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Abstract

This paper uses the methodologies developed by Blanchard and Quah (1989) and Shapiro and Watson (1988) to identify and assess the importance of supply and demand shocks in Canadian business cycles. Our principal finding is that supply shocks account for about 80 per cent of short run output fluctuations while demand shocks are responsible for more than 60 per cent of fluctuations in the unemployment rate and the inflation rate. Thus, while our results strongly support the real business cycle approach to modelling economic fluctuations, they also suggest that the traditional emphasis on demand shocks cannot be dismissed altogether.

Résumé

Les auteurs de cette étude tentent de mettre en évidence les chocs de l'offre et de la demande que subissent les cycles économique au Canada et d'en évaluer l'importance, en tirant parti des méthodes élaborées par Blanchard et Quah (1989) et Shapiro et Watson (1988). Leur principale conclusion est que les chocs de l'offre sont à l'origine de 80 % environ des fluctuations de la production à court terme, tandis que ceux de la demande expliquent plus de 60 % des fluctuations du taux de chômage et du taux d'inflation. Bien que les résultats obtenus confortent solidement l'hypothèse que la modélisation des fluctuations peuts'appuyer sur la théorie du cycle économique réel, ils n'indiquent pas moins que l'accent mis traditionnellement sur les chocs de la demande n'est pas entièrement injustifié.

1 Introduction

Explanations for the co-movements of economic aggregates depend to a large extent on the type of innovations that give rise to those movements. Traditionally, innovations are viewed as originating from the demand side (such as monetary or fiscal policies or autonomous shifts in private spending). Nominal rigidities are believed to cause inflexible price adjustments and hence large fluctuations in employment and output, but these fluctuations are considered temporary deviations from a deterministic trend.

In contrast, the viewpoint of real business cycle theorists is that variations in the economic aggregates are the result of agents' optimizing behaviour in the face of supply shocks such as shifts in technology and tastes. Since these shocks are believed to have permanent effects on the equilibrium level of output, output follows a stochastic rather than a deterministic trend.

Although an empirical assessment of supply and demand shocks would help resolve the theoretical debate, little work has been carried out because identifying supply and demand shocks from the data has been extremely difficult. However, Blanchard and Quah (1989) and Shapiro and Watson (1988) have recently developed restrictions that allow supply and demand shocks to be identified. This paper applies their techniques to the Canadian data over the period 1966-88.[1]

2 The Blanchard And Quah Approach

Blanchard and Quah were interested in recovering the temporary and the permanent disturbances from the reduced-form equations for output and unemployment.

[1]Our work began in the fall of 1988 when Blanchard and Quah's work was available in draft form and when Shapiro and Watson's work was available as NBER working paper 2589.

$$\begin{bmatrix} B_{11}(L) & B_{12}(L) \\ B_{21}(L) & B_{22}(L) \end{bmatrix} \begin{bmatrix} DY_t \\ U_t \end{bmatrix} = \begin{bmatrix} v_t^1 \\ v_t^2 \end{bmatrix}$$

where D is the first difference operator, $B(L)$'s are polynomials in the lag operator L, DY is the first difference in the logarithm of real output, U is the unemployment rate, v_t^1 and v_t^2 are the reduced-form disturbances. By assumption, these shocks are linear combination of supply and demand innovations. Blanchard and Quah presented a structural model consisting of supply and demand shocks and which has a reduced form like the one just presented. They suggested interpreting the demand shocks as temporary shocks and the supply shocks as permament shocks. Throughout this paper, we will use the demand versus supply distinction, but some readers may prefer the permanent versus temporary dichotomy. [2]

The above model is a bivariate VAR which describes the dynamic effects of supply and demand disturbances on output and unemployment. The only restriction imposed so far is that the reduced-form disturbances cannot have a permanent effect on the unemployment rate. This restriction is imposed via the assumption that the unemployment rate is stationary in level. In constrast, the assumption that output is stationary in first difference means that without further restrictions, all shocks can have a permanent effect on output.

More compactly, the model can be written as

$$\begin{aligned} B(L)X_t &= v_t \\ B(0) &= I \\ E(v_t v_t') &= \Sigma \end{aligned} \tag{1}$$

where $X_t = (DY_t\ U_t)$, $v_t = (v_t^1\ v_t^2)$ are 2×1 vectors, and Σ is the variance-covariance matrix. Assuming $B(L)$ is invertible, the moving representation

[2]The distinction between supply and demand shocks is rather vague in the literature. Throughout this paper, we refer to structural shocks as supply shocks.

of 1 is

$$
\begin{aligned}
X_t &= C(L)v_t \\
C(0) &= I \\
C(L) &= B(L)^{-1}
\end{aligned} \tag{2}
$$

The structural relationship between DY, U, the supply shocks (e_t^s) and the demand shocks (e_t^d) is assumed to be

$$
\begin{aligned}
X_t &= A(L)e_t \\
E(e_t e_t') &= I
\end{aligned} \tag{3}
$$

where $e_t = [e_t^d \; e_t^s]$. By assumption, these two shocks are serially and mutually uncorrelated, and the covariance matrix is normalized as an identity matrix.

Summarizing,

$$
\begin{aligned}
X_t &= A(L)e_t = C(L)v_t \\
E(v_t v_t') &= \Sigma \\
E(e_t, e_t) &= I
\end{aligned} \tag{4}
$$

The model is identified if we can uncover the structural shocks, e_t, from the reduced-form disturbances, v_t.

2.1 Identification

There are three ways to impose identifying restrictions. By far the most common approach is to impose zero restrictions between the endogenous and exogenous variables of the model, although it has often been criticized because the exclusion restrictions are generally derived on an ad-hoc basis. A second approach, developed by Bernanke (1986), Blanchard and Watson (1986), is known as the structural VAR approach. This approach imposes constraints on the contemporaneous relations of the data and on the variance-covariance matrix. Since these constraints are often judgmental in nature, this method has suffered the same criticisms as the first approach.

The third approach, applied by Blanchard and Quah to the model discussed here, places constraints on the long-run multipliers as well as on the variance-covariance matrix. The advantage of this method is that the long-run behaviour of the economy has been extensively studied and is reasonably well understood. Hence, the constraints are less ad hoc.

Specifically, Blanchard and Quah's key identifying restriction is that demand shocks have no long-run effects on output. For this condition to hold, the variance-covariance matrix must respect certain conditions and the long-run multipliers of demand shocks on output, $A_{11}(1)$, must equal zero. [3] Formally, the restrictions are:

i) $Se_t = v_t$

ii) $SS' = \Sigma$

iii) $C_{11}(1)S_{11} + C_{12}(1)S_{21} = A_{11}(1) = 0$

Restriction (i) sets up v_t as a linear combination of supply and demand shocks. Restriction (ii) imposes restrictions on the elements of S by constraining S to be square root of the covariance matrix Σ. Restriction (iii) imposes linear restrictions between the long-run multipliers and the reduced-form covariance matrix. Restrictions (i) and (ii) together produce one linearly independent restriction on the covariance matrix. Restriction (iii) produces the second linearly independent restriction necessary to solve for the two unknown shocks. The model is just identified when a unique matrix S diagonalizes the reduced-form covariance matrix of long-run multipliers. This method will be used in the empirical work.

Although the Blanchard and Quah approach is interesting and innovative, from a methodological standpoint there are several caveats. One weakness is that it is unlikely that the two-equation model can adequately account

[3] $A_{11}(1)$ denotes the polynomial $A_{11}(L)$ evaluated at L=1. Mathemathically, it is the sum of the coefficients in $A_{11}(L)$ at all lags.

for all disturbances in the economy. However, expanding the dimension of the model makes the identification procedure substantially more complex. Another weakness is that if there are many demand and supply shocks, some with transitory and some with permanent effects on output, and all shocks play an equally important role in aggregate fluctuations, the proposed method will not have much identifying power. As well, the model is relatively limited in its exploitation of economic theory to provide identifying restrictions, which makes it difficult to be precise about the structural dynamics. An approach that addresses the latter criticism begins with a specification of a structural model that is broad enough to allow for the interaction of various markets in the economy. We now turn our attention to one attempt to make progress along these lines, the work of Shapiro and Watson.

3 The Shapiro and Watson Approach

The basis of Watson and Shapiro's model is the neoclassical growth model enriched with business cycle dynamics. Readers can refer to the original paper for the derivation of the structural model. Briefly, their model consists of five variables and five shocks and may be represented as follows.

$$\begin{bmatrix} Dh \\ Dop \\ DY \\ D\pi \\ i-\pi \end{bmatrix} = C(L) \begin{bmatrix} e_t^h \\ e_t^{op} \\ e_t^y \\ e_t^{d1} \\ e_t^{d2} \end{bmatrix}$$

where Dh and Dy are the first differences of the logarithm of labour supply and output, $D\pi$ is the first difference of the inflation rate, $i - \pi$ is the ex-post real interest rate, and Dop the first difference of the logarithm of oil prices. There are three supply shocks, namely, demographics (e_t^h), productivity (e_t^y), oil price (e_t^{op}), and two demand shocks (e_t^{d1} and e_t^{d2}). Shaprio and Watson suggested interpreting the demand shocks as portfolio shocks and goods market shocks. More compactly, the model can be written as

$$X_t = C(L)e_t \tag{5}$$

where $X_t = [Dh, Dop, Dy, D\pi, i - \pi]$, and e_t=[e_t^h e_t^{op} e_t^y e_t^{d1} e_t^{d2}]. By assumption, all the variables in X_t are stationary. This assumption is important because it implies that, without further restrictions, all shocks can have a permanent effect on labour supply, oil prices, output and the inflation rate. As it stands, the real interest rate is the only variable unaffected by shocks in the long run.

The restrictions imposed by Shapiro and Watson to identify the shocks are as follows. First, long-run output is determined by labour supply, the level of technology and the price of oil. Second, unlike supply shocks, demand shocks are assumed not to have any long-run impact on real variables, namely, output, labour supply, the price of oil and the real interest rate. This restriction, identical to the one used by Blanchard and Quah, separate the demand from supply shocks. Third, labour supply and oil price are assumed exogenous in the long run. This restriction allows supply shocks to be decomposed into a labour supply component, a technology component, and an oil price component.

3.1 Implementation of the Restrictions

As discussed earlier, Blanchard and Quah (1988) distinguished demand from supply shocks by putting constraints on the appropriate long run multipliers and selecting a particular orthonormal transformation so as to put covariance restrictions on the matrix of unorthogonalized residuals. Unfortunately, this methodology is tractable only in low dimensional systems. The identification methodology of Shapiro and Watson also makes use of restrictions on the long run multipliers but imposes the covariance restrictions in a somewhat different way. In the Shapiro and Watson framework, identification begins with transforming the moving-average representation of the model into an autoreggressive form:

$$\beta(L)X_t = e_t \tag{6}$$

where $\beta(L) = C(L)^{-1}$ is of order p and has roots outside the unit circle. The identification restrictions are imposed by constraining the relevant long-run multipliers to zero. This requires that (i) the long-run multipliers of the two demand shocks on labour supply, the oil price, and output be zero, (ii) the multipliers of technology shocks and energy price shocks on labour supply be zero, and (iii) the price of oil be exogenous. Collectively, these restrictions imply that the matrix of long-run multipliers, $\beta(1)$, must be in the form of a block lower triangle.

$$\begin{bmatrix} \beta_{11} & 0 & 0 & 0 & 0 \\ 0 & \beta_{21} & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & \beta_{33} & 0 & 0 \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} \end{bmatrix}$$

As the above matrix indicates, there are no restrictions placed on the coefficients, β_{44} and β_{45}, meaning that the two aggregate demand shocks cannot be identified. Consequently we will consider only the joint effects of these shocks.

To this point, we have imposed restrictions only to give the variables desirable long-run properties. There is no guarantee that the causal relationships among the variables are correct. The next step is to take advantage of the triangular ordering of the model so that each shock can be calculated in a block recursive fashion. Essentially, the covariance restrictions are imposed by adding the shocks retrieved from equations with a higher ordering into the subsequent estimations. Their exact implementation will become clear when the equations are examined individually.

Consider the first equation in (6), the labour supply equation, in its unrestricted form:

$$Dh_t = \sum_{j=1}^{p} \beta_{hh,j} Dh_{t-j} + \sum_{j=0}^{p} \beta_{hy,j} Dy_{t-j} + \sum_{j=0}^{p} \beta_{h\pi,j} D\pi_{t-j} + \sum_{j=0}^{p} \beta_{hr,j}(i_{t-j} - \pi_{t-j}) + \sum_{j=0}^{p} \beta_{hop,j} Dop_{t-j} + e_t^h \quad (7)$$

According to the theoretical model, only demographic shocks can have a long-run impact on Dh_t. Hence, the long-run multipliers of the price of oil, output, the real interest rate and the inflation rate on labour supply must be equal to zero. These constraints can be imposed by using differences of Dy_t, $D\pi_t$, i_t -π_t, and Dop_t, and suitably adjusting the lag lengths in (7)[4]

With the imposition of these restrictions, we obtain:

$$Dh_t = \sum_{j=1}^{p} \beta_{hh,j} Dh_{t-j} + \sum_{j=0}^{p-1} \alpha_{hy,j} D^2 y_{t-j} + \sum_{j=0}^{p-1} \alpha_{h\pi,j} D^2 \pi_{t-j} + \sum_{j=0}^{p-1} \alpha_{hr,j}(Di_{t-j} - D\pi_{t-j}) + \sum_{j=0}^{p-1} \alpha_{ho,j} D^2 op_{t-j} + e_t^h \quad (8)$$

where the α's are functions of the β's. Equation 8 is estimated with lags of the explanatory variables as instruments because the regressors are correlated with the error term. The contemporaneous value of the oil price is also used as an instrument because it is a truly exogenous variable.

The output equation is rewritten to incorporate the restriction that demand shocks have no long-run impact on output. Hence, the coefficients on

[4] Consider the model $Y{=}A_0X_t + A_1X_{t-1} + A_2X_{t-2}$. Suppose we wish X to have no long run effect on Y, i.e. $A_0 + A_1 + A_2 = 0$. The equation can be rewritten as $Y = A_0(X_t - X_{t-1}) + A_1(X_{t-1} - X_{t-2}) + (A_0 + A_1 + A_2)X_{t-2}$. Therefore, to set the long-run multiplier to zero, a model with lag length p can be expressed in terms of the first to $(p-1)th$ first differences, dropping the $p-th$ lag altogether. For this reason, some variables in the estimated equations have a higher level of differencing than is necessary to make the variable stationary.

$D^2\pi_t$ and Di_t - $D\pi_t$ are constrained to sum to zero. In addition, the labour supply shocks retrieved from (8) are included in the estimation to ensure that demographic shocks cause output. This method has the same asymptotic result as the covariance restrictions imposed by Blanchard and Quah but is easier to implement in a model of this size. The output equation is then estimated using the same instruments as in the labour supply equation, plus e_t^h.

$$\begin{aligned} Dy_t &= \sum_{j=1}^{p} \beta_{yh,j} Dh_{t-j} + \sum_{j=1}^{p} \beta_{yy,j} Dy_{t-j} + \sum_{j=0}^{p-1} \alpha_{y\pi,j} D^2\pi_{t-j} + \\ & \sum_{j=0}^{p-1} \alpha_{yr,j}(Di_{t-j} - D\pi_{t-j}) + \sum_{j=0}^{p} \beta_{yo,j} Dop_{t-j} + \beta_{yv} e_t^h + e_t^y \end{aligned} \quad (9)$$

In the same way, the reduced forms for the inflation rate and the real interest rate are rewritten to incorporate the identifying and the covariance restrictions:

$$\begin{aligned} D\pi_t &= \sum_{j=1}^{p} \beta_{\pi h,j} Dh_{t-j} + \sum_{j=1}^{p} \beta_{\pi y,j} Dy_{t-j} + \\ & \sum_{j=1}^{p} \beta_{\pi\pi,j} D\pi_{t-j} + \sum_{j=1}^{p} \beta_{\pi r,j}(i_{t-j} - \pi_{t-j}) + \\ & \sum_{j=0}^{p} \beta_{\pi o,j} Dop_{t-j} + \beta_{\pi h} e_t^h + \beta_{\pi y} e_t^y + u_t^1 \end{aligned} \quad (10)$$

$$\begin{aligned} i_t - \pi_t &= \sum_{j=1}^{p} \beta_{rh,j} Dh_{t-j} + \sum_{j=1}^{p} \beta_{ry,j} Dy_{t-j} + \\ & \sum_{j=1}^{p} \beta_{r\pi,j} D\pi_{t-j} + \sum_{j=1}^{p} \beta_{rr,j}(i_{t-j} - \pi_{t-j}) + \\ & \sum_{j=0}^{p} \beta_{ro,j} Dop_{t-j} + \beta_{rh} e_t^h + \beta_{ry} e_t^y + u_t^2 \end{aligned} \quad (11)$$

where the disturbances u_t^1 and u_t^2 represent the linear combinations of the two demand shocks e_t^{d1} and e_t^{d2}. Since the error terms in both equations are uncorrelated with the regressors, both equations are estimated using ordinary least squares.

Lastly, the equation for the price of oil is assumed to be completely exogenous and is specified as follows:

$$Dop_t = c_op + e_t^{op} \tag{12}$$

It, too, is estimated using ordinary least squares.

4 Empirical Results

4.1 The Blanchard and Quah Approach

A key assumption made by Blanchard and Quah is that the unemployment rate is stationary. However, this assumption is invalidated by data from both the United States and Canada since the unemployment rates have drifted upwards since the late seventies. Blanchard and Quah put forward an explanation for the upward drift in unemployment. They argue that there might be two sorts of supply shocks in the economy: changes in productivity, which would have no long-run effects on unemployment, and changes in the composition of the labour force, which could have permanent effects on unemployment. However, the task of identifying three shocks would make the problem significantly more complex. As a shortcut, Blanchard and Quah suggest regressing the unemployment rate on a linear time trend and using the residuals in the estimation of the reduced-form model. Essentially, this approach filters out movements in unemployment that are supposedly due to demographic shifts, and concentrates on identifying supply shocks such as productivity shocks that are not related to demographics shifts. We followed a similar approach. More precisely, we regressed the unemployment rate on a constant and a time trend, and split the sample in 1973 to capture the upward shift in the natural rate of unemployment. This procedure produces residuals that are stationary. The residuals are then used in the bivariate VAR.

The reduced-form equations were estimated for the period 1955Q1 to 1987Q4, using data on real *GDP* and the aggregate unemployment rate. The lag length was defined as eight quarters, but the results showed little difference when shorter and longer lags were used. The structural shocks were constructed using the techniques described in Section II. The demand (e^d) and the supply (e^s) shocks, graphed in Figure 1, are extremely volatile. Supply shocks seem to be larger in the sixties and the seventies. It is also noteworthy that in the late seventies, the economy was hit by a series of negative demand and supply shocks. The cumulative effects of these shocks are reflected in the recession of 1982 .

A more informative way of analyzing these shocks is to calculate output and unemployment without demand shocks. This allows us to determine the contribution of demand shocks to output and unemployment fluctuations. The top panels of Figures 2 and 3 are the contributions of demand shocks to fluctuations in output (YND) and unemployment (UND) respectively. The same methodology was used to obtain measures of fluctuations due to supply shocks (YNS, UNS). These are shown in the bottom panels of Figures 2 and 3. The scales of Figures 2 and 3 indicate that output was affected by large supply shocks, while the unemployment rate was hit by large demand shocks. Supply shocks had very positive effects on output from the sixties until the late seventies, when a productivity slowdown began. In the late seventies and early eighties, both supply and demand shocks had negative effects on output, and both contributed to the 1982 recession. Since the recession, however, the economy has felt the effects of large and positive demand shocks. It is tempting to suggest that the supply shocks identified here are productivity shocks, since the fluctuations in output due to supply innovations closely resemble the path for productivity. The correspondence is most evident in the late seventies, when the productivity slowdown began.

4.1.1 Decomposition of Variance

Another way of analyzing the importance of supply and demand shocks is to consider the orthogonal decomposition of variance in the level of output and unemployment. Tables 1 and 2 report the percentage of variance in a k-step-ahead forecast of the levels of output and unemployment that can be attributed to demand and supply shocks. The results confirm that supply shocks have been responsible for most of the variations in output in both the short (ten quarters or less) and long runs, and that most of the fluctuations in unemployment have been due to demand shocks.

Table 1: Output

steps	demand shocks	supply shocks
1	3.1	96.8
5	15.3	84.6
10	7.9	92.0
20	6.2	93.7
30	3.9	96.5
40	2.7	97.2

Table 2: Unemployment Rate

steps	demand shocks	supply shocks
1	99.0	1.0
5	86.4	13.6
10	84.7	15.3
20	84.7	15.3
30	84.5	15.5
40	84.5	15.5

Based on the decomposition of variance and the contribution of supply shocks to output fluctuations, the Canadian data seem to support the real business cycle hypothesis that supply shocks are important.

4.1.2 Impulse Response

The dynamic effects of demand and supply disturbances can be obtained by tracing out responses of output and unemployment to demand (YD,UD) and supply shocks (YS,US) of one standard deviation. These results are presented in Figure 4. By construction, supply and demand shocks only have transitory effects on unemployment, and only supply shocks have persistent effects on output. Figure 4 shows that the effect of a demand shock peaks in two quarters, and that output then overshoots the equilibrium level before returning to control. The unemployment rate response is also humped in shape, but of opposite sign to the output response. The entire cycle takes about seven years to complete.

The responses of output and unemployment to supply shocks is quite different from their responses to demand shocks. As Figure 4 indicates, output rises monotonically in response to a positive supply shock, approaching asymptotically to the new equilibrium level. There is no evidence of overshooting, and most of the adjustment takes place in the first two years. Our dynamic analysis indicates that a one per cent supply shock will increase the level of output by about 1.6 per cent, and confirms that there will be no permanent effects on unemployment. The relationship between output and unemployment following a demand shock is rather different from that following a supply shock. One year after a positive demand shock, output is up by 0.7 per cent while the unemployment rate is down by 50 basis points. One year after a positive supply shock, however, output is up by 1.2 per cent but the unemployment rate is down by only 30 basis points. These results suggest that Okun's Law might not be independent of the source of the shocks.

We also examined the impulse responses and the decomposition of variance when the time trend in the unemployment rate was not removed. The impulse responses are somewhat different, but the decomposition of variance results are very similar to those presented above . Since detrending removes some supply shocks from the unemployment rate, the results using data with no trend removed should increase the importance of supply shocks. This is indeed the result we obtained. It is interesting to note, however, that the decomposition of variance results obtained by Blanchard and Quah are much more sensitive than ours to whether or not the unemployment rate is detrended. We turn now to results using Shapiro and Watson's specification.

4.2 The Shapiro and Watson Approach

The results are based on estimations of equations (8) to (12) over the sample $69Q4$ to $87Q4$. This is a longer sample than used by Shapiro and Watson, and therefore includes observations of falling oil prices since 1985. Data is derived from the $RDXF$ database. Labour supply, h, is measured as the logarithm of employment in the private sector multiplied by the hours worked. Output, y, is the logarithm of private sector output. The price of oil, op, is the acquistion cost of imported crude oil to U.S. refineries, and coverted to Canadian dollars. The nominal interest rate, i, is the ninety-day treasury bill rate, and π is the *ex-post* rate of inflation based on the price of private sector output. [5]

4.2.1 Impulse Response

Labour Supply Shock

The upper graph in Figure 5 shows the responses of labour supply ($RLHH$) and output ($RLYH$) to an increase in labour supply of one per cent. Output increases by 0.4 per cent and labour supply by 2.4 per cent in the long run. The responses of the inflation rate ($RIRH$), the nominal ($RBTH$) and the real interest rate ($RRRH$) are presented in the lower graph. Although

[5] As our results suggest that the oil price has no significant effect on output and employment, those results are not reported here.

the real interest rate rises by as much as 1.7 percentage points after seven quarters, the inflation rate and the nominal interest rate both increase by 1.4 percentage points in the long run since, by construction, the real interest rate has to be unchanged.

Technology Shock

A permanent one per cent technology shock causes output ($RLYY$) to rise by just over 1 per cent in the long run. Labour supply increases during the first ten quarters to a high of 1.3 per cent above control before returning to control. The real interest rate ($RRRY$) falls initially but also eventually returns to control. One might expect prices to fall as a result of technological growth, but in our simulations the inflation rate ($RIRY$) increases 1.2 percentage points in the short run and then returns to control. It is interesting to note that the adjustment mechanism of the Canadian economy seems quite slow; cycles take seven to nine years to complete. This speed of adjustment is slower than reported for the United States. Although this result could be due to some discrepancies between our data definitions and those of Shapiro and Watson, it does suggest that we should be wary of assuming that business cycle dynamics in Canada and the United States are similar.

4.2.2 Decomposition of Variance

On the whole, our results on the decomposition of variance reported in Tables 3 through 8 agree with Shapiro and Watson's finding for the United States that supply shocks have been responsible for most of the variations in output and labour supply in both the short and long runs. Oil price shocks can account for some output movements, but it is possible that much of the explanatory power is derived from three data points — the energy price shocks in 1973, 1979 and 1985.

Table 3: Labour Supply

steps	labour supply	technology	oil price	demand
1	70.2	21.5	1.2	7.1
10	36.9	44.3	1.1	17.7
20	40.3	43.7	1.4	14.6
30	59.3	30.8	0.8	9.1
40	71.4	21.7	0.5	6.4
50	78.7	16.2	0.4	4.6
∞	100.0	0.0	0.0	0.0

The results in Table 3 confirm the long-run exogeneity of labour supply, since neither oil price shocks nor technology shocks have a long-run impact on labour supply. However, technology shocks are an important source of short-run variations in labour supply, i.e. ten quarters or less.

Table 4: Output

steps	labour supply	technology	oil price	demand
1	0.0	91.3	8.1	0.6
10	4.4	88.0	2.9	4.7
20	3.2	90.0	3.6	3.2
30	5.2	87.9	4.6	2.3
40	6.3	86.8	4.9	2.0
50	7.3	85.9	5.2	1.6

As shown in Table 4, technology shocks explain more than 80 per cent of the variance in output in the short run, while both oil price and labour supply shocks explain only 5 per cent of short-term output variations. The insignificant role played by oil price shocks in explaining output, especially in the short run, contrasts the results reported by Shapiro and Watson for the United States and may reflect the asymmetric programs that were in place after the oil price shocks in the two countries.

Table 5: Inflation

steps	labour supply	technology	oil price	demand
1	0.0	0.0	0.6	99.4
10	1.9	35.3	0.8	62.0
20	1.7	50.7	0.8	46.8
30	9.3	48.4	2.5	29.8
40	22.1	40.1	3.3	34.5
50	33.0	33.1	3.7	30.2

Table 5 reveals that demand shocks are the main source of short-run variation in the inflation rate, while with a longer horizon supply shocks become just as important. The explanatory power of labour supply shocks is surprisingly strong, and we have yet to find a satisfactory explanation for this result.

Table 6: Real Interest Rate

steps	labour supply	technology	oil price	demand
1	0.0	0.0	0.9	99.1
10	50.7	12.5	7.6	29.2
20	48.2	25.7	4.9	21.2
30	46.6	29.2	4.5	19.7
40	46.5	29.5	4.5	19.5
50	46.5	29.5	4.5	19.5

Fluctuations in the real interest rate are primarily caused by supply shocks (i.e. technology and demographic shocks). As shown in Table 6, after 10 quarters over 60 per cent of the fluctuations in the real interest rate are attributable to labour supply and technology shocks.

4.2.3 Sensitivity Analysis

To gauge the robustness of our results, the decomposition of variance was performed assuming that the oil price and labour supply have deterministic trends, but with breaks in the trend functions. This modification was made because the results of the unit root tests developed by Perron (1987) (and reported in the Appendix) rejected the hypothesis of a unit root for both variables, suggesting that some of our stochastic specifications may be inappropriate. The resulting model has only one permanent shock (productivity) and four transitory shocks (labour supply, oil price and two demand shocks). Among these transitory shocks, only the oil price shock is identifiable because the oil price is assumed to be truly exogenous. The results are reported in Tables 7 to 9.

Table 7: Output

steps	oil price	technology	demand
1	0.47	98.4	1.13
10	25.80	56.89	17.31
20	30.38	53.40	16.22
30	34.17	52.68	13.15
40	36.81	52.97	10.22

Table 8: Real Interest Rate

steps	oil price	technology	demand
1	6.02	0.00	93.98
10	17.61	7.58	74.81
20	10.06	6.05	83.89
30	8.81	5.58	85.61
40	8.00	5.55	86.45

Table 9: Inflation

steps	oil price	technology	demand
1	1.89	0.00	98.11
10	5.96	33.67	60.37
20	1.60	37.75	60.65
30	1.20	37.81	60.99
40	1.12	38.74	60.14

Under these assumptions, oil price shocks account for a larger fraction of output fluctuations, while the explanatory power of productivity shocks has decreased. Together, these two supply shocks continue to explain most of the fluctuations in output. However, the ability of supply shocks to explain variations in inflation and the real interest rate has fallen substantially. Compared with the results reported earlier, demand shocks are now the primary cause of inflation and real interest movements in both the short and the long run.

5 Conclusion

Although the contributions of technology and labour supply shocks are quite sensitive to the definitions of the variables in the model and the assumption on the trend functions, the results using the Blanchard and Quah approach and the Shapiro and Watson approach consistently suggest that supply shocks, taken as the sum of labour supply, productivity and oil price shocks, are the major cause of output fluctuations. Supply shocks account for over 80 per cent of output fluctuations in the short term, and their importance increases over time. The result that short-run variations in inflation are due to demand shocks is also fairly robust. Generally speaking, our results lend support to the real business cycle view that supply shocks are important, but also suggest that demand shocks cannot be ignored.

Comparing our results for Canada with those obtained by Shapiro and Watson and Blanchard and Quah for the U.S. economy, Canadian cycles seem to be longer than those in the United States. More importantly, we find that supply shocks are more dominant in Canada and that demand shocks account for a smaller fraction of fluctuations in output and labour supply. This result is not surprising, since the Canadian economy includes a large resource sector, but reinforces the view that the real business cycle theory might provide a useful framework for analyzing developments in the

Canadian economy.

A potential weakness of our analysis is that both models assume the economy is closed. While this assumption may be appropriate for the United States, it is certainly not suitable for Canada. Research is currently underway to extend the Shaprio and Watson model to two economies. Preliminary results suggest that supply shocks are still the major cause of business cycles, but further work is required to check the robustness of those results.

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Appendix: Unit Root Tests

$$Model: Y_t = C + \mu DC_t + \beta t + dD(TB) + \alpha Y_{t-1} + \sum_{i=1}^{K} \sigma_i DY_{t-i} + \epsilon_t$$

Series	C	μ	β	d	α	SE	K
h	2.92	-0.03	0.002	0.006	0.68	0.010	6
	(5.11)	(-4.28)	(5.16)	(0.44)	(-5.11^*)		
y	2.47	-0.03	0.002	0.007	0.79	0.011	2
	(3.71)	(-3.16)	(3.64)	(0.52)	(-3.50)		
rr	-0.013	-0.009	0.0004	-0.033	0.86	0.016	5
	(-1.70)	(-0.89)	(2.19)	(-1.57)	(-1.33)		

$TB = 81Q3(0.67)$

$$Model: Y_t = C + \mu DC_t + \beta t + \delta DT_t + dD(TB) + \alpha Y_{t-1} + \sum_{i=1}^{K} \sigma_i DY_{t-i} + \epsilon_t$$

Series	C	μ	β	δ	d	α	SE	K
op^1	0.73	-0.22	0.012	-0.150	0.260	0.52	0.090	2
	(4.02)	(-2.64)	(3.69)	(-0.91)	(2.17)	-3.54^{**}		
i^2	-0.0004	-0.009	0.0004	-0.0005	-0.038	0.86	0.011	3
	(-0.07)	(-1.12)	(2.44)	(-0.98)	(-2.62)	(-1.65)		
π^3	0.01	-0.006	0.00007	-0.0003	0.006	0.84	0.010	2
	(2.05)	(-0.92)	(0.50)	(-0.69)	(0.55)	(-2.87)		

1 Sample 71Q1-87Q4 T_B=73Q1,79Q1,85Q2. T_B/T = 0.9
2 Sample 69Q1-87Q4 T_B=81Q3. T_B/T = 0.2
3 Sample 70Q1-87Q4 T_B=81Q3. T_B/T = 0.1

$$DC_t = \begin{cases} 0 & t \leq T_B \\ 1 & \text{otherwise} \end{cases} \quad DT_t = \begin{cases} 0 & t \leq T_B \\ T - T_B & \text{otherwise} \end{cases} \quad D(TB) = \begin{cases} 1 & t = T_B + 1 \\ 0 & \text{otherwise} \end{cases}$$

* and ** denote significance at the 1 per cent and 10 per cent levels respectively. $S(\epsilon)$ denotes the standard error of the regression.

Figure 1

Demand and Supply Shocks

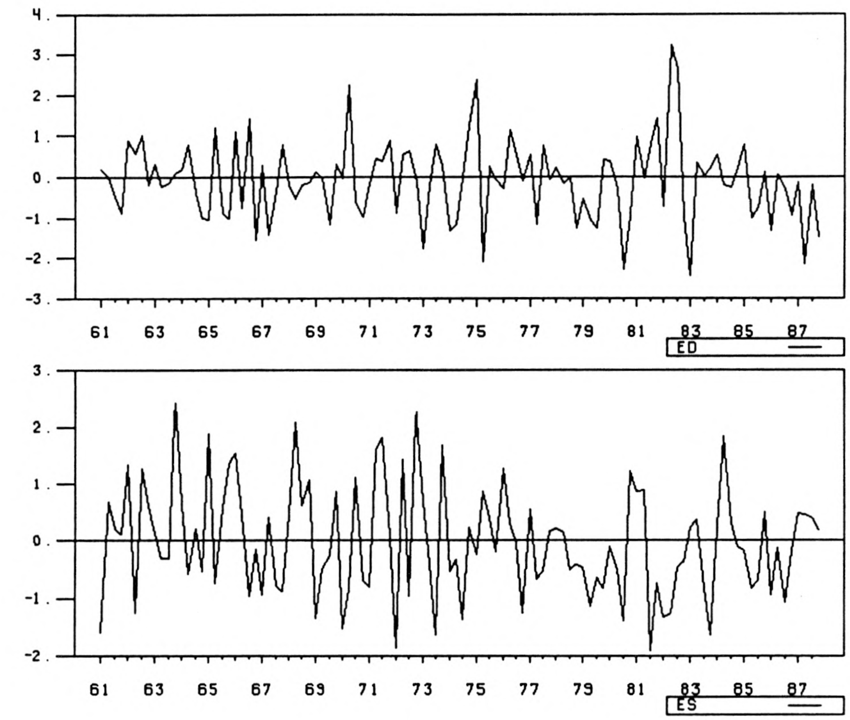


Figure 2

Output Fluctuations due to Demand and Supply Shocks

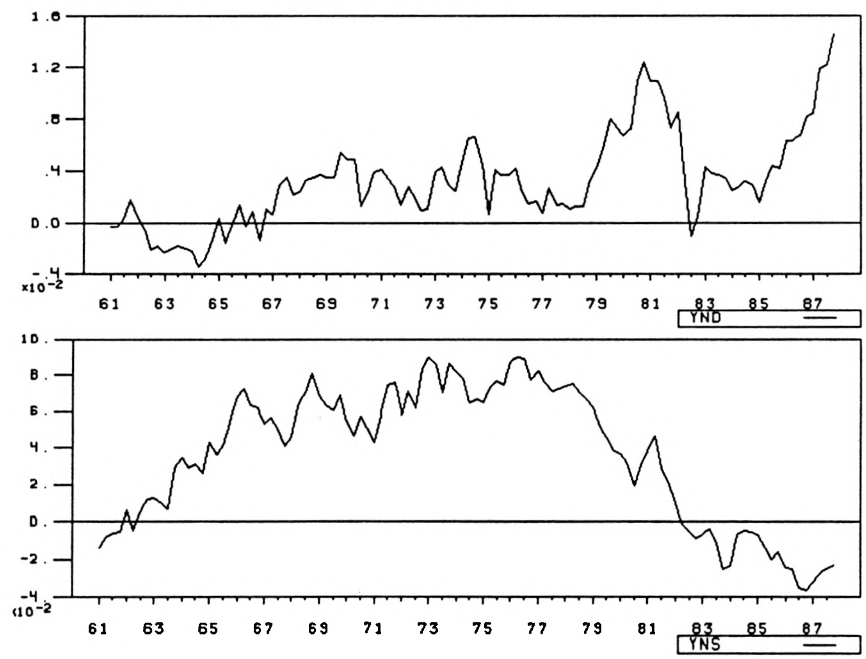


Figure 3

Unemployment Fluctuations due to Demand and Supply Shocks

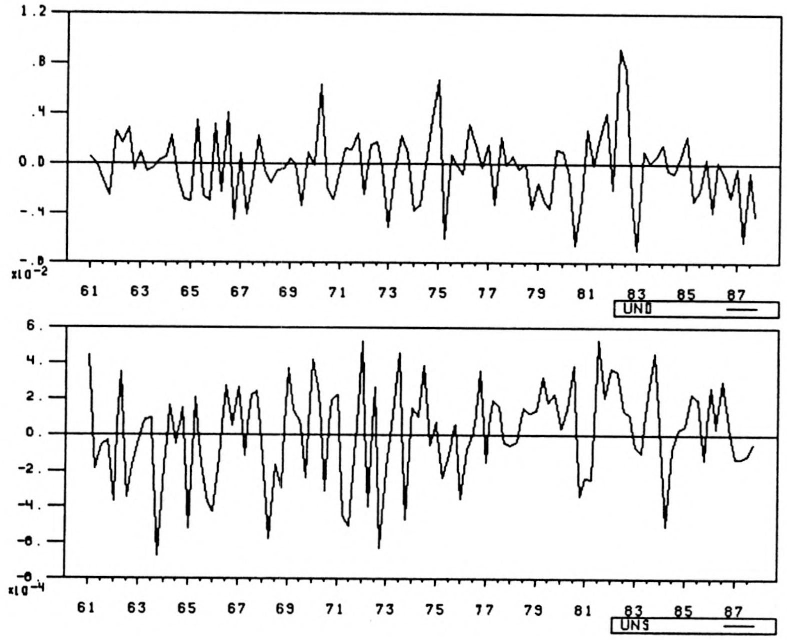


Figure 4

Dynamic Response of Output and Unemployment to Demand and Supply Shocks

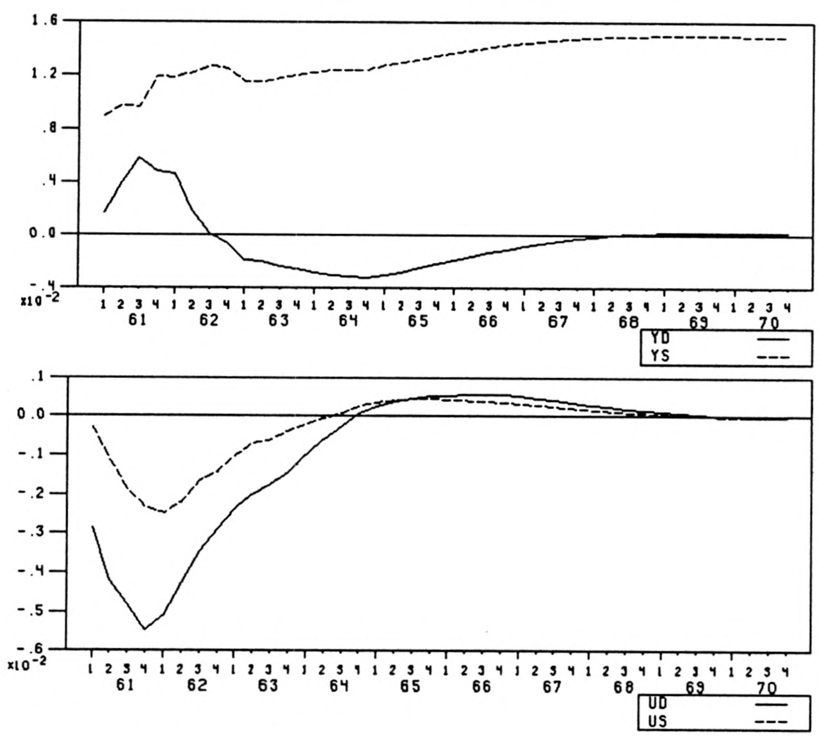


Figure 5

Labour Supply Shock

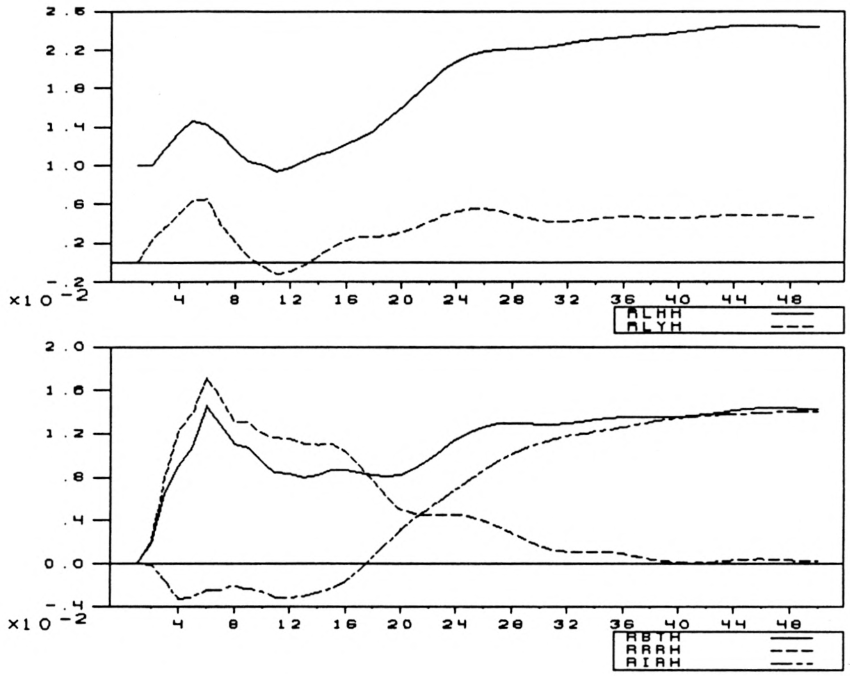
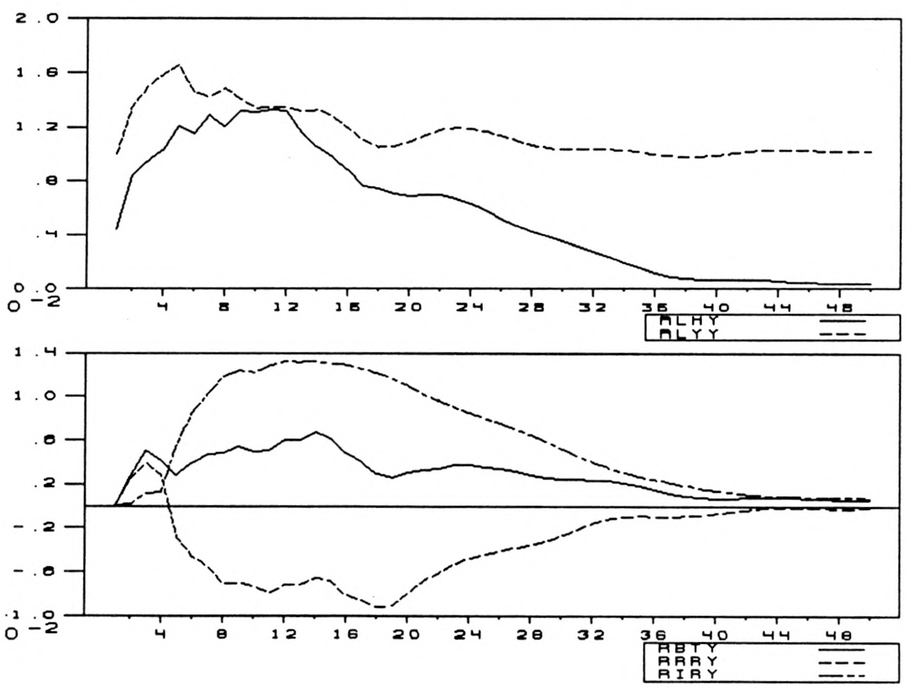


Figure 6

Technological Shock



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