Revisiting the Phillips Curve with a Structural VAR

Staff Paper #325

by

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March 1999

ABSTRACT:

The purpose of this study is to analyze the short-run dynamics of U.S. inflation and unemployment rates in response to shocks in aggregate supply and aggregate demand. The econometric model is a bivariate VAR motivated by a textbook aggregate supply - aggregate demand structure. Supply and demand shocks are identified by normalization, orthogonality, and long-run restrictions, as in Blanchard and Quah (1989). Impulse response functions are used to characterize inflation and unemployment dynamics. A number of previous studies have applied this strategy to evaluate the aggregate supply and demand model, generally concluding that the data are broadly consistent with the predictions of the model. Our study, focussing on inflation-unemployment dynamics, leads to results that are not consistent with the aggregate supply and demand model.

KEYWORDS: Inflation, Unemployment Rate, Phillips Curve, Structural VAR

1. Introduction

Our purpose is to examine the broad consistency of the data with the stylized predictions of a simple textbook Keynesian model of inflation and unemployment. Models in this class, despite their simplicity and lack of a firm foundation in general equilibrium theory, form the basis for much of what we teach our undergraduates and for much of the public and media discussion of macroeconomic events and policies. Furthermore, the "reasonableness" of more sophisticated micro-based macroeconomic models are often judged according to how well their conclusions correspond to those that come from the aggregate supply and aggregate demand framework. [1/]

The relationship between the inflation rate and the unemployment rate has long been a central issue among macroeconomists. The prevailing view, at least as reflected in mainstream undergraduate textbooks such as Mankiw (1998) and Parkin (1998), is that there is a short-run tradeoff between the unemployment rate and unanticipated changes in the inflation rate while the long-run Phillips curve is vertical. A Keynesian story to explain this would proceed as follows. When the price of output rises (falls) unexpectedly, the real wage rate falls (rises) to the extent that there are short-run nominal wage rate rigidities. In the short-run labor employment is determined only by labor demand and, therefore, labor employment will rise above (fall below) the full-employment level and the unemployment rate will fall below (rise above) the natural rate of unemployment.

We will formulate a model in which deviations of inflation and unemployment from their steady-state paths arise from unanticipated aggregate demand and (short-run) aggregate supply shocks. The shocks are propagated through the lag structure of the reduced-form VAR representation of the inflation and unemployment rates. The VAR is estimated for monthly U.S. data (1948:1-1997:12) and the structural shocks are identified using the approach developed by Blanchard and Quah (1989). We apply the estimated VAR to evaluate whether the dynamic responses of inflation and unemployment rates to aggregate demand and supply disturbances are consistent with the predictions of the Keynesian theory. We find that they are not.

The remainder of the paper is organized as follows. Section 2 presents a review of closely related literature. The model is described in Section 3. The empirical analysis is contained in Section 4. A summary of the paper and its main conclusions are provided in Section 5.

2. Literature Review

The subject and approach of this paper are closely related to work by Blanchard and Quah (1989) in two respects. First, Blanchard and Quah illustrate how a long-run restriction on the coefficients of a bivariate vector moving average can be used to help identify structural shocks in a bivariate VAR. This is the technical device we will apply to identify aggregate supply and demand shocks. Second, both papers are concerned with studying the effects of aggregate supply and demand shocks on short-run macroeconomic dynamics as implied by an identified bivariate VAR. Other papers that have applied Blanchard and Quah's identification strategy to study the dynamic effects of AD and AS shocks include Shapiro and Watson (1988) and Gali (1992), and Keating and Nye (1998). These papers are generally supportive of the aggregate demand and supply model. [2/]

However, there are some important differences, aside from our incorporating more recent data. Our concern is on the inflation and unemployment relationship. Blanchard and

Quah study the effects of AD and AS shocks on output and unemployment while Gali studies the effects of IS, LM, and AS shocks on inflation and output (and on interest rates and money). Gali's focus is on the case where the price level is an I(2) process so that the inflation rate is non-stationary but the first-difference of the inflation rate is stationary. As a result, one is led to the conclusion that IS shocks have permanent effects on the inflation rate. This is somewhat discomforting because it is out of line with the standard textbook story. We rule this out by assuming the price level is an I(1) process and so aggregate demand shocks can permanently affect the price level but have at most a temporary effect on the inflation rate. Finally, we abstract from long-run dynamics by assuming that the steady-state paths of the inflation rate, output growth rate, and unemployment rate are (exogenously determined) constants. An implication of this will be that we rule out productivity shocks as sources of short-run dynamics. This requires our model to rely on a more traditional Keynesian explanation of business-cycle dynamics than has been the case in previous studies. Although these studies have generally found empirical support for the stylized predictions of the basic AS-AD model, productivity shocks have played such a strong role that Real Business Cycle theorists (e.g., King (1993)) have suggested that the results may be more suggestive of an RBC interpretation than a Keynesian interpretation.

3. Model

The current undergraduate textbook paradigm for the explanation of aggregate price, output, and employment/unemployment determination is the aggregate supply and demand model in which the aggregate supply curve is derived from a model of the labor market and the aggregate demand curve is derived from the IS-LM model. Keynesian short-run equilibrium is derived under the assumption that there is nominal wage rigidity and labor employment is determined solely by the labor demand curve. Long-run equilibrium is derived under the assumption that nominal wages are flexible and labor employment is determined by the intersection of the labor demand and labor supply curves. Along the long-run equilibrium path, the unemployment rate is equal to the natural rate of unemployment. In the short-run, however, the unemployment rate varies inversely with the difference between short-run and long-run equilibrium labor employment.

Let LAS denote the long-run aggregate supply curve. The LAS curve is the perfectly inelastic aggregate supply curve, derived under the assumption of full-employment in the labor market. Its behavior completely determines the long-run path of output. Let AD denote the downward-sloping aggregate demand curve. The intersection of the AD and the LAS curves determines the behavior of the price level along the economy's long-run path. We assume that the economy's long-run equilibrium path is characterized by a constant growth rate of output, a constant inflation rate, and a constant rate of unemployment.

The operational supply curve in the economy at any point in time is its short-run aggregate supply (SAS) curve. In the short-run, with labor employment completely determined by labor demand and rigid nominal wages, the economy's supply curve will be upward sloping. When the economy is operating along its full-employment path the LAS, SAS, and AD curves will intersect at the same point. Thus, the long-run behavior of the SAS curve will be completely determined by the behavior of the LAS and AD curves. In the short-run, however, the intersection of the SAS and AD curves can occur at, above, or below the full-employment output level. This intersection determines the short-run equilibrium levels of price, output, and (implicitly) the unemployment rate.[3/]

Thus, deviations from the long-run equilibrium path arise from two sources. First, growth in the AD curve can occur at greater or less than the long-run average rate. In the absence of any other disturbances, the effects of these AD shocks will be to cause temporary movements in inflation, output, and the unemployment rate but permanent effects on the price level. Second, shocks that shift the SAS curve independently of the LAS curve (e.g., nominal wage shocks) will have temporary effects on inflation, output, and the unemployment rate. However, these supply shocks will also only have temporary effects on the price level (since the long-run behavior of the price level depends only on the LAS and AD curves). This restriction is the long-run restriction that we will use to identify supply and demand shocks.

More specifically, the version of the Keynesian aggregate demand-aggregate supply model we envision implies that a positive (negative) aggregate demand disturbance will temporarily increase (decrease) the inflation rate and temporarily decrease (increase) the unemployment rate, while having a permanent positive (negative) effect on the price level. A positive (negative) aggregate supply disturbance will temporarily decrease (increase) the inflation and unemployment rates with no permanent effect on the price level. Neither type of shock will have a permanent effect on the behavior of output or the unemployment rate. These are determined by the LAS curve and labor market equilibrium.

Below we sketch out a simple dynamic model that incorporates the features of the LAS-SAS-AD framework described above. Note that output and price variables are expressed in logarithmic form.

(1) $$y_t^f = g_1 + y_{t-1}^f$$

(2) $$\begin{aligned} y_t^d &= d_t - \gamma p_t, \\ d_t &= g_2 + d_{t-1} + a(L)\varepsilon_t^d \end{aligned}$$

(3) $$\begin{aligned} y_t^s &= s_t + v_t + \beta p_t \\ s_t &= s_{t-1} + g_1 - g_2 \\ v_t &= b(L)\varepsilon_t^s + c(L)\varepsilon_t^d \end{aligned}$$

(4) $$y_t^s = y_t^d = y_t$$

(5) $$u_t = un + \alpha(y_t^f - y_t)$$

The parameters α, β, and γ are positive. Equation (1) is the equation for long-run aggregate supply, which increases at the constant rate g_1. Equations (2) are the aggregate demand equations, according to which the intercept of the aggregate demand curve grows at the constant rate g_2 subject to a stationary deviation, a(L) ε_t^d, where ε_t^d is an i.i.d. demand disturbance and a(L) is a polynomial in the lag operator L ($L^s x_t = x_{t-s}$) whose roots satisfy the stationarity condition. Equations (3) are the equations for the short-run aggregate supply. In the long run it grows at the rate of growth of LAS minus the average rate of growth of AD. It can deviate from this long-run path in response to i.i.d. supply shocks (ε_t^s) or demand shocks (ε_t^d), the effects of which are propagated over time through the polynomials in L, b(L) and c(L), each of which satisfies the stationarity condition. The supply and demand shocks are mutually uncorrelated at all leads and lags. Equation (4) is the goods market equilibrium condition and equation (5) determines the unemployment rate, where un is the constant natural rate of unemployment.

4. Estimation

4.1 *Identification*

Based upon the model sketched out above we assume that the unemployment rate, u_t and the inflation rate π_t $(= p_t - p_{t-1})$ form a jointly covariance-stationary process with Wold moving-average representation

(6) $$z_t = \Gamma + C(L)\varepsilon_t$$

where $z_t' = [u_t \;\; \pi_t]$, $\Gamma' = [un \; g]$, $\varepsilon_t' = [\varepsilon_t^s \;\; \varepsilon_t^d]$, and $C(L) = C_0 + C_1L + C_2L^2 + \ldots$. The parameter g is the steady-state inflation rate, un is the natural rate of unemployment, ε_t^d and ε_t^s are the mutually uncorrelated aggregate demand and (short-run) aggregate supply shocks, and C_0, C_1, ... is a sequence of 2x2 constant matrices, satisfying stationarity and invertibility conditions. The condition that aggregate supply shocks have only a temporary effect on the price level is the condition that

(7) $$\sum_{i=0}^{\infty} C_{i.21} = 0$$

where $C_{i.21}$ is the (2,1) element of C_i.

Corresponding to the Wold moving average representation of z_t is its vector autoregressive representation, which we assume is of order k, $k < \infty$:

(8) $$A(L)z_t = \Lambda + v_t$$

where $A(L) = A_0 - A_1L - \ldots - A_kL^k$, A_0 is the 2x2 identity matrix, Λ is a constant vector, and v_t is the period t innovation in z_t.

Our objective is to use an estimate of the unrestricted VAR (8) and the long-run restriction (7) to empirically identify the vector moving average representation of z_t (6), whose innovations can be interpreted as innovations in short-run aggregate supply and aggregate demand. Blanchard and Quah (1989) provide the technical details of moving from estimates of the parameters of (8) to estimates of the parameters of (6).

4.2 *Data*

Monthly seasonally-adjusted US data over the sample period 1948:1-1997:12 were collected. The price level was measured by the logged consumer price index (all items) and the inflation rate was measured as the annualized first-difference of the logged consumer price index. The unemployment rate measure was the adult civilian labor force unemployment rate. The sample means (standard deviations) of the inflation and unemployment rates are 3.864 (4.098) and 5.734 (1.582), respectively.

The unemployment and inflation rate series are illustrated in Figure 1. The NBER-defined business cycles over this sample period are clearly visible in the unemployment rate series.[4/] The inflation rate displays much more high frequency volatility than the unemployment rate. The high-inflation rates that characterized the late 1970's and early 1980's are evident as is the relative price stability during the current decade.

We begin with some unit root tests, since the theory assumes that the unemployment rate is stationary and the price level is difference stationary. Table 1 presents results from the application of Dickey-Fuller and Phillips-Perron unit roots tests. The null of a unit root is not rejected for the price level, but it is rejected at the five-percent level for the inflation rate. The null of a unit root in the unemployment rate is rejected by the Dickey-Fuller test at the five-percent level. It is rejected by the Phillips-Perron test at the 10-percent level, but not quite rejected at the five-percent level. Overall, we conclude that our stationarity assumptions are not at odds with these data. In particular and in contrast to Gali (1992), we assume that the price level is an I(1) [vs. I(2)] process so that one-time demand shocks can have a permanent effect on the price level but not on the inflation rate.

4.3 *The Estimated Model*

An unrestricted sixth-order VAR with an intercept was fit to the u_t and π_t series. The Granger-causality F-test of the null hypothesis that u fails to cause π had a p-value of 0.097. The Granger-causality F-test of the null hypothesis that π fails to cause u had a p-value of 0.0001. Thus, at least at the 10-percent level, there is evidence of feedback between the inflation and unemployment rates.

Our main purpose in estimating this VAR was to identify the structural VMA (6), which we did following the Blanchard-Quah strategy. In the remainder of this section we explain why the estimated VMA is not consistent with the implications of the Keynesian aggregate supply and demand model.

In our representation of the Keynesian aggregate supply and demand model, short-run movements in the unemployment and inflation rates are driven by innovations in the short-run aggregate supply curve and the aggregate demand curve. Positive supply innovations shift the SAS curve rightward leading to lower unemployment and inflation rates. Positive demand innovations shift the AD curve rightward leading to lower unemployment rates and higher inflation rates.

Figure 2 illustrates the point estimates of the impulse response functions centered in two-standard error band computed by 10,000 simulations. Panels A and B illustrate the responses of the inflation rate to one unit positive aggregate demand (panel A) and aggregate supply (panel B) shocks. Notice that the response of inflation to the aggregate supply shock reflects the restriction that this shock cannot have a long-run effect on the price level. Panels C and D illustrate the responses of the unemployment rate to one unit positive aggregate demand and supply shocks, respectively.

The estimated impulse response functions are not consistent with the predictions of the model because the responses of inflation to demand shocks and to supply shocks are opposite of what the model predicts. Specifically, positive aggregate demand shocks are observed to have a negative effect on the inflation rate while positive aggregate supply shocks are observed to have a positive effect on the inflation rate in the short-run (and no long-run effect on the price level). The responses of the unemployment rate to positive demand shocks and to positive supply shocks are negative, as predicted by the theory, although the confidence interval for unemployment rate responses to aggregate demand shocks include positive unemployment rate responses in the first year following the shock.

4.4 *Discussion*

The econometric procedure we applied yields two orthogonal white noise sequences, one satisfying the long-run restriction that it has no permanent effect on the price level. We chose to call the sequence satisfying the long-run restriction aggregate demand shocks, calling the other sequence aggregate supply shocks. We could have reversed these labels. In that case we would find that positive supply shocks have negative effects on inflation while positive demand shocks have, at least initially, positive effects on inflation. Both types of shocks would still have negative effect on the unemployment rate. However, this interpretation would rely on the restriction that aggregate demand shocks cannot have permanent effects on the price level. That is, it would rely on the restriction that the long-run price level is independent of aggregate demand, the long-run price level being determined by short-run aggregate supply shocks. Clearly this restriction contradicts the standard textbook story according to which aggregate demand determines the long-run behavior of the price level. Therefore, with either interpretation of the innovation sequences we find an apparent inconsistency between our results and the predictions of the theory.

Our results raise the natural question of why, in contrast to previous studies of this sort, we have found inconsistencies between the data and the predictions of the aggregate supply-aggregate demand model. We noted in the introduction that the textbook AS-AD model plays an important role in the education of our undergraduates, in our public discussion of macroeconomic events and policy, and sometimes as a check on the plausibility of non-Keynesian macroeconomic models. However, since the rational expectations revolution in the early 1970's most of the academic research on business cycle dynamics has focussed on non-Keynesian explanations. Therefore, it might be more surprising that, for example, Blanchard and Quah (1989) and Gali (1992) were able to interpret their results from a Keynesian perspective than that we could not.

King (1993) has pointed out that these earlier studies have an identification problem arising from the fact that they do not distinguish between short-run and long-run aggregate supply shocks.[5/] Supply shocks in these models can have permanent effects on output and play an important role in explaining short-run dynamics. The identification problem arises because these shocks can be interpreted as productivity shocks, suggesting that a real business cycle interpretation might be more appropriate than a Keynesian interpretation of the results. Our model, like the textbook Keynesian model, makes a clean separation between long-run (i.e., growth) dynamics and short-run (i.e., business cycle) dynamics. So, one possible interpretation of our findings is that once productivity shocks are ruled out a priori as a source of business cycle dynamics, structural VARs may provide less support for the textbook Keynesian model than had previously been thought.

5. Conclusion

Our objective in this paper has been to apply structural VAR analysis, along the line developed by Blanchard and Quah (1989) to study monthly dynamics in postwar U.S. inflation and unemployment rates. More specifically, we adopted a strategy based upon the textbook Keynesian model to empirically identify the aggregate supply and demand shocks that drive short-run (including business cycle) movements in inflation and unemployment rates as well as the propagation mechanism through which these shocks are transmitted.

Our results, however, appear to be inconsistent with our interpretation of the Keynesian model. The theory predicts that shocks to the short-run aggregate supply curve should move inflation and unemployment in the same direction while aggregate demand shocks should move them in opposite directions. We find instead that positive shocks in short-run aggregate supply increase the inflation rate and decrease the unemployment rate. Positive demand shocks are found to decrease the inflation and unemployment rates. Therefore, although our model and methods are quite similar to those used by Blanchard and Quah (1989) and by Gali (1992), our emphasis on the Phillips curve relationship provides a very different conclusion, one that appears to be far less supportive of the textbook Keynesian model.

NOTES

1. What we call the aggregate demand and aggregate supply model is also commonly referred to as the IS-LM-Phillips curve model.
2. King (1993) has argued that the results of these studies are not as supportive of the Keynesian theory as the authors would have us believe. Keating and Nye (1998) apply Blanchard and Quah's procedure to data for a number of countries using different sample periods. They find support for the textbook Keynesian model in the post-war period, but not for nineteenth-century data.
3. See, for example, Parkin (1997), whose summary of the aggregate supply and demand model notes that "[I]n the long run the quantity of real GDP supplied is potential GDP, which is independent of the price level. The long-run aggregate supply curve is vertical....In the short run real GDP and the price level are determined by aggregate demand and short-run aggregate supply. In the long-run...aggregate demand determines the price level..." (p.160).
4. The nine NBER-defined contractions during this sample period are 1948:11-1949:10, 1953:7-1959:5,1957:8-1958:4,1960:4-1961:2,1969:12-1970:11,1973:11-1975:3, 1980:1-1980:7,1981:7-1982:11,1990:7-1991:3.
5. King also questioned the consistency of Gali's results with the predictions of the Keyensian model because the results imply that a one-time positive IS shock will initially lower real interest rates and permanently increase the inflation rate. King suggests that these (and other) responses look more like the dynamic responses to a

permanent inflation shock predicted by monetarist theory than the dynamic responses to an IS shock that Keynesian theory would suggest. We rule out the possibility of demand shocks having a permanent effect on the inflation rate by our assumption that inflation is a stationary process.

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TABLE 1

Unit Root Tests

Variable	Dickey-Fuller Test, τ_α	Phillips-Perron Test, $Z(\tau_\alpha)$
CPI (p_t)	2.283	7.239
Inflation Rate (p_t-p_{t-1})	-4.136	-13.008
Unemployment Rate (u_t)	-3.781	-2.720

Sample Period = 1948:1-1997:12

Dickey-Fuller Test [Dickey and Fuller (1979)

Augmented Dickey-Fuller Regression:

$\Delta x_t = \alpha + \rho x_{t-1} + \gamma_1 \Delta x_{t-1} + \ldots + \gamma_6 \Delta x_{t-6} + v_t$

τ_α = t-statistic for the OLS estimator of ρ around $\rho = 0$.

Phillips-Perron Test [Phillips and Perron (1988)]

Phillips-Perron Regression:

$\Delta x_t = \alpha + \rho x_{t-1} + u_t$

$Z(\tau_\alpha)$ = Phillips-Perron adjusted τ_α, using 6 lags for the variance estimation.

Critical values for τ_α and $Z(\tau_\alpha)$ for sample size 100:

10-percent level = -2.58
5-percent level = -2.89

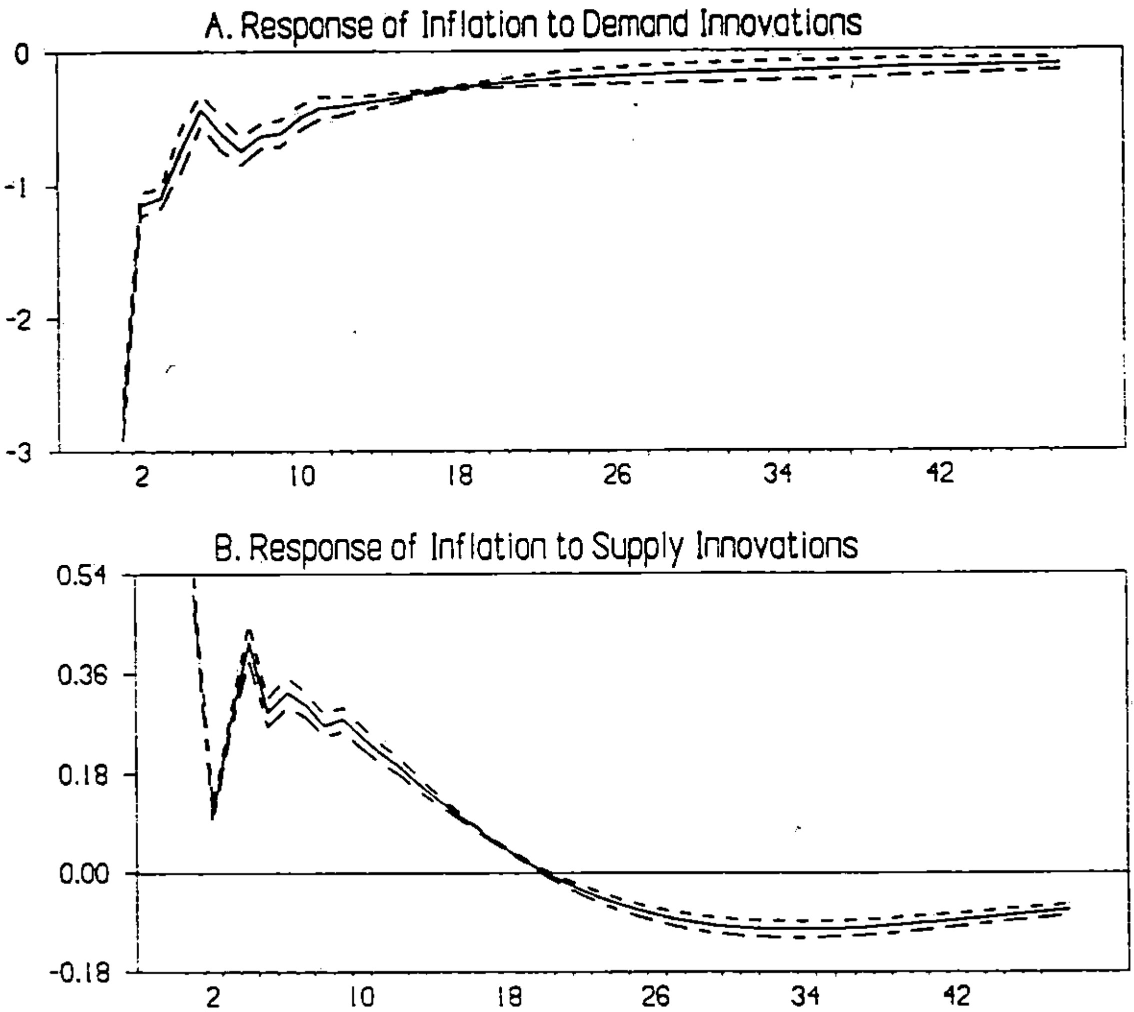

Figure 2. Impulse responses k-months after a one positive standard deviation unit shock, centered in a two standard error band.

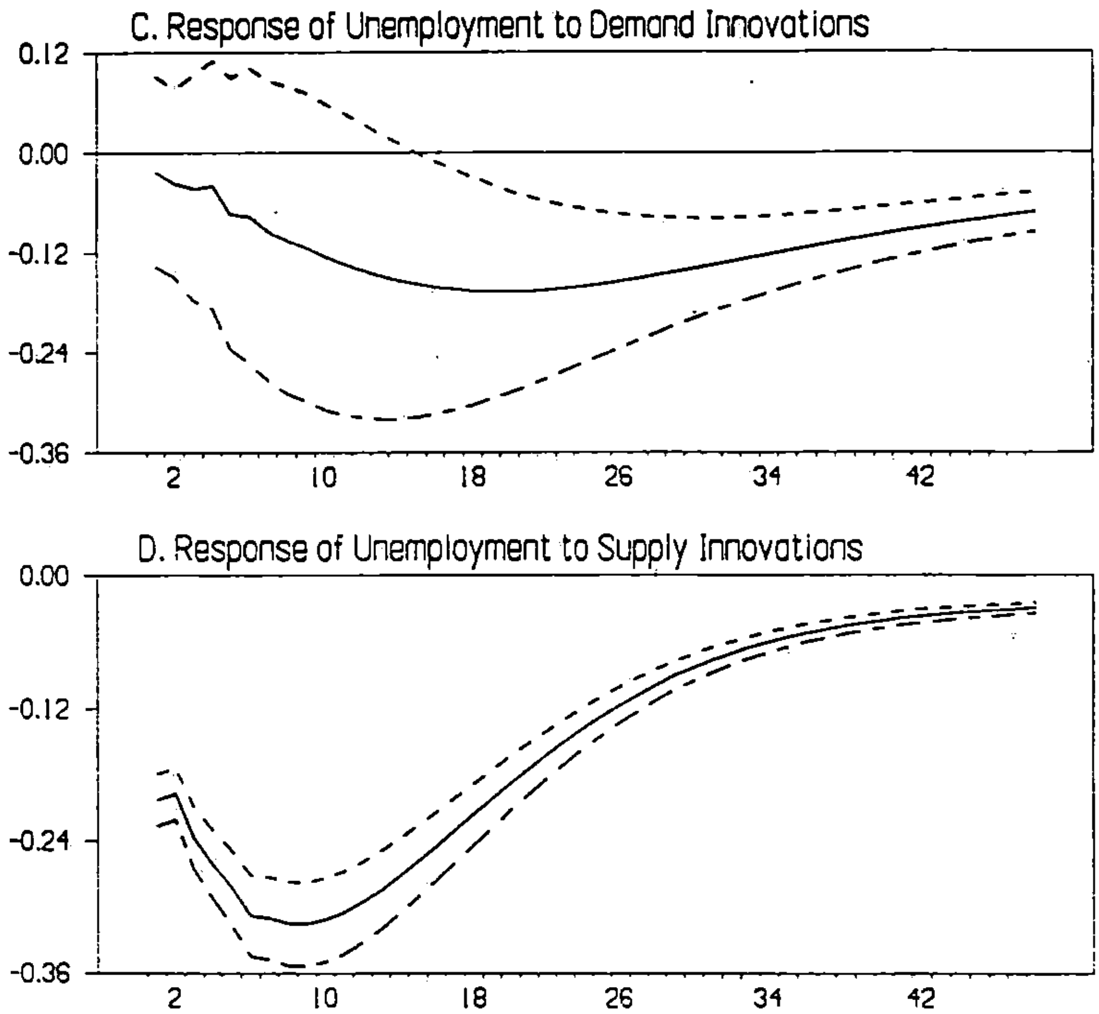

Figure 2. Continued.