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Shocks to New Zealand's Economy and the Cyclical Behaviour of the Price Level

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Non Technical Summary

The general objective of this paper is to identify shocks to New Zealand's economy and examine the relationship between prices and output during cycles. A neo-classical growth model is used, which consists of three equations that describe technology, labour supply, and the price level. The model is augmented with an oil price equation. There are a few interesting findings:

- The correlation between the price level and output is found to be negative. The response of both the price level and inflation to a shock (increase) to technology are found to be negative.

- The price level increases sharply in response to a shock to the price of oil (an adverse relative supply shock).

- In the long run, aggregate supply shocks, including oil price shocks, are far more important to the New Zealand economy than domestic aggregate demand shocks. Larger percentages of the variations of labour, the price level, and real GDP are explained by aggregate supply shocks than by aggregate demand shocks. However, in the case of the price level, aggregate demand shocks play a significant role too. In the short run, aggregate demand shocks can explain 97 percent of the fluctuations in the price level. In the long run, where aggregate supply shocks dominate, aggregate demand shocks explain about 33 percent of the variation in the CPI.

- It is interesting to note that in response to a positive demand shock, output and prices rise sharply for a very short period of time but a reversal of the shock takes place and the output level falls. This may be interpreted as an

evidence of an active monetary policy that aims to slow economic activities when facing high demand growth.

- Generally, changes in the volatility of the shocks over the sample seem to be statistically significant. We reject the hypothesis that changes of volatility of various shocks to New Zealand are constant over the period 1977-1994. On average, technology shocks are found to be more volatile than all other shocks during the 1980s, followed by aggregate demand shocks, labour supply shocks, and oil price shocks. During the period 1990-1993, oil price shocks are found to be more volatile on average than all other shocks, followed by labour supply shocks, aggregate demand shocks, and technology shocks. Thus, supply shocks seem to be more volatile than demand shocks.

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Abstract

A structural VAR system that contains three domestic variables (the price level, real GDP, and employment) along with the real price of oil is estimated for the period 1977II to 1994I. Identifying restrictions are derived from an underlying neo-classical growth model (Solow, 1956) and (Shapiro and Watson, 1988). Four shocks are identified: an oil price shock, an aggregate demand shock, a technology shock, and a labour supply shock. Impulse response functions are found to be qualitatively consistent with the predictions of the model. Supply shocks are found to be far more important than demand shocks, particularly in the long run. Supply shocks are also found to be more volatile than demand shocks. There is evidence that the price level and inflation are both countercyclical.

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1. *Introduction*

The general objective of this paper is to identify shocks to the New Zealand economy, which may provide some useful insight for policy making. Although identifying shocks is the general objective, this paper addresses the classical question of how prices (inflation) and output (detrended output) are related over the business cycles for a small open economy like New Zealand. The idea is to examine the association of New Zealand's price level (and inflation) with real output. Specifically, both conditional and unconditional cross-correlations are examined. This question remains the main concern from policy standpoint. The policy implication is that if the central bank thinks that prices are procyclical then monetary policy should be relaxed during recessions and tightened during expansions. Of course, a different set of policy reactions is drawn if prices are assumed to be countercyclical.

Procyclical behaviour of prices has occupied equilibrium business cycle models of Lucas (1972), Barro (1878), and Sargent (1976). It also played the major role of non-market clearing models of Taylor (1979, 1980), Gordon (1982), and Fischer (1976). However, empirical evidence on the relationship between prices and output is mixed.[1]

In this paper, we first proceed with estimating the conditional correlation between the price level and output using a structural VAR system based on a neo-classical growth model (Shapiro and Watson, 1988). Two familiar questions are addressed: (i) How do macroeconomic variables respond to demand and supply shocks? (ii) How much of the variance in output and the price level (and inflation) is explained by demand or supply shocks? An attempt is also made to rank shocks to the New Zealand's economy according to their volatility by testing the hypothesis

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1 For example, see Chadha and Prasad (1994), Cooley and Ohanian (1991), Friedman and Schwartz (1962, 1982), Burns and Mitchell (1964), Kuznets (1930), and Mills (1927, 1936, 1946).

that the change in volatility is significantly not different from zero. The second part of the paper contains the unconditional cross-correlation between the price level and output using different types of filters (Cooley and Ohanian, 1991 and Chadha and Prasad, 1994).

To identify shocks, the simple neo-classical growth model presented in Shapiro and Watson (1988) is adopted for New Zealand.[2] The model consists of four major equations that describe technology, labour supply, the price level, and oil prices. The model is then estimated via a VAR system, where unobservable demand and supply shocks are identified by assuming that AD shocks have transitory effect while AS shocks have permanent effects on output. Objections to atheoretical VAR method (Cooley and LeRoy, 1985) are considered by avoiding the impositions of arbitrary identifying restrictions, such as all short-run fluctuations are due to temporary demand shocks or permanent supply shocks. Further, the relative importance of AD and AS shocks is estimated at different forecasting horizons. The VAR system is then estimated using quarterly data for New Zealand for the period 1977II to 1994I. Identification is achieved by imposing zero restrictions on the long-run multipliers (i.e., some disturbances have zero long-run effect on certain elements of the VAR) in such a way so that we can estimate the contemporaneous effects of disturbances.

There are a few interesting findings. (1) the conditional correlation between the price level and output is found to be negative at all horizons. The response of the price level to a unit shock (increase) to technology is negative. (2) the price level increases sharply in response to a unit shock to oil prices (an adverse relative supply shock). (3) in the long run, aggregate supply shocks including oil price shocks are far more important to the New Zealand economy than domestic aggregate demand shocks. Larger percentages of the variations of labour, the price

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2 "That researcher's view of the propagation mechanism, or economic theory, is crucially important for identifying shocks and evaluating their effect on output. Results can change sharply as one views the data in the perspective of more or different theoretical views." (Cochrane, 1994).

level, and real GDP are explained by aggregate supply shocks than by aggregate demand shocks. However, in the case of the price level, aggregate demand shocks play a significant role too. In the short run, aggregate demand shocks can explain 97 percent of the fluctuations in the price level. In the long run, where aggregate supply shocks dominate, aggregate demand shocks explain about 33 percent of the variation in the CPI. (4) it is interesting to note that in response to a positive demand shock, output and prices rise sharply for a very short period of time but a reversal of the shock takes place and the output level falls. This may be interpreted as an evidence of an active monetary policy that aims to slow economic activities when facing high demand growth. (5) generally, changes in the volatility of the shocks over the sample seem to be statistically significant. The hypothesis that changes of volatility of various shocks to New Zealand are constant over the period 1977-1994 is rejected. On average, technology shocks are found to be more volatile than all other shocks during the 1980s, followed by aggregate demand shocks, labour supply shocks, and oil price shocks. During the period 1990-1993, oil price shocks are found to be more volatile on average than all other shocks, followed by labour supply shocks, aggregate demand shocks, and technology shocks. (6) the unconditional cross-correlations between the price level, inflation, and output are examined. These cross-correlation functions are consistent with the conditional correlation obtained from the VAR, such that the price level and inflation seem to be countercyclical.

The paper is organized as follows: The data are described in the next section. The model is presented in section 3. The structural VAR system is estimated and results are presented in section 4. Further analysis of distributions of the structural errors is found in section 5. Section 6 is an analysis of unconditional cross-correlation functions. Conclusions are presented in section 7.

2. *The Data*

Four variables are used in this paper. The real oil price (O), the ratio of total employment to total labour force (n), CPI price level (P), and real output (Y) measured by the seasonally adjusted real GDP.[3]

Table 1 reports the GDP trough-to-peak periods[4] along with annual average inflation rates. During the period 1978I to 1989II, New Zealand's annual average inflation rate declined from 13 percent at the beginning of the period to 8 percent, and to 2.8 percent during the period 1988II to 1989II.[5] Kim, Buckle, and Hall (1994) computed the average cycle length to be 15.3 quarters, the average expansion phase as 10.5 quarters, and the average contraction phase as 4.8 quarters.[6] It is interesting to note that the inflation rates seem to fall as the periods of expansions become shorter, and as the periods of contractions become longer over the sample.

3. *The Model and Shocks Identifications*

The model used in this paper is a simple neo-classical growth model, where long-run fluctuations in output can be attributed to changes in labour and technological progress (Shapiro and Watson, 1988). There are three sources for output fluctuations, namely, labour supply shocks, shocks to technology, and finally, AD shocks. In the short run, output can deviate from its long-run steady state values. Deviations can arise from (i) shocks to

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3 The real oil price 0 is defined as the natural logarithm of the nominal price plus the log of the (TWI) for New Zealand's major trading partners (the United States, Australia, the United Kingdom, Japan, and Germany) minus the log of the foreign (PPI), the producer's price index of New Zealand's major trading partners. Foreign indexes are from Dennis (1994).

4 Information about the trough-to-peak periods are obtained from Kim, Buckle, and Hall (1994.)

5 Inflation is $\ln(CPI_t) - \ln(CPI_{t-4})$.

6 The data are from 1966III to 1991II.

the permanent levels of labour input or technology, which lead to transition from one steady-state to another; or (ii) AD.

Two identifying assumptions are made. One is that AD shocks do not have a long-run impact on output. Second, the long-run level of labour supply is exogenous. These assumptions make it easy to decompose the AS shocks into shocks arising from labour input and from technology. In the long run, labour supply is not affected by AD. Labour supply n_t^* and technology T_t^* are determined by the following processes:

$$n_t^* = \alpha_n + n^*_{t-1} + \theta_n(L)e_{nt} \qquad \mathbf{1}$$

$$T_t^* = \alpha_T + T^*_{t-1} + \theta_T(L)e_{Tt} \ , \qquad \mathbf{2}$$

where n_t and T_t are the natural logarithms of the levels of labour input and technology respectively. The disturbances e_{nt} and e_{Tt} are uncorrelated shocks that affect the long-run growth, and $\theta_n(L)$ and $\theta_T(L)$ are lag polynomials that have summable coefficients and roots outside the unit circle.

The long-run log level of output is determined by an aggregate Cobb-Douglas production function:

$$y_t^* = \alpha_y n^*_t + (1-\alpha_y)K^*_t + T^*_t. \qquad \mathbf{3}$$

Assuming that the steady-state capital-labour ratio ($k^* = K^*/n^*$) is constant yields:

$$k^*_t = y^*_t + l, \qquad \mathbf{4}$$

where l is a constant capital/labour ratio (Solow, 1956). Substitution of 4 into 3 yields:

$$y^*_t = \frac{1-\alpha_y l}{\alpha_y} + n^*_t + \frac{1}{\alpha_y}T^*_t, \qquad \mathbf{5}$$

where the constant term $(l-\alpha_y l)/\alpha_y$ can be set equal to zero for simplicity. Demand shocks are given by e_{dt}, which are serially uncorrelated and uncorrelated with the labour supply and technology shocks e_{nt} and e_{Tt}. Thus, labour input and output can temporarily deviate from their long-run levels through:

$$n_t = n^*_t + \Psi_n(L)[e_{nt}, e_{Tt}, e_{dt}]^T \qquad \textbf{6}$$

and

$$y_t = y^*_t + \Psi_y(L)[e_{nt}, e_{Tt}, e_{dt}]^T. \qquad \textbf{7}$$

I assume that labour supply and output are both nonstationary processes, and first differencing is an appropriate filter to detrend these variables. Now substituting 1, 2, and 5 into 6 and 7 gives:

$$\Delta n_t = \theta_n(L)e_{nt} + (1-L)\Psi_n(L)[e_{nt}, e_{Tt}, e_{dt}] \qquad \textbf{8}$$

$$\Delta y_t = \theta_n(L)e_{nt} + \frac{1}{\alpha_y}\theta_T(L)e_{Tt} + (1-L)\Psi_y(L)[e_{nt}, e_{Tt}, e_{dt}]. \qquad \textbf{9}$$

To complete the model, the process governing the price level, P_t, is given by:

$$\Delta P_t = \Psi_P(L)[e_{nt}, e_{Tt}, e_{dt}]. \qquad \textbf{10}$$

Note that I assume that the price level is nonstationary and the inflation rate (first difference of the log of P) is a stationary process.[7] It is also assumed that all shocks defined above have a

7 The Augmented Dickey-Fuller test (Said and Dickey, 1984), the Perron test (1989, 1990), and the Gonzalez-Farias test (1994) are used to test for the non-stationarity of the variables. The latter test is recommended by Pantula-Gonzalez-Fuller (1994) over other tests such as Elliotte, Rothemberg, and Stock (1992). The null hypothesis that the variables in the system are unit root processes cannot be rejected. The inflation rate is also tested for unit root using the tests above as well as by estimating the order of integration of an ARFIMA (P,d,q) process (Diebold and Rudibusch, 1989). The conclusion is that inflation is a stationary process with high persistence (ie, long memory). Therefore, all variables in the VAR are first differenced.

long-run impact on the price level. Finally, an exogenous oil price shock is added to the model.

$$\Delta O_t = \Psi_O(L) e_{ot} . \qquad \textbf{11}$$

The moving average representation is given by:

$$\begin{bmatrix} \Delta O_t \\ \Delta n_t \\ \Delta P_t \\ \Delta Y_t \end{bmatrix} = B(L) \begin{bmatrix} e_{ot} \\ e_{nt} \\ e_{dt} \\ e_{Tt} \end{bmatrix} \qquad \textbf{12}$$

The shocks e_{ot}, e_{nt}, e_{dt}, and e_{Tt} respectively correspond to shocks to O, n, P, and Y.

Consider a kx1 vector of endogenous variables z_t. The structural moving average representation of (12) is just:

$$z_t = B(L) e_t , \qquad \textbf{13}$$

where $B(L) = B_0+B_1L+B_2L^2+..$ is a kxk matrix of polynomials in the lag operator L. The disturbance vector e_t is a kx1 white noise $\sim N(0,\Sigma_e)$, where Σ_e is diagonal. The following VAR is estimated to estimate the response of the element of z_t to innovations contained in e_t:

$$H(L) z_t = u_t , \qquad \textbf{14}$$

where $H(0) = I$,[8] and $u_t \sim N(0,\Sigma_u)$ is not a diagonal matrix. Inverting the VAR yields,

$$z_t = D(L) u_t , \qquad \textbf{15}$$

8 This implies that there are no contemporaneous variables on the RHS.

where $D(L) = H(L)^{-1}$.

Now, we can decompose the elements of D(L) by using the matrix that defines the contemporaneous structural relations, B(0), where $D(L) = B(L)B(0)^{-1}$. This gives:

$$B(L)B(0)^{-1}u_t = B(L)e_t \ , \qquad \textbf{16}$$

and,

$$u_t = B(0)e_t . \qquad \textbf{17}$$

To recover the orthogonal disturbances e_t from the estimated VAR's residuals u_t we have to estimate B(0). To do that we need two conditions. First, there must be a unique solution to Σ_e.[9] Second, the number of parameter estimates cannot exceed the number of unique elements in Σ_u (the sample covariance matrix). Note that there are k^2 unknown elements in B(0) and the matrix Σ_u contains (k(k+1)/2) unique elements, thus, a necessary condition for identification is that k^2-k(k+1)/2 = k(k-1)/2 additional restrictions be imposed. This known as the order condition.[10]

4. *Estimation and Results*

The Shapiro and Watson approach (1988) is to estimate a system that yields structural disturbances directly from the VAR system:

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9 The matrix $\Sigma_e = B(0)^{-1}\Sigma_u B(0)^{T-1}$.

10 Sim's (1980) approach is to assume that B(0) is lower triangular, thus imposing restrictions on the contemporaneous correlations of shocks. In other words, the system is recursive in nature. The criticism to this approach is that it does not reconcile with economic theory (Cooley and LeRoy, 1985). Also, Sims (1986), Bernanke (1986), Walsh (1987), and Blanchard (1989) approaches to identification is to impose zero restrictions on B(0), therefore, they do not assume a recursive system. The restrictions are also motivated by theory. Further, Blancahrd and Quah (1989) impose zero restrictions on the long-run multipliers B(1) to estimate B(0). This is similar to the Shapiro-Watson approach implemented in this paper.

$$C(L)\,z_t = e_t \;, \qquad \textbf{18}$$

where C(L) = B(L)$^{-1}$ and B(L) is the same as in 12 above. They recover the structural disturbances by (i) Letting equation C(0) ≠ I, which implies that contemporaneous values of z_t can enter the RHS of some equations.[11] (ii) Restrictions on the long-run multipliers[12] are just restrictions on the sums of coefficients of corresponding variables. (iii) Orthogonality is achieved by estimating each equation in the system sequentially then use the residuals from equation 1 to estimate equation 2, and the residuals from 1 and 2 to estimate equation 3 and so on. Final orthogonalization is achieved by applying the Choleski factorization to the variance-covariance matrix.

It is assumed that oil shocks are external relative supply shocks, unaffected by other variables, and hence, oil price is a function of its own lags. The structural shocks of the above model can be recovered by estimating a VAR model, and then using the information from the sample variance-covariance matrix to achieve identification. The long-run restrictions are imposed by setting these variables in second differences in the VAR, which yields the following model (with number of lags (J) set arbitrarily equal four):

$$\Delta P_t = \sum_{j=0}^{J}\delta_{31}\Delta O_{t-j} + \sum_{j=1}^{J}\delta_{32}\Delta^2 m_{t-j} + \sum_{j=1}^{J}\delta_{33}\Delta^2 P_{t-j} + \sum_{j=1}^{J}\delta_{34}\Delta y_{t-j} + U_{3,t} \;,$$

$$\Delta y_t = \sum_{j=0}^{J}\delta_{41}\Delta O_{t-j} + \sum_{j=1}^{J}\delta_{42}\Delta^2 m_{t-j} + \sum_{j=1}^{J}\delta_{43}\Delta P_{t-j} + \sum_{j=1}^{J}\delta_{44}\Delta y_{t-j} + U_{4,t} \;, \qquad \textbf{20}$$

Also, dummy variables that take the value of 1 in 1986II, 1986IV, 1991I and zeros otherwise are included in the VAR. The 1986II and 1991I dummies are to control for oil price changes and are therefore, included in the estimation of equation 19. The 1986IV

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11 If contemporaneous values enter in some equations then OLS does not yield consistent estimates.

12 Zero on B(1).

dummy variable is included in the output equation to control for the effects of GST.[13] Also, the VAR is estimated with four seasonal dummies.

Equation (19) is estimated by OLS, while equations (20), (21), and (22) are estimated by the Instrumental Variable technique (IV) using the contemporaneous oil price, and lags of all other variables as instruments.[14] Note that while the residuals matrix u_t is not the same as the structural disturbances matrix e_t, the residuals are still correlated. Orthogonality is achieved by a lower-triangular Choleski factorization.[15]

4.1 Impulse Response Functions

Impulse response functions are qualitatively consistent with predictions implied by the neo-classical growth model. The impulse response functions of labour supply, the price level, and real output to a one standard deviation shock in real oil prices are plotted in figures 1-3. A one standard deviation shock to oil prices tends to reduce the levels of output and employment, and raise the price level. Both output and labour fall continuously for five quarters before they settle at lower long-run equilibrium values. The effect of the shock on the price level starts about one quarter after the shock and continues for more than two years.

The impulse response functions of the price level and real output to a unit shock to labour supply are plotted in figures 4 and 5 respectively. The responses are consistent with theory-a unit

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13 Goods and Services Tax introduced in October 1986.

14 Obtaining valid instruments is a difficult task. Two important properties are required to implement an IV method of estimation: (1) Relevance (i.e., a high correlation between the endogenous regressors that is independent of those regressor's correlated with other instruments) and, (2) Exogeneity (i.e., no correlation with the innovations in the dependent variable). For further details, see Nelson and Startz (1990), Maddala and Jeong (1992), and Hall, Rodebusch, and Wlicox (1994).

15 This is a lower-triangular matrix W such that $W^{-1}\Sigma_u{}^{T-1} = I$. This implies that I can solve for $e_t = u_t W^{-1}$ and $E e_t e^T = I$. Note that the system is not recursive.

shock to labour tends to reduce the price level and output in the long run.

The impulse response functions of labour, the price level, and real output to a one standard deviation shock to aggregate demand are plotted in figures 6-8. A positive demand shock increases real output, labour, and the price level. Whilst the shock has the expected immediate positive response from the price level the inflation rate initially rises but then declines persistently (twelve impulse response functions of inflation to a unit demand shock are reported in table 2). Output increases for about two quarters, declines thereafter, and levels out after eight quarters. The small increase in output, the quick reversal of the shock, and the immediate decline in the inflation rate maybe consistent with the anti-inflationary monetary policy pursued by the monetary authority in New Zealand.

Finally, the impulse response functions of labour, the price level, and real output to a one standard deviation shock to technology are plotted in figures 9-11. Labour supply rises sharply with technological progress, continues to be high for about 3 to 4 quarters then declines to its long-run path. The CPI falls considerably and continues to be negative in the long-run. Output increases for about three to four quarters in response to a shock to technology, it then levels to its long-run level. It is clear that the price level is countercyclical in the model. The impulse response functions of inflation rate are reported in table 2. They indicate countercyclical behaviour.[16]

4.2 Variance Decomposition

The forecast error variance decomposition indicates the relative importance of shocks. In other words, it shows the importance of the shocks in explaining the average variability of output. (Recall that the oil price is assumed to be exogenous. Fluctuations in the real oil price are 100 percent self explanatory.)

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16 These results are in contrast to those in Mankiw (1989) and Chadha and Prasad (1994).

The decomposition of the variance of employment is as follows: 66.55 percent of the fluctuations in employment are explained by fluctuations in labour supply shocks, 11.49 percent by technological shocks, and about 21.11 percent by real oil price shocks.[17] Results are reported in table 3.

In the very short run (1 to 3 quarters), demand shocks seem to be very important in explaining fluctuations in the price level. Explanations range from 97 percent in the first quarter to 82 percent in the fourth quarter after the shock. Demand shocks explain 33.75 percent of the fluctuations in the CPI in the long run. Supply shocks (oil price, labour supply, and technology) seem to be increasingly important in explaining the variations of CPI in the long run. The contribution of oil price, labour supply, and technology shocks to the variations of the price level in the short run are 0.08, 2.8, and zero respectively. In the long run, about 12.4 percent of the fluctuations in the CPI are explained by technological shocks, 7.77 percent of the variations in the CPI by labour supply shocks, and 46 percent of the fluctuations in the CPI by oil price shocks.

Most of the fluctuations in real output are explained by technological and oil price changes. In the long run, 39.42 percent of the fluctuations in real GDP are explained by oil price changes, and 46.68 by technological changes. A smaller fraction, 10.5 percent is explained by labour supply shocks. The contribution of labour supply shocks to variations in real GDP is smaller than those reported for the United States (Shapiro and Watson, 1988), but closer to those reported for Australia (Moreno, 1992).[18]

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17 The variable labour supply is a ratio of employment to total labour force. This variable is not very sensitive to short-run changes in aggregate demand.

18 Before the introduction of the Employment Contracts Act (1991), (ECA) New Zealand's labour markets were characterised by state intervention with primary goals of (1) achieving and maintaining full employment, and (2) controlling the level of wages directly via a negotiations with employers and unions. Thus, the variable used has very small variations, which maybe the reason for having such a small impact on real GDP.

In summary, aggregate supply shocks are far more important than aggregate demand shocks in the long run. The contribution of aggregate supply shocks including the oil price shock to the variations of labour supply (employment ratio), CPI, and real GDP at 24 quarters ahead are 99.15, 64.35, and 96.6 respectively. In the case of the CPI, AD shocks play a significant role explaining the movements of CPI in the short run. In the long run, one third of the fluctuations (33.75 percent) in CPI is explained by AD shocks.

5. *Analysing the Structural Shocks*

The structural errors from each equation are analyzed. These errors represent unexplained variations in the dependent variables of equations 19 to 22. Plots of the standardized errors show that large shocks are apparent in all of them (figures 12-15). Table (4) presents summary statistics. It is clear that the shocks are white-noise random variables with an apparent skewness. No significant kurtosis is present in the shocks except for oil price shocks.[19] Testing for the changes in volatility of these shocks over time involves some measure of variance. I compute the following statistic

$$R_i(S) = \frac{(n-1)\hat{\sigma}^2_i}{\hat{\sigma}^2_p} \quad - \chi^2_{n-1} \qquad \textbf{23}$$

for each i=1,...m non-overlapping windows of size n.[20] The denominator is the unbiased estimate of the population variance.[21] The numerator is the variance of each of those m

[19] Kurtosis is interpreted as a sign of "large" shocks to the levels of these variables (Blanchard and Watson, 1986). The kurtosis is normalized such that zero represents a normal distribution.

[20] I choose n equal to 4 quarters because it divides easily into 60 observations and it corresponds to a calendar year.

[21] Note that the variance is equal to one.

windows. This statistic follows approximately a χ^2 with (n-1) degrees of freedom. I can test the null hypothesis that $\sigma^2_i = \sigma^2_p$ against the alternative $\sigma^2_i > \sigma^2_p$. The rejection region is given by $\chi^2 > \chi^2_\alpha$, where χ^2_α is chosen so that $Pr(\chi^2>\chi^2_\alpha)=\alpha$. For some α's, values of $R_i(S)$ falling in this region are considered "large" and indicate a rejection of the null in favour of the alternative.

With a sample size equal to 60 and n equal to 4, I estimated 15 $R_i(S)$ values for each structural shocks series. These estimates of χ^2s are reported in table 5. The rejection regions that these χ^2 statistics are compared to are $\chi^2_{(\alpha,3)}$, where α=0.95 and 0.99 levels (7.81 and 9.35 respectively). I draw 60 iid observations from the N(0,1) distribution. I then compute $R_i(S)$ for n=4, and count the number of times that $R_i(S)$ exceeds the $\chi^2_{.95,3}$ and $\chi^2_{.99,3}$ critical values under the null that $\sigma^2_i = \sigma^2_p$. I repeat the experiment 10,000 times. The empirical distribution of these counts for such a small sample show that the probability of having no values of $R_i(S)$ exceeding the critical values is identically equal to one. This means that the null can be rejected if we find one value of $R_i(S)$ > critical values. Information in table 4 indicates that all the changes in the volatility of the structural shocks are statically significant over the sample. Therefore, we can reject the null in favour of the alternative.

Looking at individual shocks over the sample during the Gulf War in 1990-1991 oil supply shocks are more significant than all other shocks. Labour supply shocks as well as oil supply shocks are also significant in 1989. Demand shocks are significant in 1988, while technology shocks are significant in 1981 and in 1983. Note that because the denominator of equation 23 is identically equal to one we can compare values of $R_i(S)$ across shocks. The average volatility during the periods 1980-1989, and 1990-1993 is computed and results are reported in table 5. Loosely speaking, the average volatility of shocks in 1980s is relatively smaller in magnitudes than those in the 1990s with the exception of shocks to technology.[22] Technology shocks are found to be significantly

22 Obviously, averaging over 10 years interval for 1980s while averaging over 4 years in the 1990s affects the results.

larger than all other shocks during the 1980s. The average declines during the period 1990-1993. During the period 1990-1993, oil supply shocks are found to be more volatile, on average, than all other shocks (e.g., the Gulf-War). Labour supply shocks and demand shocks seem to be equally volatile on average.

6. Unconditional Correlations Between Prices and Output

In the previous section we established that supply shocks are far more important to New Zealand than demand shocks. The conditional correlations between prices, inflation, and output are found to be negative. In this section, the unconditional correlations are examined. The results suggest that prices are countercyclical.

Two issues are considered in this section. (1) both CPI and GDP are non-stationary time series, therefore, de-trending the series independently is required to obtain meaningful statistics. Cooley and Ohanian (1991) and Chadha and Prasad (1994) use different filters to de-trend the series. The latter shows that the choice of the filter can affect the results. In this exercise, two different types of filters are used (a) the Hodrick-Prescott (1980) filter, and (b) the Perron (1989) segmented trend de-trending procedure. (2) price and output responses to demand impulses appear with lags. This problem is dealt with by estimating the cross-correlation functions, which are estimates of the cross-correlations at different lags and leads.[23]

6.1 Cross-Correlations Between the Price Level and Output

Aggregate output and the price level are both non-stationary

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[23] The cross-correlation function is defined as:
Install Equation Editor and double-click here to view equation. **Error! Main Document Only.**

time series. Two techniques are used to remove the trend from output and prices. First is the Hodrick-Prescott (1980) popular filter, and second is the Perron (1989) procedure.[24] The HP filter involves solving the following problem:

$$\underset{|q|}{\mathrm{MIN}} \frac{1}{T}\sum_{t=1}^{T}(y_t - q_t)^2 + \frac{\lambda}{T}\sum_{t=2}^{T-1}[(q_{t+1} - q_t - (q_t - q_{t-1})]^2, \qquad \textbf{24}$$

where y_t is the time series to be de-trended, q_t is the trend (growth component), and y_t-q_t are the residuals. In this exercise, λ is set equal to 1600 (Prescott, 1986).[25] The Perron procedure is to account for a one time shift in the mean of the series (structural break). 1985:1 is chosen as a break point, this is when New Zealand switched to a floating exchange rate. Figures 16 and 17 depict the price level and output for the two different de-trending procedures. The shaded areas are the trough-to-peak periods reported by Kim, Buckle, and Hall (1994). There are some obvious negative correlations between the price level and output in figure 16. The negative cross-correlations between the price level and output are less obvious in figure 17.

The cross-correlations at four lags and leads are reported in table 6. There is a strong negative cross-correlation between the price level and output using the HP filter and all correlations are significantly different from zero. The cross-correlations using the Perron de-trending procedure reported in the third column are mainly negative except at the third lag, the contemporaneous level, and the first lead.

6.2 Cross-Correlation Between Inflation and Output

Mankiw (1989) suggests that in the absence of identifiable real shocks, inflation tends to rise in booms and fall in recessions.

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24 I avoided the deterministic trend procedure because it is inappropriate to de-trend output. Output is a unit root process and this de-trending procedure would still result in spurious moments.

25 See King and Rebelo (1993) on the properties of the HP filter.

Figure 18 shows the first difference of the natural logarithm of GDP and inflation measured as the first difference of the natural logarithm of CPI. The cross-correlations are reported in table 7. Again, the cross-correlations are dominantly negative, except at the second lag, third lag, and the contemporaneous level.

Figure 19 shows inflation and output de-trended using the HP filter. The cross-correlations are reported in the third column of table 7. Most of the cross-correlations are negative except for the fourth and the third leads. The evidence seem to favour the hypothesis that the price level and inflation are both countercyclical.[26]

Finally, figure 20 shows the difference between inflation measured as the first difference of the natural logarithm of CPI and the de-trended price level using the HP filter. Clearly, there is a significant difference in the behaviour of these two variables. The variables seem to be moving in different directions over the cycles. The sample correlation coefficient between inflation and the HP price series is zero.

7. Conclusions

A VAR system is estimated using quarterly data for New Zealand for the period 1977II to 1994I. The Shapiro-Watson (1988) approach is used, where identification is achieved by imposing zero restrictions on the long-run multipliers (i.e., some disturbances have zero long-run effect on certain elements of the VAR) in such a way so we can estimate the contemporaneous effects of disturbances.

The results are qualitatively consistent with the predictions of the theoretical model.

(1) Inflation increases sharply for 4 to 5 quarters in response to

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[26] Chadha and Prasad (1994) found the price level to be countercyclical and inflation to be procyclical in G-7 countries.

a unit shock to oil prices (an adverse relative supply shock), and continues to be positive after 12 quarters. The price level stays unchanged for two quarters before it rises in response to a unit shock in oil prices. Output is depressed for about 5 quarters in response to the same shock.

(2) At the very short run, 7.72 percent of the fluctuations in output are explained by changes in oil prices, 2.6 percent by changes in labour supply, 6.06 percent by changes in aggregate demand shocks, and 83.6 percent by technological changes. In the long run, 39.42 percent of the fluctuations are explained by changes in oil prices, 10.5 percent by changes in labour supply, 3.38 percent by aggregate demand shocks, and 46.8 percent by technological changes. Thus, most of the variations in real GDP are particularly driven by technological shocks, and generally by supply factors. On the other hand, 46.08 percent of the variations in the price level in New Zealand is explained by oil price shocks, 33.75 percent by aggregate demand shocks, 7.77 percent by labour supply shocks, and approximately 12.38 percent of the variations is explained by technology shocks.

(3) Generally, changes in the volatility of the shocks over the sample seem to be statistically significant. Thus, we can reject the hypothesis that the volatility of the shocks are constant. On average, technology shocks are found to be more volatile than all other shocks during the 1980s, followed by aggregate demand shocks, labour supply shocks, and oil price shocks. During the period 1990-1993, oil price shocks are found to be more volatile on average than all other shocks, followed by labour supply shocks, aggregate demand shocks, and technology shocks.

(4) Prices are countercyclical. The responses of the price level (inflation) to a unit shock (increase) to the level of real output (growth) are negative. That implies a decline in the price level (inflation) in response to a favourable technology shock. Both conditional and unconditional correlation between the price level (inflation) and output

are found to be negative.

Finally, a large VAR system with many foreign variables aggregated using trade-weighted indexes is used. The system failed to produce qualitatively good results. The failure of the large open economy VAR indicates that modelling the relationships between foreign and domestic variables is essential. Future research should focus on the following: (1) a general equilibrium open economy macro model. (2) Modelling the interactions between domestic and foreign variables, and. (3) use disaggregated data for the foreign variables instead of trade-weighted indexes. I think that measurement errors as result of aggregation over countries add additional unexplained noise to the VAR. I think that future research should start with either the United States or Australia as the foreign country.

References

Backus, D.K. and P.J. Kehoe, "International Evidence on the Historical Properties of Business Cycles," American Economic Review 82 (1992), 64-888.

Barro, R., "The Equilibrium Approach to Business Cycles, in: Money, Expectations, and Business Cycles, Academic Press, New York, NY, (1978).

Bernanke, B., "Alternative Explanations of the Money Income Correlation," Carnegie-Rochester Series on Public Policy 25 (1986), 49-99.

Blanchard, O.J., "A Traditional Interpretation of Macroeconomic Fluctuations", American Economic Review (1989), 1146-1164.

Blanchard, O.J. and M.W. Watson, "Are Business Cycles All Alike? in: The American Business Cycle: Continuity and Changes, R.J. Gordon, ed., University of Chicago press, Chicago, (1986), 123-179.

Blanchard, O.J. and D. Quah, "The Dynamic Effects of Aggregate Demand and Supply Disturbances," American Economic Review 79 (1989), 655-673.

Burns, A. and W.C. Mitchell, "Measuring Business Cycles," National Bureau of Economic Research, New York, NY (1946).

Chadha, B. and E. Prasad, "Are Prices Countercyclical? Evidence from the G-7," Journal of Monetary Economics 34 (1994), 239-257.

Cochrane, J., "Shocks," National Bureau of Economic Research, Working Paper 4698, Cambridge, MA., 1994.

Cooley, T.F. and S.F. LeRoy, "A Theoretical Macroeconomics: A Critique", Journal of Monetary Economics (1985), 283-308.

Cooley, T.F. and L.E. Ohanian, "The Cyclical Behaviour of Prices," Journal of Monetary Economics 28 (1991), 25-60.

Dennis, R., "Creating Trade Weighted Indices," Data Memo D94/12, Reserve Bank of New Zealand 1994.

Dickey, D. and W. Fuller, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," Journal of the American Statistical Association 74, (1979), 427-431.

Dickey, D. and W. Fuller, "The Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," Econometrica 49, (1981), 1057-1072.

Diebold, F. and G. Rudebusch, "Long Memory and Persistence in Aggregate Output", Journal of Monetary Economics 24 (1989), 189-209.

Elliott, G., Rothenberg, T.G. and Stock, J.H., "Efficient Tests for an Autoregressive Unit Root," National Bureau of Economic Research Technical Working Paper No. 130, (1992).

Fischer, S., "Long Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," Journal of Political Economy 84

(1976), 191-205.

Friedman, M. and A. Schwartz, A Monetary History of the United States, Princeton University Press, Princeton, NJ (1962).

Friedman, M. and A. Schwartz, Monetary Trends in the United States and the United kingdom, The University of Chicago Press, Chicago, IL (1982).

Gonzalez, F. and D. Dickey, "Unconditional Maximum Likelihood Test for a Unit Root," Manuscript, North Carolina State University, Raleigh, NC., 1994.

Gordon, R., "Price Interia and Policy Ineffectiveness in the U.S. 1890-1980," Journal of Political Economy 90 (1982), 1087-1117.

Hall, A., G.D. Rodebusch, and D. W. Wilcox, "Judging Instrument Relevance in Instrumental Variables Estimation," Working Paper, Department of Economics, North Carolina State University, Raleigh, NC (1994).

Hodrick, R. and E.C. Prescott, Post War Business Cycles: An Empirical Investigation, Carnegie Mellon University, Rochester, NY (1980).

Kim, K., R.A. Buckle, and V. B. Hall, "Dating New Zealand Business Cycles," (1994)Working paper No 6/94, Victoria University, Wellington, NZ.

King, R.G. and S. Rebelo, "Low Frequency Filtering and Real Business Cycles," Journal of Economic Dynamics and Control 17 (1993), 207-231.

Kuznets, S., "Secular Movements in Production and Prices, National Bureau of Economic Research, New York, NY., (1930).

Kydland, F.E. and E.C. Prescott, "Business Cycles: Real Facts and a Monetary Myth," Federal Reserve Bank of Minneapolis Quarterly Review (1990), 3-18.

Lucas, R., "Expectations and the Neutrality of Money," Journal of Economic Theory 4 (1972), 103-124.

Maddala, L. P. and J. Jeong, "On the Exact Small Sample Distribution of the Instrumental Variable Estimator," Econometrica 60 (1992), 181-183.

Mankiw, G., "Real Business Cycles: A New Keynesian Perspective," Economic Perspectives 3 (1989), 79-90.

Mills, F.C., "The Behaviour of Prices," National Bureau of Economic Research, New York, NY., (1927).

Mills, F.C., "Prices in Recession and Recovery," National Bureau of Economic Research, New York, NY., (1936).

Mills, F.C., "Price Quantity Interaction in Business Cycles," National Bureau of Economic Research, New York, NY., (1946).

Moreno, R., "Macroeconomic Shocks and Business Cycles in Australia," Economic Review of the Federal Reserve Bank of San Francisco (1992), 34-52.

Nelson, C. R. and R. Startz, "The Distribution of the Instrumental Variables Estimator and Its t-Ratio When the Instrument is Poor One," Journal of Business 63 (1990), 125-140.

Pantula, S.G., Gongalez-Farias, and Fuller, W., "A Comparison of Unit Root Test Criteria," Journal of Business & Economic Statistics 12 (1994), 449-459.

Perron, P., "The Great Crash, The Oil Price Shock, and the Unit Root Hypothesis," Econometrica 6 (1989), 1361-1401.

Perron, P., "Testing for a Unit Root in A Time Series With a Changing Mean", Journal of Business and Economics Statistics 8 (1990), 153-162.

Prescott, E.C., "Theory Ahead of Business Cycles Measurement," Federal Reserve Bank of Minneapolis Quarterly Review (1986), 9-22.

Razzak, W., "Inflation Is It Non-Stationary or a Long-Memory Process?" Research Note (1994), Reserve Bank of New Zealand, Wellington, NZ.

Said, S. and D. Dickey, "Testing for Unit Roots in Autoregressive-Moving Average Models with Unknown Order," Biometrika 71, 1984, 599-608.

Sargent, T., "A Classical Macroeconometric Model for the United States," Journal of Political Economy 84 (1976), 207-237.

Shapiro M.D. and M. Watson, "Sources of Business Cycle Fluctuations," National Bureau of Economic Research, Cambridge, MA., (1988).

Sims, C. A., "Macroeconomics and Reality," Econometrica (1980), 1-48.

Sims, C.A., "Are Forecasting Models Usable in Policy Analysis?" Federal Reserve Bank of Minneapolis Quarterly Review (1986), 2-16.

Smith, R. T., "The Cyclical Behaviour of Prices," Journal of Money Credit and Banking 24 (1992), 413-430.

Solow, R., "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, (1956), 312-320.

Taylor, J.B., "Estimation and Control of Macroeconomic Model with Rational Expectations, Econometrica 47, (1979), 1267-1286.

Taylor, J.B., "Aggregate Dynamics and Staggered Contracts," Journal of Political economy 90, 1-23.

Walsh, C. E., "Monetary Targeting and Inflation: 1976-1984," Federal Reserve Bank of San Francisco Economic Review (1987), 5-15.

Table 1
Inflation During Trough-to-Peak Periods

Date[a]	Quarters of Expansions[a]	Quarters of Contractions[a]	Cycle[a]	Annual Average Inflation Rate[b]
1978:1 to 1982:2	17	3	20	13%
1983:1 to 1986:3	14	7	21	10%
1988:2 to 1989:2	4	8	12	8%

a: Information are from Kim, Bukle, and Hall (1994). b: Computed as $\ln(CPI_t)-\ln(CPI_{t-4})$

Table 2
Impulse response functions of inflation
to a one standard deviation shock to AD & AS

Lags	Response of inflation to an AD shock	Response of inflation to Technology shock
1	0.0065	-0.00000
2	0.0042	-0.00155
3	0.0036	-0.00220
4	0.0033	-0.00289
5	0.0029	-0.00361
6	0.0027	-0.00296
7	0.0025	-0.00243
8	0.0024	-0.00207
9	0.0022	-0.00165
10	0.0020	-0.00147
11	0.0018	-0.00135
12	0.0016	-0.00125

Table 3
Variance Decompositions

Quarters Ahead	Proportion of Variance Explained by Shocks to:			
	Oil Price	Labour Supply	Technology	Aggregate Demand
Employ-ment				
1	4.93	95.07	0.00	0.00
4	11.85	70.79	16.18	1.74
8	19.14	66.65	13.24	0.96
12	20.14	66.72	12.24	0.88
24	21.11	66.55	11.49	0.83
GDP				
1	7.72	2.61	83.60	0.06
4	24.45	10.48	60.66	4.39
8	35.68	10.10	50.55	3.66
12	37.18	10.30	48.95	3.55
24	39.42	10.50	46.68	3.38
CPI				
1	0.08	2.80	0.0	97.10
4	4.57	5.95	7.42	82.05
8	26.92	7.92	12.84	52.31
12	37.14	7.87	12.72	42.25
24	46.08	7.77	12.38	33.75

Table 4
Summary Statistics of the structural shocks
Estimated for the Sample 1978:4 to 1994:1

Shock	Mean	Median	Variance	Skewness[1]	Kurtosis[2]	Fisher-Kappa Test[3]	K-S-B-D Test[4]	Prob (Q) statistic[5]
Oil Price	0.078	-0.03408	1.0	2.024354	9.546912	2.9903	0.0881	0.802 0.662
Labour Supply	0.036	0.018	1.0	0.311447	-0.60393	3.8907	0.1362	0.318 0.326
Demand	-0.038	-0.0082	1.0	-0.30327	0.752357	3.2766	0.1388	0.362 0.214
Technology	-0.007	-0.0976	1.0	0.307801	-0.33514	3.3553	0.1292	0.760 0.796

(1) The skewness is normalized by standard deviation and compared to a zero for a normal distribution.
(2) The kurtosis is normalized such that it is zero for a normal distribution.
(3) The Fisher-Kappa test tests for white-noise errors. The 5% critical value with sample size 50 is 6.567.
The statistics imply that we cannot reject the null hypothesis of white-noise.
(4) The Kolmogrov-Simrnov-Bartlett-Durbin test to test for randomness. The statistic is the maximum absolute difference of the standardized partial sums of the periodogram and the CDF of a uniform (0,1) random variable.
The 5% critical value is 1.36
(5) Probability of χ^2 at lags 6 and 12.

Table 5
Estimated $R_i(S)$ statistics

Windows (m)	Year	$R_i(S)$			
Shocks	n=4	Oil Price	Labour supply	Demand	Technology
1 Average	1979	2.7871	1.70205	1.9102	0.95879
2	1980	0.5288	6.85441	2.4618	2.55946
3	1981	1.0129	3.13222	2.9337	7.72532*
4	1982	0.5407	0.55825	0.0932	2.85938
5	1983	0.5398	0.67405	3.2949	9.19430*
6	1984	0.1481	1.13213	0.2946	3.39137
7	1985	0.8817	0.74627	0.7708	2.28563
8	1986	2.3817	0.56357	1.8756	4.09472
9	1987	1.4161	5.86745	4.7049	0.67167
10	1988	0.5406	0.31904	11.3870*	1.86296
11 Average	1989	10.6823* 1.69	9.76132* 2.69	4.0657 2.89	1.91711 3.32
12	1990	0.3689	1.62697	0.8824	0.46262
13	1991	20.4765*	3.86020	2.6101	0.71750
14	1992	1.3739	4.95490	4.9696	2.12413
15 Average	1993	1.3209 5.88	3.24717 5.86	2.7456 3.82	4.17504 2.35

Statistically significant.
* Average Volatility. The 95% value is 7.81 and the 99% is 9.35 with n=3.

Table 6

Cross-Correlations of Prices and Output
Using Different Filters (1977II-1994I)

	Filter Type	
Lag	HP Filter	Perron Filter
-4	-0.20238	-0.23608
-3	-0.29217	-0.21396
-2	-0.28278	-0.00224
-1	-0.22619	0.08105
0	-0.20097	0.18781
1	-0.17285	-0.09308
2	-0.10838	-0.00895
3	-0.05678	0.09351
4	-0.06215	-0.14742
Q(1 to 4)	3.4932 (0.47)	2.8781 (0.57)
Q(-4 to -1)	18.6992 (0.000)	7.9644 (0.09)
Q(-4 to 4)	25.0197 (0.003)	13.3117 (0.15)

A negative lag denotes a lead. Q statistics are the Ljung-Box to test for zero correlations. Marginal significance levels are in parentheses.

Table 7
Cross-Correlations of Inflation and Output Using Different Filters. Inflation is the First Difference of Ln(CPI)

Lag	a	b
-4	-0.19284	0.2356
-3	-0.19596	.04146
-2	-0.08965	-0.05048
-1	-0.02553	-0.04650
0	0.04621	-0.05010
1	-0.09429	-0.12587
2	0.03052	-0.10036
3	0.11461	-0.00342
4	-0.01142	-0.01233
Q(1 to 4)	1.6705 (0.79)	1.8644 (0.76)
Q(-4 to -1)	6.2038 (0.18)	4.5946 (0.33)
Q(-4 to 4)	8.0238 (0.53)	6.6347 (0.67)

a: Output is $\Delta \ln Y_t$.
b: Output is HP filtered