag{7}$$

where c_1 is the regression coefficient of η_t on υ_t (i.e. $c_1 = \sigma_{\eta\upsilon}/\sigma_\upsilon^2$) and c_2 is the regression coefficient of η_t on ε_t (i.e. $c_1 = \sigma_{\eta\varepsilon}/\sigma_\varepsilon^2$). From equation (7) that foreign and domestic supply shocks are orthogonal to each other since $E[\upsilon_t\varepsilon_t] = E[\delta_{1t}\delta_{2t}] = 0$. Moreover, a pure innovation in aggregate demand, δ_{3t}, has no contemporaneous effect on υ_t or ε_t since $E[\upsilon_t\delta_{3t}] = E[\varepsilon_t\delta_{3t}] = 0$. It is clear, however, that shocks to both foreign and domestic supply will result in a contemporaneous shift in the aggregate demand schedule.

In the circumstances described by equation (7), it is straightforward to show that the BQ decomposition recovers the orthogonal shocks δ_{1t}, δ_{2t} and δ_{3t}. Consider

$$\Sigma_e = G \begin{bmatrix} \sigma_\upsilon^2 & 0 & \sigma_{\upsilon\eta} \\ 0 & \sigma_\varepsilon^2 & \sigma_{\varepsilon\eta} \\ \sigma_{\upsilon\eta} & \sigma_{\varepsilon\eta} & \sigma_\eta^2 \end{bmatrix} G'. \tag{8}$$

From equation (7) it follows that

$$\begin{bmatrix} \sigma_{\upsilon}^2 & 0 & \sigma_{\upsilon\eta} \\ 0 & \sigma_{\varepsilon}^2 & \sigma_{\varepsilon\eta} \\ \sigma_{\upsilon\eta} & \sigma_{\varepsilon\eta} & \sigma_{\eta}^2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ c_1 & c_2 & 1 \end{bmatrix} \begin{bmatrix} \sigma_{\upsilon}^2 & 0 & 0 \\ 0 & \sigma_{\varepsilon}^2 & 0 \\ 0 & 0 & var\left(\delta_{3t}\right) \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ c_1 & c_2 & 1 \end{bmatrix}'. \tag{9}$$

Substituting equation (9) into (8) yields

$$\Sigma_e = HIH'$$

where

$$H = \begin{bmatrix} \sigma_{\upsilon} & 0 & 0 \\ \dfrac{\gamma + c_1\alpha}{(1+\alpha)}\sigma_{\upsilon} & \dfrac{\gamma + c_2\alpha}{(1+\alpha)}\sigma_{\varepsilon} & \dfrac{\alpha}{(1+\alpha)}\sigma_{\delta 3} \\ -\dfrac{(\gamma - c_1)}{(1+\alpha)}\sigma_{\upsilon} & -\dfrac{(1-c_2)}{(1+\alpha)}\sigma_{\varepsilon} & \dfrac{1}{(1+\alpha)}\sigma_{\delta 3} \end{bmatrix}$$

and $\sigma_{\delta 3}$ is the standard deviation of δ_{3t}.

Given the estimates of Σ_e, the estimated elements of the matrix G in equation (3) will be identical to the corresponding element of H. Hence, the orthogonal shocks from the BQ decomposition are identical to δ_{1t}, δ_{2t} and δ_{3t}. Innovation accounting using the orthogonalization in equation (7), therefore, yields results that are identical to those in Figure 2 and Table 2. The important point to note, however, is that the decomposition does not attribute all the movement to a shift in the aggregate supply schedule. Instead, as illustrated in Panel *b* of Fig. 1, shocks to υ_t and ε_t result in a contemporaneous change in η_t and thus a shift in the aggregate demand schedule.

5.2 Supply shocks do not shift the demand curve

A second orthogonalization is to assume that the supply shock has no affect on aggregate demand,

$$\begin{aligned} \upsilon_t &= \delta_{1t} \\ \varepsilon_t &= c_3\delta_{3t} + \delta_{2t} \\ \eta_t &= c_1\upsilon_t + \delta_{3t} \end{aligned} \tag{10}$$

In this setup, aggregate demand can shift in response to a foreign supply shock, υ_t, or a pure demand shock, δ_{3t}. A pure supply shock, δ_{2t}, has no contemporaneous effect on aggregate demand. This is the movement from A to B in Panel b of Fig. 1. Notice that since δ_{2t} does not effect η_t, while δ_{3t} affects both η_t and ε_t, shifts in aggregate demand curve are 'prior' to shifts in the aggregate supply curve.

The impulse response functions for the second orthogonalization are shown in Fig. 4. Again, the solid lines are the estimated impulse response functions and the dashed lines represent a 90% confidence interval. The six panels depict the impulse responses of Δy_t and $\Delta\pi_t$ to υ_t, ε_t and η_t. Panel c of Fig. 4 indicates that demand shocks have a large and immediate effect on output. The reason is clear: this orthogonalization has demand shocks causally prior to supply. Since the correlation between ε_t and η_t is strongly positive, positive demand shocks (i.e., movements in δ_{3t}) shift the aggregate supply curve. This is in contrast to the BQ decomposition (see Panel c of Figure 2) in which demand shocks have little effects on output.

A second important difference between the two orthogonalizations concerns the effects of supply shocks on inflation. As shown in Panel e of Figure 4, a positive supply shock (i.e., a one standard deviation increase in δ_{2t}) is associated with a large and immediate decline in inflation by almost 2.2 standard deviations. With the orthogonalization given by equation (10), a supply shock moves the economy down a given aggregate demand curve. Hence, prices fall when supply increases. Although $\Delta\pi_t$ rebounds in the next period, the cumulated impact of a positive supply shock on the level of inflation is strongly negative.

[**Figure 4 about here**]

Not surprisingly, the variance decompositions yield the same information as the impulse responses. Table 3 indicates that the alternative ordering greatly expands the role of aggregate demand shocks on explaining output variability. When the BQ decomposition is used (see Table 2), demand shocks account for less than 1% of the forecast-error variance in Australia's output growth. This proportion jumps to approximately 20% when aggregate demand is causally prior to aggregate supply. Also, as suggested by Panel e of Figure 4, at most forecast horizon, aggregate supply shocks (i.e., shifts in δ_{2t}) account for more than 85% of the forecast-error variance in inflation. Unlike Panel a of Figure 3, this result implies that aggregate demand is very inelastic since supply shocks have large price effects.

[**Table 3 about here**]

Of course, it is possible to have other other cases where ε_t and η_t both respond to δ_{2t} and δ_{3t}, but these orthogonalizations will be a linear combination of the two extremes represented by (7) and (10). In is not possible, in one short paper, to comment on which of these extreme cases is to be preferred. Obviously, New Classical economists will prefer the BQ decomposition in that demand shocks have no effect on aggregate supply. New Keynesians, on the other hand, would feel comfortable with many aspects of the ordering implied by equation (10). Indeed, it is our view that both extremes are problematic. In equation (7) there is the undesirable feature that supply shocks, δ_{2t}, necessarily shift the aggregate demand curve. Similarly, (10) has the undesirable feature that demand shocks, δ_{3t}, induce movements in the aggregate supply curve. Perhaps the most useful feature of these two decompositions is that it is possible to identify shocks in aggregate supply and aggregate demand, υ_t, ε_t η_t, and the uncorrelated innovations δ_{1t}, δ_{2t} and δ_{3t} which allow a number of historical experiments to be undertaken. This issue is addressed in the next section using the context of Australian inflation targeting as an illustration.

6 Analysis of inflation targeting in Australia

It is clearly of interest to determine what the Australian economy might have looked like in the absence of inflation targeting. Of course, in order to perform such a counterfactual analysis some assumptions need to be made concerning the behavior of demand and supply in the absence of inflation targeting. Assume that the true model is given by equation (7) in which case the counterfactual is obtained by asking how the economy would have behaved if the feedback parameters c_1 and c_2 were set to zero.

Before proceeding, it is important to point out a number of caveats about performing such a counterfactual analysis. *First*, any conclusions drawn on the basis of this kind of analysis is critically dependent on the specification of the original model. Obviously there is a tradeoff. The more rich the VAR specification, the more ad hoc the assumptions required to achieve identification. The specification chosen here reflects a view that the optimal balance is this tradeoff is achieved in this three-variable VAR model. *Second*, any policy experiment that is conducted using a VAR is subject to the Lucas Critique. If the inflation-targeting rule were to change, it is quite possible that the model's other parameters would change as well. *Third*, for the purposes of this counterfactual enquiry, all of the correlation between ε_t and η_t is attribued to inflation targeting. If there are other factors causing this positive correlation between relationship between ε_t and η_t, the impact of inflation targeting will be overestimated. *Fourth*, inflation targeting can offset aggregate demand shocks as well as aggregate supply shocks. When the RBA targets inflation by properly offsetting demand shocks, it acts to reduce the variance of aggregate demand curve. There is no way of estimating how demand would have behaved in the absence of inflation targeting. This method, therefore, only allows the estimation of what Australia's inflation and output growth rates would have been had aggregate demand not moved contemporaneously with aggregate supply.

As indicated by Cover *et al.* (2004), one useful feature of this alternative decomposition is that it yields a direct measure of excess demand, or 'inflationary pressure', measured by

$$\eta_t - \varepsilon_t - \gamma \upsilon_t$$

It is also possible to calculate the counterfactual level of inflationary pressure as the hypothetical level that would have prevailed had η_t not changed in response to shocks to aggregate supply. These two series, labeled Actual and Hypothetical respectively, are shown in Panel *a* of Fig. 5. Notice that the actual series measuring inflationary pressure is far less variable than the hypothetical series. Moreover, the spikes in the actual series are usually far smaller than those in the hypothetical series. It seems therefore that the RBA does a reasonable job in mitigating the effects of supply shocks on inflation. Panel *b* of the figure shows the actual values of $\Delta\pi_t$ and the counterfactual values that would have prevailed had η_t not responded to υ_t and ε_t.

Similarly, 'output pressure' can be measured as the sum of the contemporaneous demand shock, supply shock, and γ multiplied by the US supply shock. Hence, the tendency for output to increase over its conditional expectation can be measured by

$$\eta_t + \varepsilon_t + \gamma \upsilon_t$$

The solid line, labeled 'Actual' in Fig. 6, shows smoothed values of the output gap as the four-month moving average

$$\frac{1}{4}\sum_{i=0}^{3}\left(\eta_{t-i} + \varepsilon_{t-i} + \gamma \upsilon_{t-i}\right)$$

The hypothetical output gap that would have prevailed had aggregate demand been orthogonal to supply shocks is also computed. As shown by the dashed line in Fig. 6, the smoothed value of the hypothetical gap is far less variable than the actual gap. The figure shows that inflation targeting in the presence of supply shocks entails a cost in terms of extra output variability. As discussed in reference to Fig. 3 above, in the presence of a positive value of ε_t, the aggregate demand curve must shift in order to preserve an inflation target. The simultaneous increase in the aggregate demand and supply curves will stabilize the inflation rate by will increase the change in output.

Since demand shocks have no long-run effect on output, it may be argued that the cost of inflation targeting is measured by changes in the variance of output. For several sample periods, Table 4 reports the standard deviations of the output gap (y_gap), the output gap constructed using values of η_t that are orthogonal to supply shocks (y_gap^*), actual output growth (Δy), and output growth (Δy^*) constructed using hypothetical values of η_t. Also shown are percentage differences between these actual and hypothetical measures as well as the minimum and maximum values of each variable. Note that the standard deviations of the variables are not very different between the pre-inflation-targeting and the inflation-targeting periods. Given the results in Fig. 6, it is not surprising to find that the actual output gap is far variable than the hypothetical gap output in any of the periods. Moreover, the minimum (maximum) values of the actual series are less (more) than those of the hypothetical series.

It seems therefore that inflation targeting has exacerbated the effects of supply shocks on the output level. However, the differences between actual and hypothetical output levels are small. Over the inflation-targeting period, the standard deviation of output growth was 0.005466. Had demand not responded to these supply shocks, the standard deviation would have been 0.005362. Hence, the standard deviation of output growth was magnified by and estimated 2% as a result of inflation targeting. Over the 1982:1 to 2003:4 period, the average value of output growth was 3.27% at an annual rate; a $\pm$ two standard deviation range was 2.622% to 3.918% (i.e. 3.27% $\pm$

0.648%). In the absence of inflation targeting, it is estimated that a ± two standard deviation range would have been 2.634% to 3.906% (i.e. 3.27% ± 0.636%).

7 Conclusion

This paper uses an AD-AS model to identify a structural VAR for Australia. Unlike the standard Blanchard-Quah decomposition, the method proposed in this paper does not require that the correlation between demand and supply shocks to be zero. In this particular instance, the basic premise of the paper is supported by the result that the correlation coefficient between aggregate demand and supply shocks in Australia is 0.736. While there are different ways to rationalize this finding, it is clear that assumptions about the correlation between structural shocks have important effects on VAR results. For example, if demand shocks have an effect on the aggregate supply curve, aggregate demand shocks can account for approximately 20% of the forecast-error variance in Australia's output growth. This contrasts sharply with a traditional BQ decomposition in which demand shocks would account for less than 1% of the forecast-error variance in Australia's output growth.

A further use of the alternative decomposition proposed in this paper is that it yields direct measures of excess demand and the output gap. One interesting result that emerges from the analysis is that the policy of targeting inflation in Australia has exacerbated the effects of supply shocks on the output level.

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