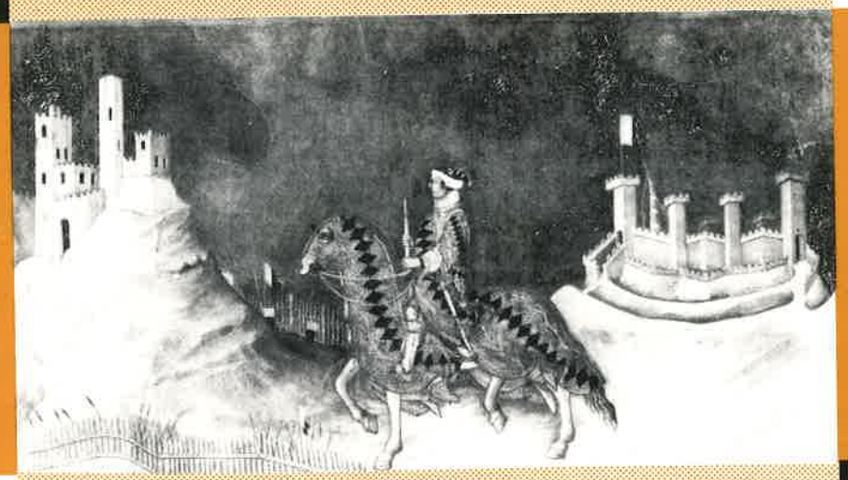
UNIVERSITA DEGLI STUDI DI SIENA

QUADERNI DEL DIPARTIMENTO
DI ECONOMIA POLITICA

Masanao Aoki
Riccardo Fiorito

ANALYSIS OF US REAL GNP AND UNEMPLOYMENT INTERACTIONS : STATE SPACE APPROACH



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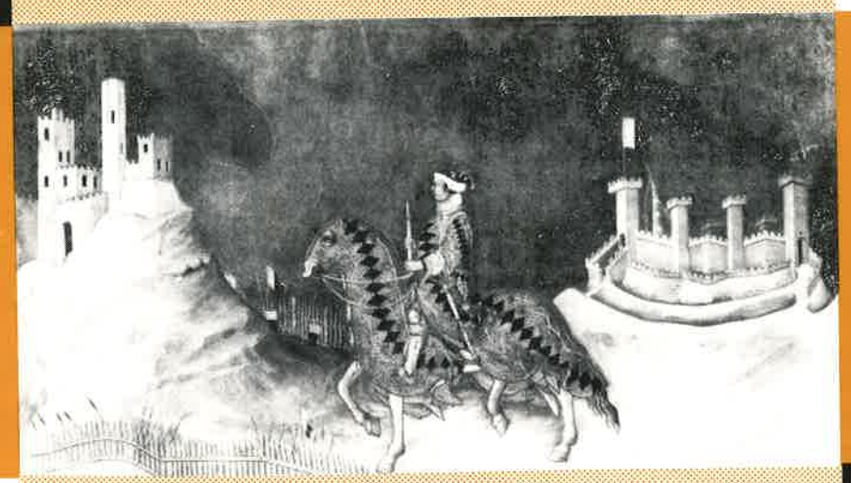

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ANALYSIS OF US REAL GNP AND UNEMPLOYMENT INTERACTIONS: STATE SPACE APPROACH

Siena, giugno 1991

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1. Introduction

Earlier studies of monetary policy effectiveness have mostly focused on dynamic responses of output and unemployment to changes in nominal stock of money. With the notable exception of Okun (1962), output and unemployment have usually been considered as symmetric responses to changes in environment, despite the fact that labor market was generally considered less flexible than good markets. Although different in perspectives and results, this literature regards the business cycles as co-movements among aggregate variables, which are possibly explained by movements in some structural factors. Economic fluctuations were usually treated as stochastic serially correlated disturbances around a deterministic trend or level which approximates some unobservable natural rate. Subsequent research inspired by ARMA modeling paid much closer attention to the sources of nonstationarity found in many economic variables (for example, see Nelson-Plosser, 1982), but business cycle analysis was confined to the univariate GNP series for which statistical tests were available.

Despite low power of the tests which could hardly discriminate between a unit and a near-unit root at .97, say, a number of studies came to advocate first differencing the series to achieve stationarity. This is hardly surprising because univariate unit root dynamics lack econometric identification, and because quite different or conflicting explanations of the same stochastic process may be offered. One one hand, Nelson and Plosser (1982) have, for example, shown that if GNP follows a random walk then short-run swings account for a minor portion of the overall variance, as required by real business cycle theory which emphasizes innovations in technology. On the other hand, Campbell and Mankiw (1987) interpret the unit root in real output as an argument against the natural rate view. Presence of unit root(s) implies that fluctuations are not only long lasting but also are persistent: for example, 1^{40} is 1, while $.97^{40}$ is less than one third of the original shock. Regardless of the power of the tests, it is obvious that in the univariate GNP series parameter estimates can be seriously biased unless GNP is totally independent of other variables.

Thus, construction of VAR models which jointly model GNP with other main economic variables is a natural step to extend business cycle analysis from univariate GNP behavior to a set of macroeconomics variables as are state space models (Aoki, 1987), either because they provide more realistic multivariate analysis or because, unlike one-period ahead prediction errors, innovation sequences account for differences in short and long-run responses. Both approaches lack, however, econometric identification and this makes it difficult to test for alternative explanations of the economy. In particular, VAR results are sensitive to the way by which non-stationarity series are detrended (see Eichenbaum-Singleton, 1986; Fiorito, 1988). State space models do not suffer from this difficulty in principle. Models may have different representations, constraining the state vector to have a unit root as in Clark, 1987, or allowing for a more general dynamics as in Aoki, (1988a).

The purpose of this paper is to investigate whether unemployment in the US may be explained by co-movement in output only, for example as in Evans, (1987) and Blanchard-Quah, (1988), or it can also be affected by monetary shocks. Moreover, we want to ascertain whether output and unemployment respond symmetrically to demand and supply disturbances i.e. whether Okun's law still holds in the US when supply factors and money are introduced. A simple structural model is used to identify supply, demand and monetary disturbances in a state space innovation model. Unlike Beveridge-Nelson, (1981), cycle and trends are not treated separately but are related through a two-step procedure (Aoki, 1989a) where short-run fluctuations can affect long-run behavior. Cycles and trends are also treated as not independent in Prescott (1986); the business cycle is considered in his work as a short-run adjustment to exogenous shifts driven by real, i.e, supply side forces only, however. Cycles here are obtained as residuals from the first stage of the state space modeling, which lets the algorithm to select the magnitude of the roots, or possibly, of the common stochastic trends. As required by a business cycle definition, residuals of the first stage do not need to be white and actually display cross and serial correlation, which is modeled in the second stage to produce a vector-valued innovation process. The residuals obtained in the second stage should be serially uncorrelated but possibly mutually correlated. Instead of adopting -- as in standard VAR practice -- an arbitrary, i.e., non-unique Choleski decomposition, we utilize identifying restrictions of the contemporaneous shocks to evaluate the dynamic response of the economy to its structural disturbances.

The paper is organized as follows. Section 2 describes a new detrending procedure used in this paper. Section 3 posits the structural model to identify structural innovation to be used in multiplier analysis. The estimated state space model is presented in Section 4 and 5. Responses of the estimated model to various structure shocks are discussed in Section 6 with and without money in the model. The paper concludes with Section 7.

2. State Space Representation for Trends and Cycles *

Suppose that the data series have rational spectral density and that the dynamics of linear time-invariant data-generating process is such that all the eigenvalues of the dynamic matrix A are not greater than one in magnitude. We collect all eigenvalues of magnitude greater than some critical value ρ into one class, C_1 as representing slower or longer-run dynamic modes, and the rest into the other class C_2. When there is a clear gap between these two classes of eigenvalues, the exact value of ρ does not matter. For example, suppose that there is no eigenvalue of magnitude between .89 and .97. Then any value of ρ between .89 and .97 will classify all the eigenvalues into two mutually exclusive classes.

* This section is based in part on Aoki (1988, 1989a)

We next construct aggregate state vectors and their dynamic equations by introducing a set of basis vectors which spans the right invariant subspace of the matrix A associated with the eigenvalues in C_1, and another set of basis vectors to span the left invariant subspace of A associated with the eigenvalues in C_2. This particular association yields what we call common mode dynamic representation † of longer-run or slower-moving components of the data series. Suppose that there are k eigenvalues of Class 1. Then let P be $n \times k$ such that

$$AP = P\Lambda$$

where

$$P'P = I_k \quad ,$$

and S be $n \times (n-k)$ such that

$$S'A = NS'$$

where

$$S'S = I_{n-k} \quad .$$

Note that $S'P = 0$. Then, the original state transition equation for an n-dimensional state vector, z_t, becomes in the new coordinate system

$$z_t = Ps_t + Sf_t$$

i.e.,

$$s_t = P'z_t$$

and

$$f_t = S'z_t$$

are the two aggregate (sub-) state vectors; the vector s_t representing slow modes and f_t representing fast modes. From the dynamic equation $z_{t+1} = Az_t + Be_t$, they evolve with time according to

$$\begin{bmatrix} s_{t+1} \\ f_{t+1} \end{bmatrix} = [P, S]^{-1} A [P, S] \begin{bmatrix} s_t \\ f_t \end{bmatrix} + [P, S]^{-1} Be_t$$

noting that

$$[P, S]^{-1} = \begin{bmatrix} P' \\ S' \end{bmatrix}$$

the dynamic equation becomes

† If the opposite assignment is made, we obtain an error-correction model representation in the sense of Sargan (1964) of the original state space model. See Aoki (1988c).

$$\begin{bmatrix} s_{t+1} \\ f_{t+1} \end{bmatrix} = \begin{bmatrix} \Lambda & P'AS \\ 0 & N \end{bmatrix} \begin{bmatrix} s_t \\ f_t \end{bmatrix} + \begin{bmatrix} P' \\ B' \end{bmatrix} Be_t \tag{1}$$

which is related to the data vector by

$$y_t = CPs_t + CSf_t + e_t \tag{2}$$

Eq. (2) expresses the data vector as the sum of the slow modes, fast modes, and the innovation vector, and (1) is the recursive representation of the dynamics. If there is only one eigenvalue close to one, then λ is that eigenvalue. Then s_t is a scalar-valued "trend" term. If $\lambda = 1$, then s_t is a random walk term. (The residuals are weakly dependent.)

A practical procedure to produce the representation (2) is to use the algorithm described in Aoki (1987) in two steps.* We describe the procedure for the case in which there is one eigenvalue λ near 1. To eliminate the effects of nonzero initial condition, we normalize each component of the data vector by its initial value and take its logarithms, if all components of the data vector seem to be trending. If not, only those trending components are treated this way.

Let y_t be the data vector, thus properly scaled. The first stage of the algorithm builds a model:

$$y_t = C\tau_t + w_t$$

$$\tau_{t+1} = \lambda\tau_t + r_t$$

where τ_t is a common "trend" term (the s_t variable in (2)), and w_t is the residuals. The series r_t is the residual $\tau_{t+1} - \lambda\tau_t$, where λ is estimated from $\{\tau_t\}$.

Since the variable τ_t removes the effects of the slower modes which contribute to "nonstationary" appearance of the series, the residuals w_t should be weakly stationary.

Let $\bar{w}$ be the sample mean of w_t. The $w_t - \bar{w}$ is modeled again by the algorithm which produces

$$w_t - \bar{w} = Hx_t + e_t \tag{3}$$

$$x_{t+1} = Fx_t + Ge_t$$

and where e_t is the innovation in w_t. Using L^{-1} as the lead operator, as in $L^{-1}\tau_t = \tau_{t+1}$, the transfer function from e_t to w_t is given by (ignoring the $\bar{w}$ term) $I + H(L^{-1}I - F)^{-1}G$. This is the closed form expression for the shorter-run multiplier. The infinite series in L is the Wold decomposition for w_t.

*An improved way of extracting a common trend series is mentioned in Aoki (1990). Alternatives are discussed in Phillips and Hansen (1990) or Park and Phillips (1988, 1989).

The variable τ_t captures the slow dynamic modes (trend) (if such exists) common to the component series in the data vector y_t. The matrix C distributes or disaggregate these modes (trends) to individual series. Therefore the residuals $r_t = \tau_{t+1} - \lambda\tau_t$ is related to the innovation vector e_t in w_t by $r_t = \phi x_t + be_t$ with some ϕ and b.

The transfer function from w_t to y_t is written as

$$y_t = w_t + \frac{C}{L^{-1} - \lambda} r_t \quad .$$

Jointly, we express y_t as

$$y_t = C\tau_t + Hx_t + \bar{w} + e_t$$

and

$$\begin{bmatrix} \tau_{t+1} \\ x_{t+1} \end{bmatrix} = \begin{bmatrix} \lambda & \phi \\ 0 & F \end{bmatrix} \begin{bmatrix} \tau_t \\ x_t \end{bmatrix} + \begin{bmatrix} b \\ G \end{bmatrix} e_t .$$

The total or joint multiplier is obtained as

$$\left[I + \frac{Cb}{L^{-1} - \lambda} \right] + (H + \frac{c\phi}{L^{-1} - \Lambda})(L^{-1}I - F)^{-1}G$$

which can be expressed as the sum of the long-run multiplier $I + \frac{C\phi(\lambda I - F)^{-1}G}{(L^{-1} - \lambda)}$ and the short-run multiplier $[H - C\phi(\lambda\tau - F)^{-1}]\,(L^{-1}\tau - F)^{-1}G$

3. The Structural Model

Let a non-stationary data vector y be modeled by

$$A_0 y_t = A(L)y_t + \eta_t \tag{4}$$

where η_t is a vector of structural disturbances. This structural model is decomposed into a contemporaneous part, A_0, and an unrestricted dynamic part, $A(L) = A_1 L + A_2 L^2 + \cdots$, where $L^j Y_t \equiv Y_{t-j}$. Usually A_0 is a sparse matrix whose zero restrictions are guided by economic theory. When $A_0 = I_n$ the model is a VAR which can be identified as shown by Bernanke (1986) and Sims (1986).

This procedure can be generalized to the two-stage state-space model described in section 2 without confining Λ in (1) to be a scalar. Note first that the reduced and final form of the model are:

$$y_t = A_0^{-1}A(L)y_t + A_0^{-1}\eta_t$$

and

$$y_t = [I - A_0^{-1}A(L)]^{-1}A_0^{-1}\eta_t \equiv Z(L)\eta_t \quad , \quad Z_0 = A_0^{-1}\eta_t \quad .$$

Assuming that structural disturbances are uncorrelated, the covariance matrix $E(\eta\eta') = \Sigma$ is diagonal while the covariance matrix of the unrestricted state space model $E(ee') = \Omega$ will generally be non-diagonal. Structural disturbances are related to the innovations in η_t through the relation*

$$\eta_t = A_0 e_t \quad , \tag{5}$$

and hence the covariance Σ is related to the innovation covariance matrix by

$$\Sigma = A_0 \Omega A_0' \quad . \tag{6}$$

Since Ω has $p(p+1)/2$ distinct elements where $p =$ dim y_t, we need to impose $p(p-1)/2$ zero restrictions on the off-diagonal terms of A_0 since its diagonal terms may be taken to be one.

Let us now formulate our structural model as follows:

$$U_t = -\alpha_{12}GNP_t + lags + \eta_{1t} \quad \textit{(Aggregate Supply)} \tag{7}$$

$$GNP_t = -\alpha_{21}U_t + \alpha_{23}M_t + lags + \eta_{2t} \quad \textit{(Aggregate Demand)} \tag{8}$$

$$M_t = lags + \eta_{3t} \quad \textit{(Money Feedback Rule)} \tag{9}$$

where U, GNP and M denote respectively unemployment level, real GNP and nominal money stock (M1). All coefficients are positive*. Here $p = 3$ and the model is just identified. The level of unemployment U_t measures the excess supply of labor in unit of workers:

$$U_t \equiv L_t^s - L_t^d \quad .$$

Aggregate supply of goods is inserted as Okun's equation, Blanchard (1989) Blanchard-Quah (1989). No parameter bounds required by Okun's law, i.e., $0 < |\alpha_{12}(1)| < 1$ is assumed. Unlike Okun's law, moreover, labor supply is allowed to vary over time

$$L_t^s = \varepsilon_{1t} \quad ,$$

where ε_{1t} reflects stochastic factors affecting both population and participation rates. Once labor demand is extracted from the linear, short-run, production function posited as

*Even when y_t is nonstationary (4) is the correct relation between e_t of (3) and η_t of (4).

* Actually the reported signs are those required in equilibrium. When current variables are conditional on dynamics, theoretical restrictions apply to $\alpha_{ij}(1)$ polynomials.

$$L_t^d = \alpha_{12}GNP_t + \varepsilon_{2t} \quad ,$$

it is apparent that η_{1t} is an unobserved component disturbance

$$\eta_{1t} \equiv \varepsilon_{1t} - \varepsilon_{2t}$$

which combines both labor supply and productivity shocks. Since these variables have opposite effects on the real wage we can consider the latter approximately constant. Thus price and wage equations are ignored. Similarly, aggregate supply takes the form of Okun's equation, and is independent of real wages.

These assumptions are made, of course, for the simpler analysis, yet may be expected to hold reasonably well for the US data. See Appendix 1, Table 1. The table shows that the real wage has a smaller variance than those of labor supply and demand.

Equation (8) is a condensed version of the IS-LM model. Aggregate demand is determined by consumption and investment components: consumption expenditure is affected mostly by the employment level - thus negatively by unemployment - while investment expenditure depends inter alia on interest rates, thus on the nominal money stock. Fiscal and monetary shocks are captured by η_{2t} and η_{3t}, where the latter denotes unpredictable departures of the money stock from its predicted path.

Because of information lags, monetary policy, (9), is assumed not to react to contemporaneous shocks in GNP or unemployment. Money does not affect contemporaneously the supply equation because of time-to-build argument, i.e., time-to-hire new workers in this paper.

Lacking an interest rate equation, we can not separate out money supply from money demand disturbances†. Similarly, participation and productivity shocks can not be disentangled in the supply side. Despite this, we decided to keep the model in the present form in order to have a direct comparison with the output/unemployment studies in the literature where typically no money is introduced and only casual attention is paid to detrending.

We solve (6):

$$\sigma_1^2 = \Omega_{11} + 2\alpha_{12}\Omega_{12} + \alpha_{12}^2\Omega_{22} \quad ,$$

$$\sigma_2^2 = \alpha_{21}[\alpha_{21}\Omega_{11} + \Omega_{12} - \alpha_{23}\Omega_{13}] + \Omega_{22} + \alpha_{21}\Omega_{12} - \alpha_{23}\Omega_{23}$$
$$- \alpha_{23}[\Omega_{23} + \alpha_{12}\Omega_{13} - \alpha_{23}\Omega_{33}] \quad ,$$

$$\sigma_3^2 = \Omega_{33} \quad ,$$

† This issue is specifically addressed by Ghali (1989).

$$0 = \Omega_{13} + \alpha_{12}\Omega_{23} \quad ,$$

$$0 = \alpha_{21}\Omega_{13} + \Omega_{23} - \alpha_{23}\Omega_{33} \quad ,$$

$$0 = \alpha_{21}(\Omega_{11} + \alpha_{12}\Omega_{12}) + \Omega_{12} + \alpha_{12}\Omega_{22} - \alpha_{23}(\Omega_{13} + \alpha_{12}\Omega_{23}) \quad .$$

The data of the model come from OECD sources (Main Economic Indicators, Paris, several years). The relevant variables are unemployment, real GNP and nominal money stock (M1) in the US, all expressed in levels. The data are quarterly, seasonally adjusted, and ranged from 68:1 to 88:4.

4.0 Stochastic Trends and Related Cycles

The first stage of the model has been estimated taking one-dimensional state vector ($n = 1$) and selecting a Hankel matrix ($J = K = 1$) to describe the autocovariance of the observation vector. The one dimensional state was selected because of the ratio between the first and second singular value (30.3) is large enough to justify retention of the largest eigenvalue (.986) as the nearly-integrated root of the state vector. The choice of the Hankel matrix dimension can not be tested precisely but much depends on the desired smoothness of the multiplier profile and on the sample size. In the first stage, an excessively high value of K should be not selected to avoid an overfit of the stochastic trend to the observed non-stationary variables. The multiplier results and the same shape of the trends were, however, robust to the change of K which was then fixed to be 1.

A common stochastic trend found for unemployment, money, and GNP (see Fig. 1) could seem a bit puzzling, given the expected negative relation between unemployment on one hand and money and GNP on the other: but this is not the case because our variable is not the unemployment rate as in previous studies (Evans, 1987; Blanchard-Quah, 1989), but the unemployment level whose trend both reflects increases in population and in participation rates†.

The first stage parameters are:

$$\lambda = .986 \quad , \quad B = [.756 \quad .326 \quad .369] \quad , \quad C = \begin{bmatrix} .828 \\ .296 \\ .777 \end{bmatrix}$$

The stochastic trend dynamics is disaggregated by the elements of matrix C which are about .8 for unemployment, and nominal money; and about .3 for real GNP. Thus unemployment growth tends to be substantially higher than the GNP growth, by a ratio which is not too far from the one found in Okun's law even though here there is a co-movement

† Presumably, these studies have selected the unemployment rate because it is much "closer" to being stationary than the unemployment level. This fact reflects, of course, also the non-stationarity of the labor supply in the US (See Table 1, Appendix 1). In the sample period the participation rate in the US is raised by 0.60 in 1968 to 0.66 in 1988. Meanwhile, the working age population is increased by an annual rate of about 1.5%.

instead of a negative relation and even though this co-movement should not be interpreted cyclically.

If one considers these trends as a long-run stochastic equilibrium path, it may be observed that real output growth is approximately 1/3 of the money growth, suggesting a rather steep aggregate supply curve or a situation not too far from long-run neutrality. First stage residuals are - as expected - both serially and mutually correlated *. In all cases the white noise hypothesis is rejected by Box-Ljung test (B27) but also a cursory view at the sample autocorrelation functions reveals a very slow tendency to decay.

Table 1 - Sample autocorrelations for cyclical residuals

Lags	1	2	3	4	5	10	15	20	27	B(27)
U	.87	.77	.65	.52	.43	.09	.02	.00	-.01	203.5
GNP	.92	.81	.66	.51	.36	-.11	-.17	-.09	.10	218.4
M1	.94	.86	.77	.67	.57	.18	.04	.01	.00	292.9

The correlation between residuals (See Table 2) is always high and consistent with the expected signs at a zero lag; unemployment is negatively correlated with nominal money (-.89) and GNP (-.88). M1 and GNP are positively correlated (.93). In terms of the traditional leading indicator approach, it may be of interest to look at the cross-correlations at several leads and lags even though they should not be interpreted in terms of temporal causality because residuals are not white.

Unemployment and money disturbances display, however, the strongest negative correlation at the first few leads of unemployment. Since forcing variables must occur before their effects, one could interpret this fact in terms of an inverse association between money and unemployment changes a few periods later. Conversely, when unemployment disturbances precede those of M1 there is also a short-run negative correlation which suggests a possible trade-off between unemployment and money.

* Looking at variability (i.e. standard deviation scaled by arithmetic mean), GNP residuals are found to be much more volatile (110.1) than those of M1 (15.6) and unemployment (3.1).

Table 2

Leads (-) and lags correlations between cyclical variables (68:3 88:4)

LAGS (*)	UNEMPLOYMENT/MONEY	UNEMPLOYMENT/GNP	MONEY/GNP
-20	.04 .04 .03 .03 .03 .03	.03 .03 .04 .05 .07 .09	.02 .03 .03 .02 .01 .00
-14	.00-.03-.07-.12-.16-.22	.09 .07 .04 .01-.03-.09	-.01-.02 .00 .01 .05. 09
-8	-.31-.40-.51-.61-.72-.80	-.18-.29-.41-.53-.66-.77	.15 .23 .32 .42 .53 .64
-2	-.87-.91-.89-.79-.68-.58	-.87-.92-.88-.76-.61-.48	.75 .85 .93 .87 .79 .68
4	-.49-.40-.32-.26-.22-.17	-.35-.24-.14-.07-.03 .00	.56 .44 .33 .23 .14 .08
10	-.14-.12-.10-.09-.09-.09	.02 .05 .07 .07 .07 .06	.02-.02-.08-.11-.13-.13
16	-.08-.08-.07-.04-.01	.06 .06 .06 .06 .07 .07	-.13-.13-.13-.12-.11

Similarly, the cross-correlations between unemployment and real GNP seem to be two-sided and stronger in the first few quarters while M1/GNP association appears to be still two-sided but fairly positive in the short-run and mostly negative when the number of the lags is increased.

5. Selecting the Second Stage

The second stage model aims at an accurate tracking of the business cycle, i.e. of the residuals from first stage. Since the quality of the model depends on the statistical properties of second stage innovations - which is the innovation of the first stage residuals - a sequential procedure from the first to the second stage is adopted. Given the long transmission periods of economic shocks, it is reasonable to believe that the dimension of the Hankel matrix should not be too small. The dimension of the state vector of the second stage (i.e. of F-matrix), was found by using a reformulation (Aoki, 1989b) of a test suggested by Bartlett. Sensitivity analysis lead us to select a value of 3 for K and 2 for n. The estimated matrices are then:

$$F = \begin{bmatrix} .869 & -.123 \\ .154 & .776 \end{bmatrix} \quad ; \quad \lambda(F) = 0.822 \pm j.130$$

$$G = \begin{bmatrix} 4.820 & -4.648 & 6.078 \\ -.871 & 1.871 & -17.792 \end{bmatrix} \quad ; \quad H = \begin{bmatrix} .111 & -.015 \\ -.175 & -.041 \\ -.064 & -.003 \end{bmatrix}$$

This model of the second stage produces both a vector of serially uncorrelated innovation and an accurate prediction of the first stage residuals.

* Negative lags are leads. "Lags" denotes the correlation between the first series and the second at the given lag.

6. Responses to Structural Shocks

6.1 Real Shocks Only

When we drop money and model only unemployment and real GNP series, the structure of the identification is essentially that of the Choleski decomposition. To identify the structural shocks (θ_t) from the observed ones (e_t) it is necessary to have one zero restriction in the bivariate system:

$$\begin{bmatrix} e^u \\ e^{gnp} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} \\ a_{21} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \theta^s \\ \theta^d \end{bmatrix}$$

One way to achieve the condition of just identification is to assume in the contemporaneous model that unemployment depends on supply shocks only ($a_{12} = 0$); the other is to assume that GNP depends on demand shocks only ($a_{21} = 0$). Since the (identified) bivariate model is introduced here merely to illustrate how business cycles can be affected by the omission of a money variable, we investigate both cases without committing ourselves to a particular choice. Actually, the results of the two models were so similar to justify henceforth our reference to a bivariate case only.

Supply Shocks: When a supply shock occurs, unemployment displays a stronger response than GNP does (Fig. 3.1 - 3.2). The latter being a combination of labor supply and productivity, unemployment is expected to increase in the short-run. Actually, impulses are indeed long lasting both for unemployment and GNP. Moreover, unemployment response at its peak is higher than GNP, a fact which clearly is not compatible with static Okun's law.

GNP is reduced at the beginning because productivity takes time to affect activity. When this happens GNP is just slightly increased because it is not sustained by demand impulses. Then it decays slowly without producing those fluctuations predicted by real business cycle models.

Demand Shocks: In the short-run demand shocks are compatible with Okun's law since, at the initial peak value, real GNP rises more than the percentage by which unemployment is reduced (Fig. 4.1 - 4.2). However, GNP response is not sustained over time and almost vanishes in about 10 quarters. Conversely, unemployment is reduced by demand shocks just in the very short-run, being afterwards increased by its own dynamics and by GNP dampening.

Unlike previous studies (Blanchard-Quah, 1989), both demand and supply disturbances decay in the long-run. Similarly there is no confirmation that most real GNP fluctuations come from productivity shifts. These differences may depend in one case on the fact that our model does not constrain supply shocks to be persistent and in the other that supply shocks include also labor participation and demographic shifts which have no reason to be related to technology.

6.2 The Complete Model

Introducing money in the structural model, we evaluate how demand and supply disturbances affect variables in a nominal environment and which (if any) are the dynamic impulses transmitted by unanticipated money shocks.

The first implication is that supply shocks are still long lasting while demand shocks have a short duration. A second implication is the rejection of Okun's law even in the demand case since - unlike the bivariate model - unemployment reacts more than GNP. A third implications is that a money shock induces long-lasting fluctuations in GNP and especially in unemployment which - still in this case - is too responsive to be compatible with Okun's law. Finally, the (implied) price response seems to be faster and more flexible than that suggested by typical contract literature.

Supply Shocks

A supply shock has long-lasting effects on the economy. As in the bivariate model, in which money is ignored, there is no behavior consistent with Okun's law since unemployment is much more responsive than GNP. This is hardly surprising in view of the fact that supply shock arises also from labor sector, i.e., rising unemployment without increasing productivity.

Since increases in productivity can not entirely account for the gap between unemployment and GNP response, it appears that labor supply shocks are much more relevant than recognized by Okun's law which implies that unemployment depends on labor demand only. (Otherwise it is unwarranted to interpret the asymmetry between unemployment and real GNP in terms of increasing labor returns.)

In our experiment there is still an asymmetry. However it works in the opposite direction: as shown in Fig. 4, GNP has a rather small peak, being driven, as before, by demand forces. Since we can not disentangle shifts in supply for labor from productivity shifts, the transmission of the overall supply shock can only be tentatively interpreted: if labor supply and productivity shifts are approximately balanced, real wages should be fairly constant and productivity changes are mildly pro-cyclical. Conversely, if technology shocks prevail, productivity changes become more procyclical, and hence real wage rise and increasing returns have to be assumed.

In the US the latter interpretation has, perhaps, some relevance in manufacturing, where employment fluctuates much less than output. Certainly is not correct in an aggregate economy where the share of manufacturing employment is less than 20% of GNP (which should be then a more appropriate reference for an overall unemployment measure (Appendix 1, Table 1).

If labor demand fluctuates equally or even more than real GNP, then there is no longer a room for labor hoarding interpretation of aggregate employment swings; similarly, the view that increasing returns prevail cannot be accepted, which is a equivalent to Okun's law. In our simulations, while labor market seems to be more responsive to quantities than prices, the market for

goods appears to behave in the opposite way: inspecting money response to a supply shock (Fig. 4) we observe that not only money impulses are small but also they will lie below real GNP impulses. If M_1 is interpreted as a reaction function it seems that GNP, not unemployment, is the relevant target. In this case, however, no change in velocity should be considered to match the difference between real GNP and the nominal stock. Conversely, if M_1 traces back money demand response, all the difference between nominal stock and real GNP multipliers can not be attributed to prices because of changes in velocity [9].

In any case, the gap between nominal money and real GNP response is too large at the beginning of the shock to be reconcilable with the idea that prices are sluggish in the short run [10]. We could then conclude that a supply shock reduce prices to some extent as a result of a productivity increase. If labor supply also rises, a wage reduction is conceivable, which leaves, real wages substantially unchanged.

In this respect, it is well known that real wages in the US show not enough variability to justify wider fluctuations in labor quantities (Appendix 1, Table 1). Thus it is reasonable to attribute about the same weights to labor and productivity as sources of supply shocks. This assignment reduces the relevance of those explanations of business cycle that stressing the role of productivity [11] as ultimate and only source of economic fluctuations.

Demand Shocks

Demand shocks have a shorter span of effects; all impulses decay in about three years. As mentioned before, GNP is mostly driven by aggregate demand shocks and seems to be almost neutral to supply shocks. However, when money is introduced Okun's law does not hold any longer since unemployment response is still higher (Fig. 4) than GNP responses. Demand shocks affect both GNP and unemployment, but with different magnitude. Expenditure innovations affect production and hiring decisions. Additional employment exerts pressure on wages as higher level of demand does for prices.

Since labor supply remains approximately unchanged in this case, all the decrease in unemployment can be attributed to cyclical expansion. Thus, decreasing returns would prevail in aggregate, as a result of countercyclical changes in productivity.

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9 Velocity should increase, since it is generally accepted that the US has a positive but less than unity elasticity of money demand to real GNP (Goldfeld, 1973). Also, velocity increase should not be large because interest rates would barely react to such mild changes in demand for money.

10 This result is also found, but not discussed, by Ghali (1989) when a supply or an IS shock occurs.

11 Of course, there is a difference between labor and total factor productivity which can not be pursued in this model because we were not interested to introduce a capital shock equation.

As shown before, this explanation seems to fit well some typical features of US labor market such as:

- heterogeneity of workers

- large increase in labor supply

- union decentralization

- sectoral differences in terms of skill requirements

Worker heterogeneity is natural in an immigrant-based growth of labor supply where ethnic barriers can be loosened by working hard and cheap. Large systematic increase in labor supply would be more difficult to absorb unless new entrants are available for unskilled, cheaper, and non-permanent jobs. A spectacular increase in employment over the sample period did not occurred in manufacturing but in small, labor intensive, services (Appendix 1, Table 2) where unionization was weak, and in most cases skilled labor is not required.

Combining all these factors [12], it is reasonable to argue that non-manufacturing firms have a selective demand for labor which may suggest an analogy with LIFO inventory accounting: secondary workers are utilized when the economy faces a boom and it becomes difficult to further increase the efforts of primary workers at hand. Worked hours in manufacturing are, indeed, much less volatile in the US than in Europe where, the employment stock is usually a hoarded variable. Thus, secondary workers are not only the last to be hired (Last-In), they also are the first to be fired (First-Out) when a recession starts since the adjustment in per capita worked hours (Appendix 1, Table 1) is not flexible enough to match the actual or predicted slack in demand. This adjustment pattern also produces a counter-cyclical productivity pattern since LIFO-type workers are generally less skilled than primary workers and try then to offset a lower productivity with a lower reservation wage.

We can then conclude that our results for unemployment are very reasonable since US stylized data can not be explained by a labor hoarding -- Okun's type story. In turn, the same data are very easy to accommodate in a LIFO model of labor force utilization where secondary workers act as a buffer stock again unexpected demand changes.

Turning now our attention to money response, a reaction function seems more plausible than an exogenous shift in demand because a nominal stock of money responds less than the real GNP one in a situation where demand for cash balances should naturally increase. Since the structural model assumes that a reaction function is not utilized instantaneously, the gap between nominal stock and real GNP may be understood in terms of the policy goal to disinflate the economy when both unemployment is (largely) reduced and demand is increased

12 A good reference is Doeringer's and Piore's (1971) analysis of dualistic labor markets. The correspondence between selective demand for labor and counter-cyclical productivity pattern was first developed by the late Ezio Tarantelli in an article written in Italian (Produttivita del Lavoro, Salari e Inflazione, Ente Einaudi, Roma, 1970).

Money Shock

The most striking effect of a monetary shock is a large and quick response of unemployment. Decrease in M_1 by a unit causes unemployment to overshoot which reaches a peak value (1.6) after six quarters. Then it decreases at a slowering rate before decaying to zero. The observed shape of money innovations seems to suggest some sort of self-adjusting pattern, as if the Fed would consider it too risky to sustain the original shock.

Comparing these results with those obtained in the bivariate model, one could be tempted to say that introducing money is at least worthwhile in order to show its ability to alleviate unemployment in the short-run. Yet, a convincing story for this success has to be told. A possible story is that money contraction causes a rise in the real interest rate which increases unemployment because of intertemporal substitution in labor supply (Hall, 1980). An increase in the real interest rate seems, indeed, to be justified by the fact that a monetary contraction raises the nominal rate, while prices are again reduced by a negative surprise in M_1 (Fig. 7).

However, intertemporal substitution effect on unemployment seems too large to be true when compared with previous studies and also because that the corresponding IS effect of real GNP is much weaker. Actually a negative innovation in M_1 produces in a very short-run an increase in the level of activity which is difficult to understand. A tentative explanation could be that aggregate demand is dominated by consumption expenditure for which a price reduction may be more stimulating than a real rate increase is depressing for investment. The rationale behind this explanation could be that consumption decisions are much more short-sided than investment and labor supply are. But this is very difficult to justify if the agents utilize the same optimization framework, while it can not explicitly evaluated on empirical grounds unless a fully specified model is provided.

Thus, quick and large effects of monetary shocks on unemployment is still a piece of empirical evidence searching for a comprehensive explanation.

7. Conclusions

In this paper we apply a two-stage state space approach (Aoki, 1988) to estimate a structural model for unemployment, real GNP and M_1 in the US. While the model is in the spirit of the so-called structural VAR approach as in Bernanke (1986), Sims (1986), the state space model is utilized to extract stochastic trends from non-stationary data, without constraining the series to have one or more unit roots. Cyclical variables, which are modelled in the second stage, do not have persistent response to innovations.

A few constraints introduced in the model are economic rather than statistical in nature, which are designed to relate estimated innovations to corresponding set of structural disturbances.

Traditional models to explain output and unemployment are then reconsidered by introducing money. This produces an IS-LM model in which Okun's equation provides an aggregate supply schedule and a nominal stock enters as a delayed reaction function because of information lags. As Blanchard-Quah (1989), Okun's law is a mongrel of supply and demand schedules and are difficult to isolate in the original formulation. However, their evidence still supports Okun's law in a framework where aggregate supply shocks are constrained to be permanent while demand shocks obey long-run neutrality.

We find that Okun's law behavior applies solely to short-run demand disturbances in a bivariate real model without money. When money is introduced, Okun's law does not hold any longer; unemployment is always more responsive than real GNP. This result is very robust in our simulations and fully conforms to high variability of employment and labor supply found for the US economy rather than in Europe.

However, a refutation of Okun's law requires also a reconsideration of labor hoarding as a suitable story to explain (the lack of) labor market fluctuations. Even though a mild procyclical productivity is usually found in manufacturing, labor force share in services is overwhelming and the aggregate labor productivity is, therefore, counter rather than procyclical. This is a very reasonable statement, considering how segmented is the US labor market and how frequent are supply shocks from large waves of new entrants, both characterized at the beginning by lower productivity and reservation wages.

Unemployment also responds to monetary innovation, presumably through changes in the real rate as implied by intertemporal substitution models. This version, however, neither requires money neutrality in the short-run nor assumes that firms' labor demand has to accommodate any increase in labor supply. Indeed, this is presumably the main reason why money impulses affect negatively unemployment in the short-run. In particular, the effect of money shock on unemployment is higher than the one found for real GNP, which is mostly stimulated by shocks in aggregate demand. Thus, real GNP is mostly driven - as in Keynesian models - by transient shifts in fiscal policy, and is less responsive to supply disturbances not sustained by demand stimuli.

Money effects on real GNP have no clear-cut interpretation, except that they contribute more than other disturbances to its fluctuations. The difficulty is due in parts to the fact that we can not disentangle money supply effects from demand effects in our small facilitate model. The difficulty is also due to our choice made to facilitate comparisons with previous studies of M_1 as the relevant money stock i.e. of a variable which is far less controllable than other instruments of monetary policy.

Finally, we mention some additional, but not minor, results that deserve, perhaps, some future research:

- All innovations decay in the long-run. Demand shocks decay first, while money and aggregate supply innovations are indeed long-lasting even if they do not persist in any technical sense.

- Prices display in the short-run a degree of flexibility which is higher than expected

Indeed, these results are obtained implicitly since our model does not have a price or a wage equation. However, nominal responses are always below those of real GNP. Even accounting for changes in velocity, still it remains to be explained why the gap is wider at the beginning rather than at the end of the impulse.

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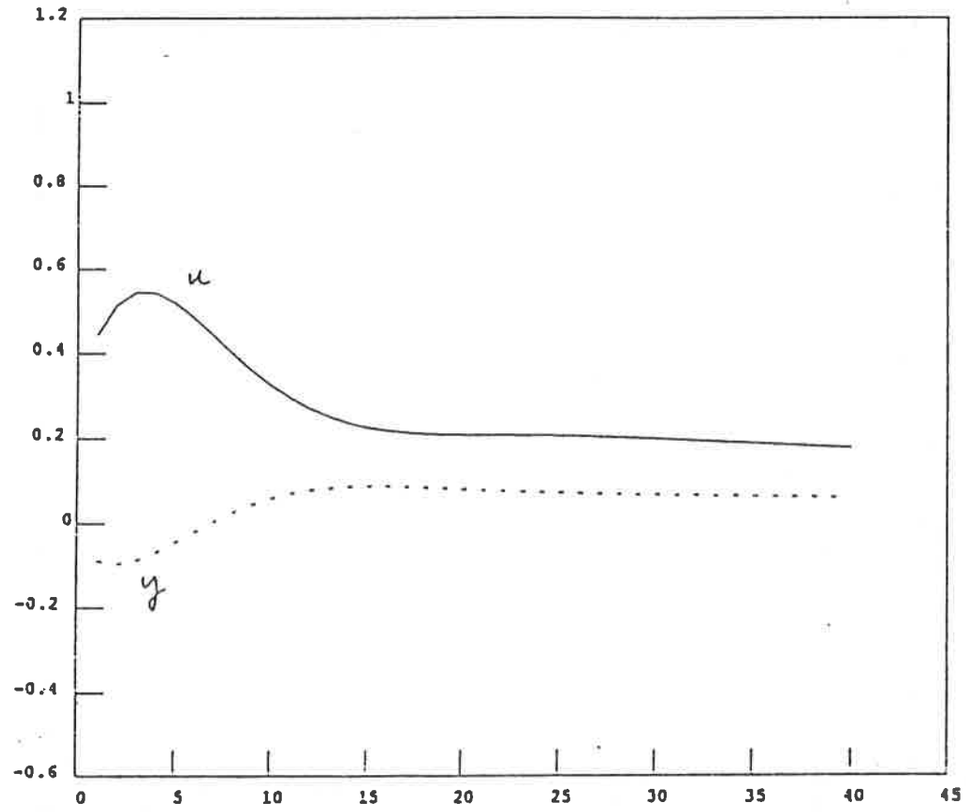
Fig 3.1 Aggregate Supply Shock



Time

Fig. 4.1 Aggregate Demand Shock

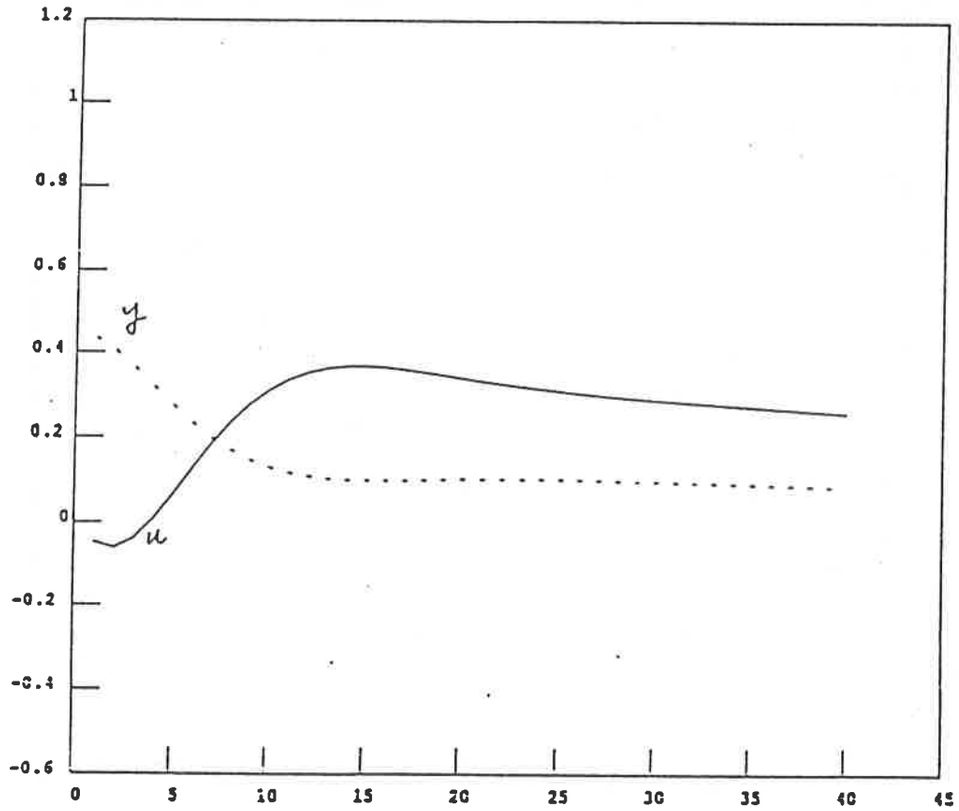


Fig. 5 Aggregate Supply Shock

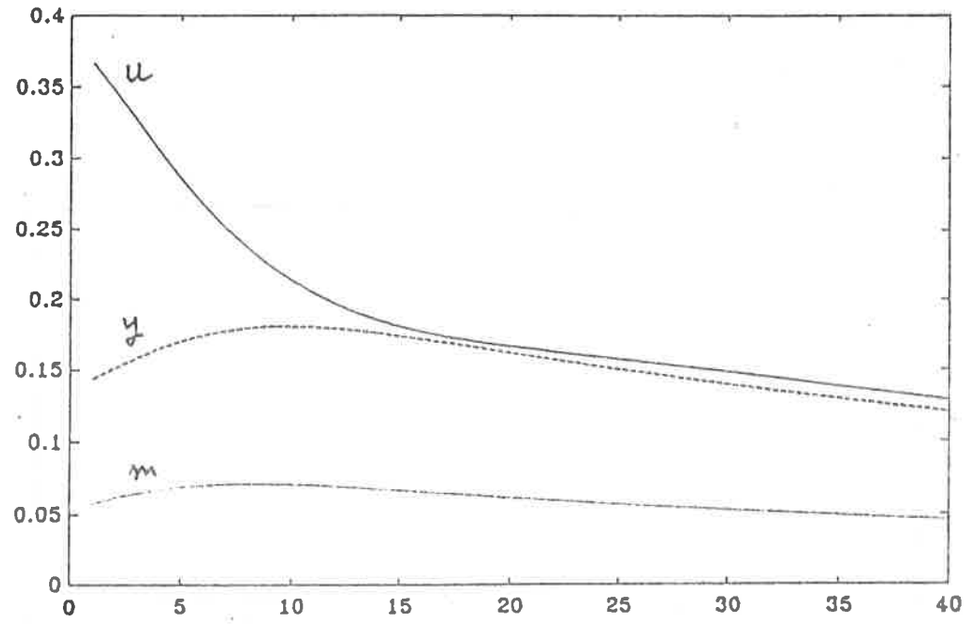


Fig. 6 Aggregate Demand Shock

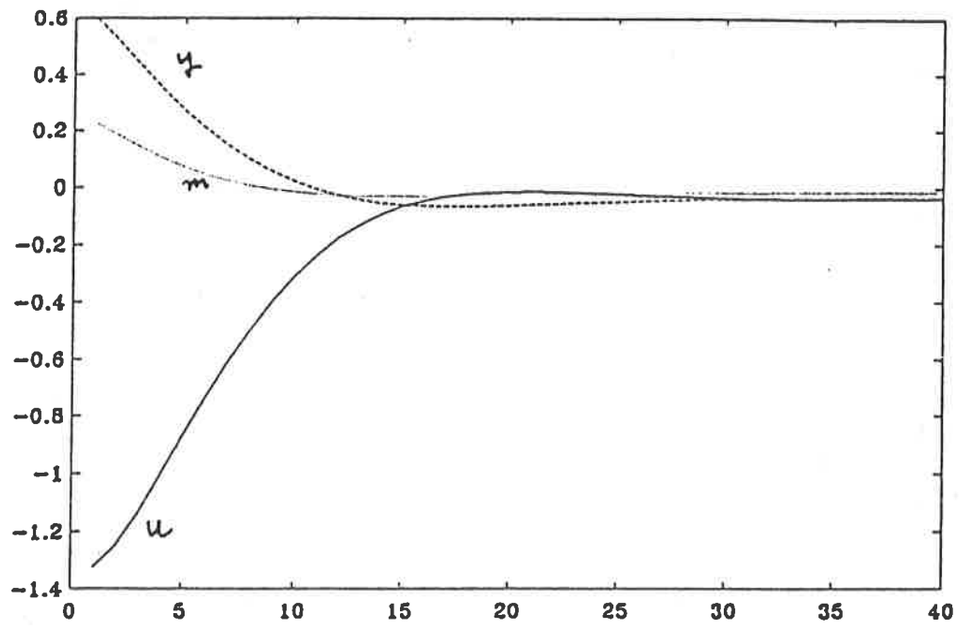
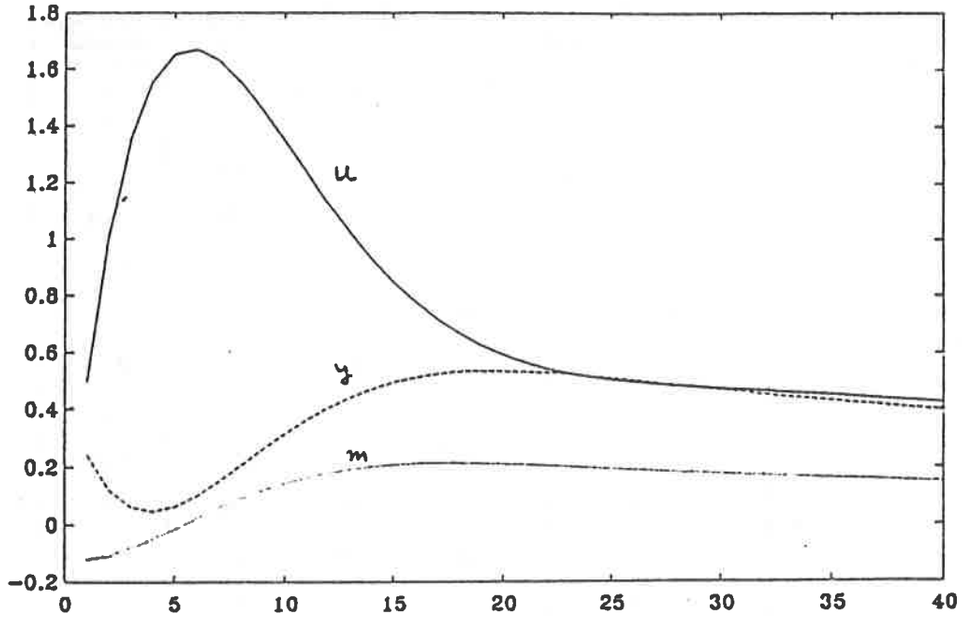


Fig. 7 Money (negative) Shock



Appendix 1 - Stylized Facts

Table 1 - Summary Statistics on Selected Variables (1968-88)

	Variability(*)	Autocorrelation at year 1	2	3	Average Annual Growth
GNP	0.16	.83	.67	.51	2.7
L	0.13	.85	.70	.56	2.1
π	0.03	.75	.55	.34	0.6
L_m	0.04	.45	-.16	-.31	0.0
H_m	0.01	.45	-.03	-.11	0.0
L_r	0.16	.84	.69	.53	2.8
LF	0.14	.86	.73	.59	2.2
U	0.33	.79	.52	.36	6.1
U_r	0.25	.67	.26	.09	-
W_m	0.39	.89	.77	.63	6.3
CPI	0.40	.91	.82	.72	6.3
RW_m	0.03	.69	.24	.00	0.0

(*) Standard deviation scaled by arithmetic mean
Source: OECD, Main Economic Indicators, seasonally adjusted

Legenda: (1) GNP: Real GNP at 1982 prices
(2) L : Civilian Employment
(3) π : Labor productivity = (1)÷(2)
(4) L_m : Employment in Manufacturing
(5) H_m : Weekly hours per worker in manufacturing
(6) L_r : Non-manufacturing employment = (2)-(4)
(7) LF : Civilian labor force
(8) U : Level of Unemployment
(9) U_r : Unemployment rate
(10) W_m : Hourly earnings in manufacturing (1985=100)
(11) CPI: Consumption Price Index (1985=100)
(12) RW_m: Real wages in manufacturing = (10)÷(11)

Table 2 - Variability and growth of sectoral employment and GNP

	Employment(*) Variability	Growth	GNP Variability	Growth	π
Agriculture(+)	0.04	-0.9	0.13	2.0	2.9
Mining	0.21	1.2	0.05	-0.2	-1.4
Construction	0.12	2.4	0.08	-0.2	-2.6
Manufacturing	0.04	0.0	0.17	2.7	2.7
Durable goods	0.05	0.0	0.18	2.8	2.8
Nondurable g.	0.03	0.0	0.15	2.6	2.6
Transportation	0.07	1.2	0.18	1.3	0.1
Trade	0.17	3.0	0.19	3.5	0.5
Wholesale	0.14	2.4	-	-	-
Retail	0.18	3.2	-	-	-
Finance and Insurance	0.20	3.5	0.19	3.4	-0.1
Services	0.26	4.5	0.25	4.2	-0.3
Government	0.11	2.0	0.07	1.2	-0.8

(+) Labor force data
(*) Employees on non agricultural payrolls

Source: Economic Report of the President, January 1989

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