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SOURCES OF OUTPUT FLUCTUATIONS DURING THE INTERWAR PERIOD: FURTHER EVIDENCE ON THE CAUSES OF THE GREAT DEPRESSION

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ABSTRACT

This paper decomposes output fluctuations during the 1913 to 1940 period into components resulting from aggregate supply and aggregate demand shocks. We estimates a number of different models, all of which yield qualitatively similar results. While identification is normally achieved by assuming that aggregate demand shocks have no long run real effects, we also estimate models that allow demand shocks to permanently affect output. Our findings support the following three conclusions: (i) there was a large negative aggregate demand shock in November 1929, immediately after the stock market crash; (ii) aggregate demand shocks are mainly responsible for the decline in output through mid to late 1931; (iii) beginning in mid 1931 there is an aggregate supply collapse that coincides with the onset on severe bank panics.

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1 Introduction

The economic turmoil of the interwar period continues to provide a fertile ground for empirical macroeconomic research. In particular, there remain several competing theories for both the initiation and the severity of the Great Depression of the 1930s. Using a recently developed set of econometric tools, we decompose output fluctuations during the interwar period into movements that were caused by aggregate supply innovations and those that resulted from innovations to aggregate demand. The purpose of this paper is to provide a description of the data that must be accounted for by any explanation of the Great Depression that maintains that only aggregate supply disturbances can have permanent effects on the level of output. In doing this, we supply estimates of both the timing and the magnitude of supply and demand shocks during the period from mid-1913 to 1940.

While our empirical results include an examination of the periods from 1913 to 1928 and 1934 to 1940, our main interest is in studying the years of the Great Depression — 1929 to 1933. As a result, it is useful to begin with a very brief summary of what we think is the current consensus description of the causes of the Depression.[1] Any complete explanation for the Depression must address three questions: (1) Why did it start? (2) Why was it so deep? And (3), Why did it last so long? The monetary hypothesis of Friedman and Schwartz (1963) appears to be dominant in answering the first question. Tight money, beginning in 1928, bears primary responsibility for the onset of the Depression. Hamilton (1987) provides a convincing discussion of both the extent and importance of this contractionary monetary policy.[2]

The answer to the second question — why the depression was so deep — is the most contentious. The leading candidate is the debt-deflation hypothesis suggested by Fisher in his 1933 paper, and more recently formalized by Bernanke and Gertler (1989

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[1] Clearly this summary cannot do justice to the individual theories cited. For a statement of all of the implications of any given piece of the story, the reader must go to the original sources. Furthermore, we do not mean to imply that everyone necessarily agrees with all aspects of the view we state. A recent paper by Bernanke and James (1991) provides an excellent survey of some of the current issues under debate.

[2] While Temin appeared to disagree with the thesis of this argument in his original 1976 book, he no longer does. See Temin (1989).

and 1990). The debt-deflation hypothesis is based on the notion that the nearly 30% cumulative deflation of 1930–32 was primarily responsible for the depth of the Depression. The argument proceeds as follows. Since unanticipated deflation increases the burden of nominal debt, it caused debtors to default on loans. This led to bank failures and the collapse of the financial system. But there is some debate over whether the deflation was actually unanticipated [see Cecchetti (1992), Hamilton (1992), and Nelson (1991)]. If not, then theories that rely on high *ex ante* real interest rates, and the resulting collapse of consumption and investment, might be more relevant than the debt-deflation hypothesis.[3]

The reason for the Depression's length, the answer to the third question, seems to be the least controversial of the three. Bernanke's (1983) theory of the collapse of financial intermediation is the leading explanation. He argues that there was an increase in the cost of intermediation that resulted in a large number of otherwise creditworthy borrowers being denied loans. This increase in cost was essentially a risk premium demanded by risk averse bankers who had withstood the series of banking panics beginning in late 1930. While there are demand side effects, the story is mainly one of contraction in aggregate supply.[4]

Finally, Romer (1990) provides evidence that some of the blame for the contraction can be traced directly to the stock market crash of 1929. This substantiates certain aspects of Temin's (1976) original hypothesis that the initial contraction in output in 1929 resulted from a collapse of consumption expenditure. Romer argues that the stock market crash created immediate income uncertainty resulting in a decline in the purchase of consumer durables, for which she provides substantial empirical support.[5]

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[3] Examples of these competing theories can be found in the simple IS-LM theory of Gordon and Wilcox (1981) and the classical theory in Cecchetti (1988).

[4] It is worth noting that the gold standard has become increasingly prominent in discussions of the Great Depression. The main argument, due to Eichengreen (1990) and Hamilton (1988), is that the operation of the gold standard was largely responsible for the propagation of the Depression from the U.S. to other industrialized countries. The contention is that as soon as the U.S. began to deflate in 1930, the gold standard forced all countries that were running current account deficits to deflate as well. See Temin (1989) and Bernanke and James (1991) for discussions.

[5] Cecchetti (forthcoming) argues that the stock market crash itself was caused by monetary forces, suggesting that the Temin consumption-collapse hypothesis may not be completely distinct from the Friedman and Schwartz monetary hypothesis.

This paper employs two related econometric procedures, together with monthly U.S. data, to provide evidence that clarifies the relative importance of these various theories both in the timing and magnitude of the effects. First, we apply the methodology developed by Blanchard and Quah (1989). They show that, if demand disturbances are assumed to die out in the long run, then a vector autoregression can be used to separate aggregate demand innovations from aggregate supply innovations. In addition, we use Shapiro and Watson's (1988) modification of Blanchard and Quah. Shapiro and Watson make a further identifying assumption in order to decompose aggregate supply fluctuations into those that arise from labor supply disturbances, and those that can be traced to technology shocks.

The second procedure we use is the one suggested in Galí (forthcoming). By assuming that neither money demand nor money supply shocks have a contemporaneous effect on output, and that contemporaneous price shocks do not enter the money supply rule, he shows how to separate aggregate demand movements into fluctuations that result from shocks to money demand, a money supply component, and a residual that he labels 'IS' innovations.

All of our results support three important conclusions about the course of the Great Depression. First, there was a very large negative aggregate demand shock in November 1929, immediately following the stock market crash. Furthermore, the Galí procedure suggests that, consistent with the Romer thesis, this shock did not have monetary origins. Second, aggregate demand contraction was responsible for output declines from the peak of the business cycle in August 1929 through the middle of 1931. After this, aggregate supply declines are entirely responsible for the continued drop in output. This, together with the finding of a large negative money demand shock in the fall of 1931, suggests the importance of the Bernanke hypothesis.

The remainder of the paper is divided into six sections. Section 2 provides a summary of the structural models we study. First we describe the Blanchard–Quah methodology that is based solely on long run identifying restrictions. Next, we present a brief description of Shapiro and Watson's modification, followed by a discussion of Galí's use of short run restrictions to identify IS and LM disturbances. Section 3 discusses the econometric issues associated with the construction of both point estimates and confidence intervals for various quantities of interest. Section 4 provides a brief description of the data together with a number of tests. We present tests for seasonal unit roots for individual time series, conventional stationarity tests, and tests for the parameter stability of the reduced form vector autoregressions (VARs) that are needed to construct estimates of the structural model. Section 5 reports the empirical results. We begin with the two models that use the Blanchard–Quah restrictions. In the first we examine data on output, prices and interest rates beginning in January 1910. The second, which is the Shapiro and Watson model, adds hours. Data availability forces us to begin the estimation of this model in June 1920. We then examine the Galí model using output, prices, interest rates and the M2 definition of money, for the 1910 to 1940 sample period. In addition to making comments about the Great Depression, the results allow us to draw conclusions about the likely causes of output fluctuations in both the 1920–21 recession and the 1937–38 downturn. In Section 6 we examine the robustness of our conclusions to a change in the identifying assumptions. Following Galí and Hammour (1991), we assume that aggregate demand shocks have permanent *negative* effects that are roughly of the same magnitude as the positive long run effects of aggregate supply shocks. This change has very little impact on our primary conclusions about the sources of output fluctuations during the Great Depression. Section 7 contains concluding remarks.

2 Modeling Output Fluctuations

The purpose of this section is to describe the structural models that we study. What follows is a simple summary of the methods developed by Blanchard and Quah (1989), Shapiro and Watson (1988) and Galí (forthcoming). This is followed in Section 3 by a description of the econometric methods used to generate both point estimates and confidence intervals for the models.

The remainder of this section is divided into two parts. In the first, we present the models based solely on the Blanchard and Quah, and Shapiro and Watson assumptions about long run effects. We discuss the way in which the restrictions allow for identification. Section 2.2 describes the Galí model, and shows how the use of short run restrictions allows identification of various demand side shocks.

2.1 The Blanchard-Quah Identification

Suppose that the economy is driven by two sets of shocks, aggregate supply and aggregate demand. We are interested in distinguishing between the two in order to study their relative importance for output fluctuations. Blanchard and Quah (1989) proposed as an identifying restriction the assumption that aggregate demand shocks have no *permanent* effect on output. Put differently, they assume that output in the long-run is determined only by aggregate supply shocks, with aggregate demand innovations resulting in purely *temporary* deviations around the 'trend'.[6] The Blanchard-Quah assumption is consistent with a wide class of theoretical models. For example, it nests certain equilibrium, or 'real', business cycle models since it allows aggregate supply disturbances to affect output in the short-run. However, models that violate this assumption do exist, such as models that generate the 'Tobin effect' of money growth on capital accumulation. It is plausible, however, that the potential permanent effects of aggregate demand disturbances on output are much less significant in size than the effects of aggregate supply shocks, and thus, as Blanchard-Quah argue, the assumption is a good (although imperfect) approximation to the real world.[7]

The Blanchard-Quah restriction is sufficient for identification if the set of aggregate

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[6] It is worth noting that the essence of the long run restrictions is to separate permanent from transitory components of output movements. An alternative to the *aggregate supply-aggregate demand* labels used by Blanchard and Quah is to note that in most models *nominal* shocks do not have long run real effects. This would dictate that we label the permanent shocks as *real* and the temporary shocks as *nominal*. While some aspects of our interpretation may be affected by this change, the major implications of our empirical findings are not.

[7] In Section 6 of the paper we examine the implications of assuming that aggregate demand shocks have permanent effects of a specific type. Our conclusions are robust to this change.

supply shocks has a single element. To illustrate, consider our first model given by

$$\begin{bmatrix} (1-L)y_t \\ (1-L)p_t \\ r_t \end{bmatrix} = A(L) \begin{bmatrix} u_t \\ v_t^1 \\ v_t^2 \end{bmatrix} , \tag{1}$$

where y is output and p is the price level both in logs, r is the real interest rate, u is an aggregate supply shock, v^1 and v^2 are aggregate demand shocks, and $A(L)$ is a 3x3 matrix polynomial in the lag operator L. All of the innovations in (1) are assumed to be i.i.d. and uncorrelated contemporaneously. The long run effects of the three structural shocks on the variables are given by the elements of $A(1)$:

$$A(1) = \begin{bmatrix} a_{ys} & a_{y1} & a_{y2} \\ a_{ps} & a_{p1} & a_{p2} \\ a_{rs} & a_{r1} & a_{r2} \end{bmatrix} ,$$

so that a_{ij} gives the long-run response of variable i to the shock j (and where 1 and 2 denote for v^1 and v^2 , respectively). The Blanchard-Quah restriction that the aggregate demand shocks have no long-run effect on output implies that $a_{y1} = a_{y2} = 0$. [The assumption that none of the variables permanently affects the real interest rate is implied by the inclusion of the *level* of the real interest rate, rather than its first difference, in (1).] The matrix $A(1)$ then becomes:

$$A(1) = \begin{bmatrix} a_{ys} & 0 & 0 \\ a_{ps} & a_{p1} & a_{p2} \\ a_{rs} & a_{r1} & a_{r2} \end{bmatrix} . \tag{2}$$

As in Shapiro and Watson (1988), the two aggregate demand shocks v^1 and v^2 cannot be separately identified, but can be thought of as linear combinations of the underlying IS and LM shocks. Nevertheless, we are able to estimate the innovations to aggregate supply and aggregate demand, from which we can draw conclusions about their relative importance for output fluctuations.

Of course, the Blanchard-Quah assumption is not sufficient if we want to identify more than one aggregate supply disturbance. In this case, additional assumptions are necessary. Consider, for example, our second specification, which uses the Shapiro and Watson (1988) identification restriction that long run labor supply is unaffected by either demand or technological shocks. The model can be written as

$$\begin{bmatrix} (1-L)h_t \\ (1-L)y_t \\ (1-L)p_t \\ r_t \end{bmatrix} = \tilde{A}(L) \begin{bmatrix} u_t^N \\ u_t^T \\ v_t^1 \\ v_t^2 \end{bmatrix}, \tag{3}$$

where h is the log of hours, u^N is the labor supply shock, u^T is the technology shock, and $\tilde{A}(L)$ is a 4x4 matrix of lag polynomials.[8]

The Blanchard-Quah restriction now implies that four elements of $\tilde{A}(1)$, $\tilde{a}_{h1}$, $\tilde{a}_{h2}$, $\tilde{a}_{y1}$, $\tilde{a}_{y2}$, are zero. This is still sufficient for separating the demand from the supply shocks. But to disentangle the labor supply from the technology innovations we must impose the additional restriction that $\tilde{a}_{hT} = 0$, or that labor supply in the long-run is determined only by its own innovations. The matrix $\tilde{A}(1)$ can be written as

$$\tilde{A}(1) = \begin{bmatrix} \tilde{a}_{hN} & 0 & 0 & 0 \\ \tilde{a}_{yN} & \tilde{a}_{yT} & 0 & 0 \\ \tilde{a}_{pN} & \tilde{a}_{pT} & \tilde{a}_{p1} & \tilde{a}_{p2} \\ \tilde{a}_{rN} & \tilde{a}_{rT} & \tilde{a}_{r1} & \tilde{a}_{r2} \end{bmatrix}. \tag{4}$$

Hall's (1988) comments on Shapiro and Watson (1988) suggest that there is a problem in identifying labor supply by assuming that $\tilde{a}_{hT} = 0$. The restriction is that in the long run, technological shocks only effect the real wage, not employment.

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[8] We refer to (3) as the 'Shapiro-Watson model,' which is not quite accurate. Our model differs from theirs in two small ways. First, they use the second difference of prices — the change in inflation — while we use the first difference. As we discuss in Section 4 below, we believe that inflation is stationary over our sample, while it may be the difference in inflation that is stationary during the post-WWII period that Shapiro and Watson study. In addition, they include oil prices as a fifth variable. Given their interest in fluctuations from 1951 to 1987, this is clearly appropriate, but there is no equivalent justification for the interwar period.

This means that the long run labor supply curve is vertical. This assumption seems questionable. While we do present results for the effects of u^N and u^T separately, we note that if the long run labor supply curve has positive slope, the two shocks will represent linear combinations of the true innovations to labor supply and technology. Without some additional information we can only identify total aggregate supply disturbances by adding the two effects together.

2.2 The Galí Identification

The attractive feature of the Blanchard-Quah identifying restriction is that it relies on plausible and generally defensible assumptions about the long-run behavior of real variables. A disadvantage is its failure to identify separate components of the aggregate demand shock. Such an identification would be of significant value in our attempt to explain the causes of the Great Depression. For example, any attempt to measure the relative contribution of the Friedman and Schwartz (1963) monetary hypothesis and the consumption hypothesis of Temin (1976) and Romer (1990) requires that monetary shocks be explicitly identified.

Galí (forthcoming) has proposed a method that allows identification of three types of demand shocks: IS shocks, money demand shocks, and money supply shocks. This extra information does not come without a price, which in this case is additional assumptions about contemporaneous effects. Our view is that the loss of generality is justified by the insight that this approach affords.

In Galí's method, there are four structural disturbances: aggregate supply shocks u^S, money supply shocks u^{MS}, money demand shocks u^{MD}, and IS shocks u^{IS}. The model is

$$\begin{bmatrix} (1-L)y_t \\ i_t \\ r_t \\ (1-L)(m_t-p_t) \end{bmatrix} = G(L)\begin{bmatrix} u_t^S \\ u_t^{MS} \\ u_t^{MD} \\ u_t^{IS} \end{bmatrix}, \qquad (5)$$

where i_t is the nominal interest rate, and m_t is the log of the money stock.

The Blanchard and Quah restriction continues to suffice for identifying the aggregate supply shock. But identifying the three aggregate demand shocks requires two additional assumptions. Galí proposes first assuming that neither money demand nor money supply affect output contemporaneously. This assumption seems particularly plausible in our case, since we use monthly data. Galí's second assumption is that contemporaneous prices do not enter the money supply rule. This restriction, which is more questionable than the first one, identifies a money demand function, and allows estimation of u^{MD} and u^{MS} separately.

3 Econometric Issues

In this section we describe the methods used to obtain point estimates and confidence intervals associated with the models described in Section 2. For all three models, point estimates are derived from the reduced form VARs, while confidence intervals for the quantities of interest are constructed using Monte Carlo procedures.

3.1 Point Estimates

While we compute estimates of the structural form for all three models using the same basic procedure, for ease of exposition the following discussion treats only the case of the three variable model. Estimation of the four variable, Shapiro-Watson model, is identical, while estimation of the Galí model requires some slight modifications that we will mention at the end.[9]

Obtaining point estimates of the structural model is best understood by rewriting the structural form, equation (1) as

$$x_t = A(L)e_t \tag{6}$$

and its reduced form as

$$R(L)x_t = \eta_t , \tag{7}$$

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[9] Shapiro and Watson (1988) pg. 118–121 present an alternative, instrumental variables procedure that can be used to estimate both of the models that rely solely on long run restrictions.

where $R(0) = I$, the η_t's are i.i.d., implying that they are orthogonal to the lagged x_t's, and $E(\eta\eta') = \Sigma$. It immediately follows that $A(L)e_t = R(L)^{-1}\eta_t$. This allows us to write $A(0)e_t = \eta_t$, and $A(L) = R(L)^{-1}A(0)$. As a result, given an estimate of $A(0)$ we can recover estimates of both the structural innovations, the e_t's, and the structural parameters, the components of $A(L)$.

To show how $A(0)$ is estimated, note that $A(0)E(ee')A(0)' = \Sigma$, where $E(ee')$ is diagonal by construction. Normalizing $E(ee') = I$, we obtain the result that $A(0)A(0)' = \Sigma$. In a system with n variables, Σ has $\left[\frac{n(n+1)}{2}\right]$ unique elements, and so complete identification requires an additional $\left[\frac{n(n-1)}{2}\right]$ restrictions. For a three variable model, three more restrictions are needed. The Blanchard and Quah restrictions on $A(1)$ provide two of these. The long-run restrictions come directly from the fact that several elements of $R(1)^{-1}A(0)$ must be zero. These are simple linear restrictions on the elements of $A(0)$. In the case of the models of Section 2.1, there are two long run restrictions, and so we have eight restrictions with nine unknowns. Consequently, we cannot separate the two aggregate demand shocks. But since our interest is in their sum, this makes little difference.

The actual implementation of the procedure is as follows. First, we estimate the reduced form VAR to obtain $\hat{R}(L)$, $\hat{\eta}_t$ and $\hat{\Sigma}$. Next we invert $\hat{R}(L)$ to obtain the reduced from vector moving average (VMA) representation of the model.[10] Summing the VMA coefficients yields an estimate of $R(1)^{-1}$ and allows us to form the linear restrictions implied by the long run constraints. We can think of these, together with the covariance matrix restrictions that $A(0)A(0)' = \Sigma$, as providing us with a system of $(n^2 - 1)$ nonlinear equations in n^2 unknowns. For the three variable model, we add the arbitrary restriction that $A_{23}(0) = 1$ to allow estimation.[11]

The Galí procedure differs only in the restrictions imposed to estimate the equivalent of $A(0)$, $G(0)$. His identification implies that $G_{12}(0) = G_{13}(0) = 0$ and that $G_{23}(0)^{-1} + G_{24}(0)^{-1} = 0$, where $G_{ij}(0)^{-1}$ is the (i, j) element of $G(0)^{-1}$. For the four

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[10] A simple way to do this computationally is to construct the companion form of the VAR as described in Sargent (1987, pg. 309).

[11] We choose this particular arbitrary restriction since it is identical to the one implied by Shapiro and Watson's use of a Choleski decomposition following estimation by instrumental variables.

variable model this yields sixteen nonlinear equations in sixteen unknowns.[12]

3.2 Computing Confidence Intervals

Confidence intervals for estimates associated with the models in Section 2 can be constructed in various ways. Before discussing the method we use, it is worthwhile to describe the quantities we are interested in estimating. In Section 5 we present results for both variance decompositions and for what are generally referred to as historical decompositions. Each of these can be understood clearly by examining the first line of equation (1). The output equation in the three variable model is

$$y_t = \frac{A_{11}(L)}{(1-L)}u_t + \frac{A_{12}(L)}{(1-L)}v_t^1 + \frac{A_{13}(L)}{(1-L)}v_t^2 , \tag{8}$$

which can be rewritten as

$$y_t - y_{t-k-1} = \sum_{i=0}^{k} c_{11}(i)u_{t-i} + \sum_{i=0}^{k} c_{12}(i)v_{t-i}^1 + \sum_{i=0}^{k} c_{13}(i)v_{t-i}^2 \tag{9}$$

where $c_{jk}(i)$ is the coefficient on L^i in the lag polynomial $\frac{A_{jk}(L)}{(1-L)}$. The right-hand side of equation (9) is just the deviation in y_t from the forecast generated at time $(t-k-1)$.

Both the variance decompositions and the historical decompositions follow directly from (9). The portion of the variance in output forecast errors at horizon k accounted for by the aggregate supply shocks, the u_t's, is simply

$$V_u(k) = \frac{\sum_{i=0}^{k} c_{11}(i)^2}{\sum_{i=0}^{k} c_{11}(i)^2 + \sum_{i=0}^{k} c_{12}(i)^2 + \sum_{i=0}^{k} c_{13}(i)^2} .$$

The historical decomposition separates the output forecast errors into parts that can be accounted for by the various shocks. The portion of the deviation in the *level* of output from its forecast $(k-1)$ periods earlier that can be assigned to aggregate

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[12] We solve the nonlinear equation systems using the GAUSS procedure *nlsys*, with the settings.

supply shocks is just the first term in (9):

$$H_{yu}(t) = \sum_{i=0}^{k} c_{11}(i) u_{t-i} \; .$$

The impact of aggregate demand shocks can be computed by summing the second and the third terms of (9).

It is clear from the discussion thus far that both the variance decompositions and the historical decompositions are functions of the structural coefficients, the $A(L)$'s. These, in turn, are functions of the reduced from parameters $R(L)$ and Σ. The historical decompositions are also functions of these as well as the reduced from residuals themselves.

There are several ways to compute confidence intervals for these quantities. A straightforward one uses Monte Carlo techniques based on specific distributional assumptions about the OLS estimates of (R, Σ), $(\hat{R}, \hat{\Sigma})$. To see how this is done, it is useful to write the point estimate of a particular variance decomposition as

$$\hat{V}_u(k) = v(\hat{R}, \hat{\Sigma}) \; ,$$

and likewise for the historical decompositions:

$$\hat{H}_{yu}(t) = h(\hat{R}, \hat{\Sigma}; x_t) \; ,$$

where x_t is the data. Then, following the procedure described in Doan (1990) Chapter 10.1, we construct a sequence of Monte Carlo draws of Σ from an inverted-Wishart distribution, each of which is then used to generate a draw for R. For each draw of (R^i, Σ^i) we can use the method of Section 3.1 to compute the structural model A^i, and then values of the variance decompositions and historical decompositions follow immediately.[13]

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[13] An alternative to this Monte Carlo procedure is to estimate the covariance matrix of $(\hat{R}, \hat{\Sigma})$ using Hansen's (1980) Generalized Method of Moments procedure on a exactly identified system, and then use the first order approximation constructed from the derivatives of the functions $v(\hat{R}, \hat{\Sigma})$ and $h(\hat{R}, \hat{\Sigma}; x_t)$ to compute confidence intervals. While this procedure makes fewer explicit distributional

The Monte Carlo draws yield two pieces of information — the mean and the standard errors of variance decompositions and the historical decompositions computed over the draws. It is standard practice [See, for example, Shapiro and Watson (1988), Blanchard and Quah (1989) and Fackler and Parker (1990)] to report the point estimates of the variance decompositions and the historical decompositions based on the values at the point estimates of the parameters together with standard errors calculated from the Monte Carlo draws. But this ignores the fact that the Monte Carlo draws yield an estimate of the bias in the point estimates.

An estimate of this bias can be derived directly from the mean of the draws. For the case of the historical decompositions, we can write this mean as

$$\overline{H_{yu}(t)} = \frac{1}{N}\sum_{i=1}^{N} h(R^i, \Sigma^i; x_t) ,$$

where N is the number of draws. The estimated bias is

$$Bias = \overline{H_{yu}(t)} - \hat{H}_{yu}(t) ,$$

and so the bias-corrected estimate of the historical decomposition is

$$\tilde{H}_{yu}(t) = 2\hat{H}_{yu}(t) - \overline{H_{yu}(t)} .$$

The estimate of the standard error of the bias-corrected estimate of the historical decomposition is just the standard deviation of the Monte Carlo draws computed using the mean of the draws.[14]

While we report bias-corrected estimates of the historical decomposition where the bias appears quite large, we follow the standard practice in reporting the variance decompositions. In theory, individual elements of a variance decomposition, a single

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assumptions, it relies on a first order approximation that is unlikely to be very accurate in view of the size of the bias — a second order term — that we find when we perform the Monte Carlo experiments.

[14] The Monte Carlo experiment presumes that the estimates $(\hat{R}, \hat{\Sigma})$ are the true values, and so an estimate of the bias is computed assuming that the bias is the same when $(R, \Sigma) = (\hat{R}, \hat{\Sigma})$ as it is when (R, Σ) equal their true values.

value of $V_u(k)$ for example, must lie between zero and one hundred. This is true of both $\hat{V}_u(k)$ and of the mean of the Monte Carlo draws, $\overline{V_u(k)}$. But it need not be true of a bias-corrected estimate of $V_u(k)$. In fact, as is obvious from the bias-correction, the result can be less than zero or exceed one hundred.[15]

4 Unit Roots and Structural Stability

Prior to the estimation of the three models of Section 2, it is useful to present two sets of test results: (1) univariate tests for unit roots at both seasonal frequencies and the zero frequency for the raw data series, and (2) tests for the structural stability of the reduced form VARs.

The stationarity tests are needed to determine both the degree of differencing and the nature of seasonal adjustment that is required prior to implementing the procedures described in Section 3. The purpose of this is to ensure that the error vector is covariance stationary for each of the models that we estimate and that we treat seasonality properly. While the tests have numerous well known problems,[16] they do provide information about the low frequency properties of the data.

The purpose of testing the structural stability of the VARs is to allay fears that the model parameters are substantially different before and during the Great Depression. If the model is not stable, it would be difficult to interpret results based on full sample estimates.

Before proceeding, it is worth providing a brief description of the data itself. (A full description, along with a list of sources, is in the appendix.) Output is measured by industrial production. For prices, we use a cost of living index. Hours is total man hours worked in twenty-five manufacturing industries surveyed by the National Industrial Conference Board. The commercial paper rate is used to measure the interest rate, and money is M2 from Friedman and Schwartz (1963).

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[15] In practice this problem is likely the result of the fact that the distributional assumptions used to generate the Monte Carlo draws, the normality of $\hat{R}$ for example, is incorrect. But we know of no real alternative, and so the solution to this problem awaits further research.

[16] See the recent survey by Campbell and Perron (1991).

First, we examine the seasonal pattern of the data using the Beaulieu and Miron (forthcoming) extension of Hylleberg, Engle, Granger and Yoo (1990)'s analysis. They develop a testing procedure that examines whether unit roots are present at both seasonal frequencies and frequency zero. The tests are based on the regression

$$\tilde{\Phi}(L)x_t = \alpha + \beta t + \sum_{i=2}^{12} \gamma_i S_{it} + \sum_{i=1}^{12} \pi_i \Phi_i(L)x_t + \sum_{i=1}^{m} \tilde{\Phi}(L)x_{t-i} + \epsilon_t$$

where the $\Phi_i(L)$'s are lag polynomials defined in Beaulieu and Miron's equation (5), and the S_{it}'s are seasonal dummy variables. The procedure is to estimate the equation by OLS, including as many lags of the dependent variable as is required for the residuals to be serially uncorrelated. The null hypothesis for the test is that there are unit roots at all frequencies, including zero.

As Beaulieu and Miron show, for no unit roots to exist at any seasonal frequency, π_i must equal zero for $i = 2$ and for at least one member of each of the sets $\{\pi_3, \pi_4\}$, $\{\pi_5, \pi_6\}$, $\{\pi_7, \pi_8\}$, $\{\pi_9, \pi_{10}\}$ and $\{\pi_{11}, \pi_{12}\}$. This means that the test for seasonal unit roots involves one t-test, the test for $\pi_2 = 0$, and five F-tests, for $\pi_{i-1} = \pi_i = 0$ for $i = \{4, 6, 8, 10, 12\}$. Finally, the t-statistic for π_1 is a test for a unit root at the zero frequency.[17]

Table 4 reports the results of the Miron-Beaulieu tests both with and without a time trend. In all cases, the residuals in the regressions are serially independent when $m = 0$,[18] and so we exclude lags of the dependent variable. The results suggest that there are no unit roots at any of the seasonal frequencies, and so we seasonally adjust the data on hours, output, prices, and money using deterministic dummy variables. Furthermore, the results for $\pi_1 = 0$ suggest that, except for the real interest rate, all of the variables contain one unit root at the zero frequency, and so they require differencing.

Next, we examine Dickey-Fuller tests for the presence of a unit root at the zero frequency using the seasonally adjusted data. The results of this are reported in

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[17] The tests are for seasonal unit roots at frequencies equal to $\{\pi, \frac{\pi}{2}, \frac{2\pi}{3}, \frac{\pi}{3}, \frac{5\pi}{6}, \frac{\pi}{6}\}$.

[18] We establish this by examining both the autocorrelograms and the Box-Pierce statistics computed from the residuals of the regressions.

Table 1: Seasonal Unit Root Tests

Variable	trend	π_1	π_2	$F_{3,4}$	$F_{5,6}$	$F_{7,8}$	$F_{9,10}$	$F_{11,12}$
Sample Period: 1911:06 to 1940:12								
Output (y_t)	no	−1.68	−6.80†	30.97†	51.29†	26.52†	32.82†	28.55†
	yes	−2.87	−6.85†	31.31†	52.02†	26.55†	33.22†	29.41†
Prices (p_t)	no	−2.33	−5.29†	28.55†	38.59†	27.56†	42.68†	32.04†
	yes	−1.97	−5.28†	28.46†	38.41†	27.48†	42.44†	31.98†
Nominal Money (m_t)	no	−1.53	−5.32†	10.03†	11.21†	13.00†	16.20†	18.44†
	yes	−2.02	−5.32†	28.49†	24.79†	40.97†	38.57†	45.99†
Real Money (m_t-p_t)	no	0.15	−5.68†	30.05†	25.91†	32.21†	37.84†	42.23†
	yes	−1.85	−5.71†	30.28†	26.18†	32.68†	38.21†	41.07†
Real Interest Rates (r_t)	no	−3.73*	−5.43†	28.24†	35.06†	27.63†	39.02†	35.11†
	yes	−3.73*	−5.42†	28.18†	34.96†	27.56†	38.89†	35.06†
Sample Period: 1921:10 to 1940:12								
Output (y_t)	no	−1.86	−4.14†	21.64†	21.57†	24.70†	22.41†	23.05†
	yes	−2.18	−4.14†	21.60†	21.57†	24.64†	22.38†	23.14†
Prices (p_t)	no	−1.07	−5.20†	22.04†	30.73†	20.09†	20.95†	18.92†
	yes	−2.07	−5.21†	21.97†	30.95†	19.64†	21.23†	18.53†
Hours (h_t)	no	−1.70	−4.03†	23.67†	23.98†	45.52†	24.10†	34.65†
	yes	−2.02	−4.04†	23.35†	24.10†	43.43†	24.06†	34.38†
Real Interest Rates (r_t)	no	−4.12†	−5.27†	22.56†	29.46†	20.03†	20.28†	19.07†
	yes	−4.02†	−5.28†	22.58†	29.46†	20.12†	20.30†	19.19†
Frequency of Seasonal Unit Root		0	π	$\frac{\pi}{2}$	$\frac{2\pi}{3}$	$\frac{\pi}{3}$	$\frac{5\pi}{6}$	$\frac{\pi}{6}$

* — significant at the 5% level † — significant at the 1% level

Tests are for the null hypothesis that the series contains unit roots, versus the alternative that it does not. The statistics under π_1 test for a unit root at the zero frequency, while the remaining statistics test for seasonal unit roots at various frequencies. Simultaneous rejection of unit roots at all nonzero frequencies implies the absence of any seasonal unit root. Critical values are from Beaulieu and Miron (forthcoming) Table A.1. Data sources are listed in the appendix. All tests were performed using RATS programs supplied by J. Beaulieu.

Table 1: Dickey-Fuller Tests

	Level		First Difference	
Variable	t-test $\hat{\tau}_\mu$ and ($\hat{\tau}_\tau$)	F-test Φ_3	t-test $\hat{\tau}_\mu$ and ($\hat{\tau}_\tau$)	F-test Φ_3
	Sample Period: 1911:06 to 1940:12			
Output (y_t)	-1.89 (-3.13)	5.06	-4.82** (-4.82**)	11.99**
Prices (p_t)	-2.18 (-1.97)	2.44	-3.51** (-3.69**)	7.01**
Real Money ($m_t - p_t$)	-0.10 (-2.72)	3.98	-4.23** (-4.26**)	9.46**
Real Interest Rates (r_t)	-3.60** (-3.61†)	6.74*		
	Sample Period: 1921:10 to 1940:12			
Output (y_t)	-2.24 (-2.34)	2.87	-4.88** (-4.88**)	9.33**
Prices (p_t)	-1.25 (-3.12)	3.68	-3.11† (-3.05)	5.09
Hours (h_t)	-1.92 (-2.34)	2.87	-4.88** (-4.88**)	12.52**
Real Interest Rates (r_t)	-2.45 (-2.81)	4.52		

† — significant at the 10% level
* — significant at the 5% level
** — significant at the 1% level

Values in parentheses are for tests that include the trend. Test are for the null hypothesis that the series contains unit root versus the alternative that it is stationary. The t-tests are based on Fuller (1976), while the F-tests are from Dickey and Fuller (1981). The critical values for $\hat{\tau}_\mu$ and $\hat{\tau}_\tau$ are from Fuller (1976) Table 8.5.2 pg. 373, and for Φ_3 they are from Dickey and Fuller (1981) Table VI, pg. 1063. With the exception of the interest rate, all of the variables are in logs. Data sources are listed in the appendix.

Table 1. These statistics, due to Fuller (1976) and Dickey and Fuller (1981), are based on the regression

$$\Delta x_t = \alpha + \beta t + \gamma x_{t-1} + \sum_{i=1}^{12} \delta_i \Delta x_{t-i} + \epsilon_t \ .$$

We examine both the general case including the time trend, as well as the case without the trend in which β is restricted to equal zero. The table reports two statistics, labelled the 't-test' and the 'F-test'. The t-test is for the null hypothesis of a unit root, $\gamma = 0$, versus the alternative that the series is stationary in levels, $\gamma < 0$. Fuller (1976) refers to these statistics as $\hat{\tau}_\mu$, for the case without a trend, and $\hat{\tau}_\tau$ when the trend is included. We also report results for an F-test examining the null hypothesis that β and γ are zero simultaneously, when the trend is included. This is Dickey and Fuller's Φ_3. For all of these computations we include twelve lags of Δx_t in the regression.

From these results we conclude that output, hours, prices, and real money are well modeled as stationary in first differences, while the real rate is likely to be stationary in levels. This all implies that the nominal interest rate is stationary in levels as well. It is interesting to note that there is evidence that inflation is stationary, implying that we need to difference the price level once at most. This is in contrast to most results for the post-WWII period that suggest inflation has a unit root, and so it is the second difference of the price level that is used in the analysis.[19]

In order to test for the structural stability of the models we study, we employ a procedure described by Christiano (1986) that is based on Sims (1980). The method

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[19] There is substantial disagreement in the literature over the differencing required to achieve stationarity in these series. For example, Cecchetti (1992) concludes that inflation is likely to be stationary over the 1920 to 1940 period, while Hamilton (1992) prefers to model the price level as a stationary variable. There is a similar divergence of opinion over whether output is stationary in levels or first differences. Cecchetti and Lam (1991) discuss this problem in a univariate context, and conclude that for the study of fluctuations at horizons of five to ten years, difference and trend stationary models have very similar implications. This suggests that our results would be robust to estimating the models in levels, but including a trend.

Table 2: Tests of Structural Stability

(p-values are in parentheses)

Beginning of 2nd Period	(Y,P,R) Model	(H,Y,P,R) Model	Galí Model
1929:1	133.86	191.97	221.82
	(0.07)	(0.57)	(0.10)
1929:9	138.04	203.33	226.05
	(0.04)	(0.34)	(0.07)
1929:11	143.24	212.89	244.69
	(0.02)	(0.19)	(0.01)
1931:9	126.30	217.08	237.49
	(0.15)	(0.14)	(0.02)
1933:4	105.16	196.61	199.78
	(0.64)	(0.47)	(0.41)
Degrees of Freedom	111	196	196
Full Sample	1910:1 to	1920:6 to	1910:1 to

Test statistics are asymptotically χ^2 with degrees of freedom equal to the value listed in each column. See the text for a description of the test.

requires estimating the system:

$$R_0(L)x_t + R_1(L)x_t d_t = \eta_t \ , \tag{10}$$

where d_t is a set of dummy variables that equal one from the beginning of the second period to the end of the sample. The test statistic is equal to $(T-k)[ln(|\Sigma^c|) - ln(|\Sigma^u|)]$, where T is the number of observations, k is the number of coefficients in one equation in (10) and Σ^c and Σ^u are the covariance matrices of the errors in the constrained system in which $(R_1(L) = 0)$, and the unconstrained system respectively. The test statistic is asymptotically Chi-squared with degrees of freedom equal to the number of constraints — $\left(\frac{k}{2}\right)$ times the number of equations.

Table 2 presents results for several possible breaks: (1) the beginning of 1929; (2) September 1929, the month following the business cycle peak; (3) November 1929, the month following the stock market crash; (4) September 1931, one month after Britain left the gold standard; and (5) April 1933, the month following both the end of the contraction and when the U.S. left the gold standard. The results are split. There is certainly evidence that the VARs estimated using data beginning in 1910 shift during 1929, although it is not overwhelming. But this is clearly not the case for the four variable model estimated beginning in mid-1920. This leads us to conclude that the only way to treat all the formulations equally is to estimate them over the entire sample period for which data is available.

5 Empirical Results

This section presents the estimates of the models described in Section 2 using the techniques introduced in Section 3. We present three sets of results: (1) the output–price–interest rate model for 1910 to 1940; (2) the Shapiro–Watson output–hours–price–interest rate for 1920 to 1940; and (3) the Galí output–price–interest rate–money model for 1910 to 1940.

For all three models, we begin by examining the standard variance decompositions, which measure the percentage of the variance in the forecast errors of a particular variable, at a given forecast horizon, that is the result of innovations to the variables in the system, on average. We then present bias-adjusted estimates of the historical decomposition of output fluctuations into the components that are estimated to result from the various shocks. These are essentially the weighted sums of impulse responses, where actual innovations are used as the weights. We also present standard errors based on the Monte Carlo experiments described in Section 3, with 2500 draws. This procedure allows us to draw conclusions about the likely sources of movements in output at specific times.

5.1 Blanchard and Quah: 1910 to 1940

We begin our discussion of the empirical results with the output–prices–interest rate model described in Section 2.1. Table 3 reports the variance decomposition for

Table 3: Variance Decomposition, Output–Prices–Interest Rate Model

(Monthly, 1910 to 1940, standard errors are in parentheses)

Fraction of Variance Explained By Aggregate Demand			
Horizon in Months	Output	Prices	Nominal Interest Rates
1	52.1	93.3	50.1
	(33.5)	(17.4)	(28.8)
6	55.4	97.8	58.5
	(33.1)	(18.1)	(28.6)
12	51.4	99.1	67.8
	(31.9)	(17.4)	(27.5)
24	39.0	98.9	76.5
	(30.5)	(18.1)	(27.6)
36	32.2	98.0	80.8
	(29.1)	(18.9)	(27.8)

Values are the percentage of the forecast error variance explained by shocks to aggregate demand. They are computed from the estimation of (7) subject to (2). Numbers in parentheses are standard errors computed using the Monte Carlo procedure described in Section 3. All of the Monte Carlo results are based on 2500 draws with random numbers generated using the GAUSS *rndn* procedure with the default settings.

the model. Since the model's two aggregate demand shocks cannot be separately identified, we include the sum of their effects. The table presents the fraction of the forecast error variance for each variable that is attributable to aggregate demand on average. This is the difference between the actual level and its forecast from equation (1), at a particular horizon. The impact of aggregate supply is simply 100 minus the value in the table.

The estimates imply that, at a one year horizon, over one-half of the variance in output is explained by aggregate demand, and that the effect dies out slowly, remaining at 32% at a three year horizon, even though the identifying restrictions require that the infinite horizon impact be zero. While imprecise, these estimates are well within the range reported by Blanchard and Quah (1989) using quarterly post-WWII data. They find that demand explains between 39% and 98% of the forecast error to output at the one year horizon, and between 13% and 68% at a three year horizon.[20]

The variance decomposition confirms the general belief that aggregate demand innovations are largely responsible for changes in both prices and the nominal interest rate. Even at a one month horizon, aggregate demand shocks account for over 90% of the variance in prices, and over 50% of the variance in the nominal interest rate. These increase to 98.0% and 80.8% at thirty-six months, at which point they are growing very slowly.

While the variance decomposition in Table 3 provides substantial information about the importance assigned to both aggregate demand and aggregate supply shocks, it is silent on the actual effect of a given shock at a specific time. It is possible, however, to use the estimation results to compute the likely source of output movements during a given month or year. Using the estimates of the orthogonal innovations $(\hat{u}_t, \hat{v}_t^1, \hat{v}_t^2)$, together with the estimated impulse response coefficients, $\hat{A}$, we can decompose output movements into those accounted for by innovations to either aggregate supply or aggregate demand. In computing the results for the historical decompositions, we set k in the expression for $H_{yu}(t)$ to twenty-four months. This means that we are reporting estimates of the influences of shocks on the deviation of output from the level that would have been forecast from information two years earlier.

Figures 1A and 1B report the bias-adjusted historical decomposition of output fluctuations from November 1913 to December 1940, together with one standard error bands — the first three plus years are lost to differencing variables, including lags in the estimation, and computing the first value of the cumulative effect. We also include vertical lines indicating NBER reference cycle peaks and troughs, labelled 'P' and 'T'. Unlike the variance decompositions, these historical decompositions are estimated fairly precisely. The results clearly illustrate that both demand and supply shocks are of substantial importance in generating output fluctuations. But closer inspection

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[20] The range of the Blanchard and Quah results, reported in their Tables 2 and 2A-C, reflects differences in detrending procedures.

Figure 1A: Components of Forecast Error for Output: Aggregate Supply
Output, Price and Interest Rate Model, Monthly 1910–1940
Bias Adjusted with One Std. Error Band

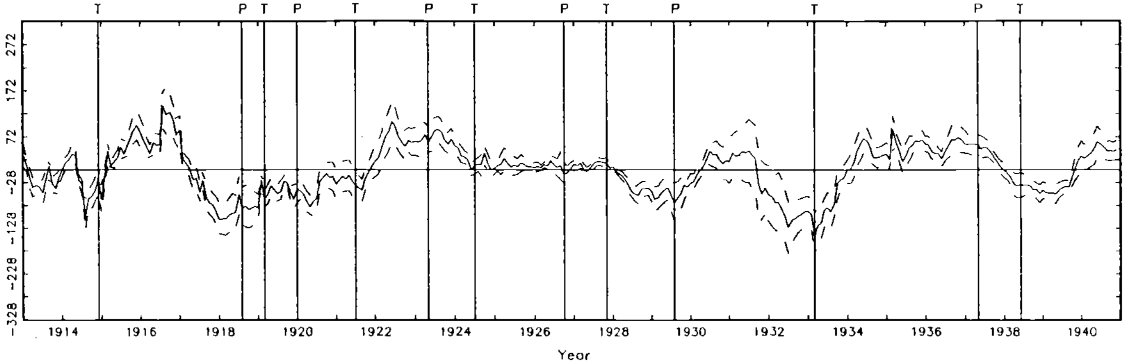
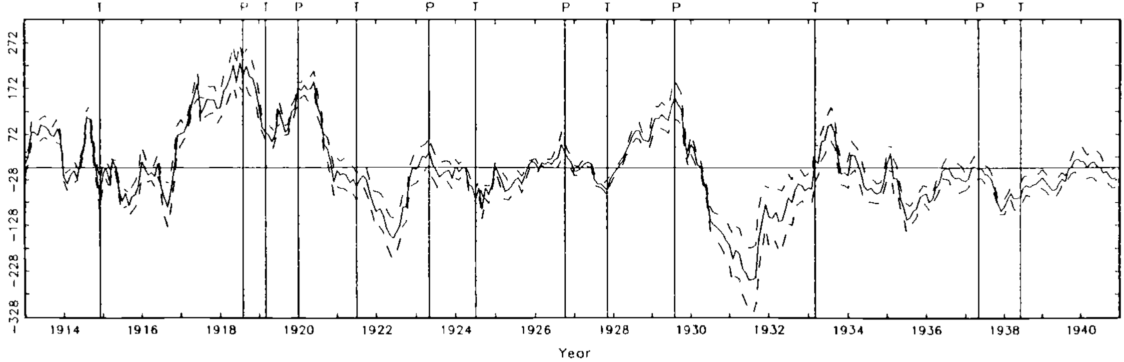


Figure 1B: Components of Forecast Error for Output: AD
Output, Price and Interest Rate Model, Monthly 1910–1940
Bias Adjusted with One Std. Error Band



allows several interesting conclusions. First, aggregate demand contractions play a dominant role in every downturn during the period. Furthermore, the estimates confirm Romer's (1988) claims that the 1920–22 recession would have been worse, had it not been for positive aggregate supply shocks.

The figure also provides substantial information about the period of the Great Depression. We note three findings that we believe to be robust to any analysis of this type. First, aggregate demand contraction bears primary responsibility for the downturn from November 1929 through late 1931. Second, the aggregate demand contraction began in earnest immediately following the stock market crash of 1929. This is the sharp decline traced out just to the right of the vertical line representing the August 1929 business cycle peak. The shock following the stock market crash is estimated to be −3.18 — the innovations are standard normal variables, and so this is a very unlikely event. In fact, it is the second largest negative shock between 1921 and 1940. The largest is an aggregate supply innovation of −4.47 in October of 1931, the month that Britain left gold and a time when the banking system was collapsing.

The third and final result concerns the importance of aggregate supply beginning in mid-1931. As Figure 1 shows, negative innovations to aggregate supply bear full responsibility for the continued decline in output throughout 1932. This is consistent with Bernanke's (1983) hypothesis that the banking panics raised the cost of credit intermediation, and caused a form of credit rationing whereby small business borrowers could no longer qualify for loans. Bernanke argues that this caused a protracted nonneutrality, inhibiting timely recovery of the economy in the 1930's. His interpretation suggests that we should equate the collapse of the banking system with the aggregate supply disturbances in the figure, but the dating of the impact is consistent with Temin's (1989, pg. 49–53) discussion of the timing of bank failures. In contrast to both Friedman and Schwartz (1963), who date the first bank panics as occurring in late 1930, and Bernanke (1983), who discusses the 1930–33 period as a whole, Temin suggests that the banking system collapse did not begin in earnest until the summer of 1931.

It is worth noting that these results provide evidence concerning the likely causes of the 1937–38 downturn. This is the recession that Friedman and Schwartz (1963) believe to have been caused by the increase in the reserve requirement in May of 1937 — a purely monetary aggregate demand disturbance. The plot in Figure 1 suggests that the causes of this output decline can be traced in large part to negative innovations in aggregate supply. While there is a large aggregate demand contraction, it does not come until November 1937, five months after the reserve requirement increase was implemented.

The remainder of this section has two goals. First, we hope to show that these results, especially those in Figure 1, are robust to changes in the specification. To this end we provide estimates of the Shapiro-Watson model. Second, we present estimates of the Galí model in an attempt to extract from the aggregate demand innovations a component that can be traced to monetary disturbances. Finally, in Section 6 we examine the implications of altering the identifying assumptions used to construct the estimates.

5.2 Shapiro–Watson: 1920 to 1940

By adding an equation for hours to the previous model, together with an additional identifying restriction, we obtain the output–hours–prices–interest rate model estimated by Shapiro and Watson. This four variable system is based on equation (3) of Section 2. As described there, Shapiro and Watson separate aggregate supply innovations into two components: one that they label labor supply and the rest, which they call technology. We present this decomposition below, but reiterate that it relies on the assumption that the labor supply curve is vertical in the long run.

Table 4 presents the variance decomposition for the Shapiro–Watson model estimated over the 1920 to 1940 sample, along with standard errors.[21] The table includes the sum of the effects of the two aggregate demand disturbances, and omits the percentage of the variance accounted for directly by the labor supply/hours innovations,

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[21] We are prevented from estimating the Shapiro–Watson model that includes hours for the full sample period beginning in 1910 since we have been unable to locate monthly data on hours worked prior to June 1920.

Table 4: Variance Decomposition, Output–Hours–Prices–Interest Rate Model (Monthly, 1920 to 1940, standard errors are in parentheses)

Source of Innovation	Horizon in Months				
	1	6	12	24	36
	Fraction of Variance in Output				
Technology	46.0	29.6	21.9	18.7	16.2
	(24.5)	(22.0)	(20.3)	(19.7)	(18.7)
Aggregate Demand	0.3	16.5	13.5	10.9	9.0
	(16.6)	(19.6)	(18.4)	(17.0)	(15.0)
	Fraction of Variance in Hours				
Technology	0.98	18.0	13.1	10.3	8.15
	(14.9)	(19.3)	(18.2)	(17.4)	(16.1)
Aggregate Demand	22.2	24.2	18.8	14.9	12.3
	(22.8)	(21.9)	(20.3)	(18.5)	(16.3)
	Fraction of Variance in Prices				
Technology	0.12	8.66	14.0	15.2	13.9
	(5.41)	(10.8)	(13.9)	(15.6)	(15.7)
Aggregate Demand	98.2	73.8	56.8	43.5	39.4
	(8.6)	(15.3)	(17.3)	(17.5)	(17.0)
	Fraction of Variance in Nominal Interest Rates				
Technology	26.5	22.2	28.2	30.5	30.5
	(21.9)	(20.3)	(20.4)	(20.5)	(20.6)
Aggregate Demand	31.2	43.3	49.4	54.9	56.3
	(24.7)	(25.9)	(25.3)	(25.3)	(25.4)

Values are the percentage of the forecast error variance explained by shocks to a particular variable. They are computed from the estimation of the equivalent of (7) subject to (4). Numbers in parentheses are standard error computed using the Monte Carlo procedure described in Section 3 with 2500 draws.

which is just 100 minus the sum of the two values reported. These results are in sharp contrast to those in Table 3. In particular, aggregate demand disturbances bear only a small amount of the responsibility for both output and hours fluctuations over all horizons, even those of less than one year. In fact, the percentage of output forecast error variance accounted for by aggregate demand at a six month horizon is 16.5%. This is far below the 55% reported in Table 3. In addition, aggregate supply disturbances, in large part in the form of labor supply shocks, now bear a much larger responsibility for real interest rate movements.

The change in the sample period is the primary reason for the difference in the variance decompositions reported in Tables 3 and 4. In estimating the three variable system of Section 5.1, we are able to use data beginning in 1910. This period includes substantial variation in output, including six full business cycles. With data from 1920 forward, our estimation actually begins in October 1921, which means that we lose the entire 1918–19 recession and part of the recession of 1920–21. Furthermore, in the longer sample period there is a clear sense in which output moves away from some trend and then comes back several times prior to the Depression. For the shorter sample, the Depression provides virtually all of the variation in output, and the economy has not moved back to trend by December 1940. This means that in the 1920 to 1940 period the identifying assumption that demand shocks are temporary forces aggregate supply to account for a larger fraction of the variance in output.[22]

Figures 2A and 2B graph the bias-adjusted historical decomposition of output into the aggregate demand and aggregate supply components, together with one standard error bands. These calculations now begin in October 1923. The results are very similar to those in Figure 1, although the standard error bands are a bit wider. In particular, there is an aggregate demand innovation of −4.35 standard deviations in November of 1929. This is the third largest drop in the sample, with larger aggregate supply drops occurring in October 1931 and in March 1933. The figure also confirms that the aggregate demand declines are the major cause of the initial fall in

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[22] These observations are confermed by estimating the three variable model over the 1920 to 1940 sample yields results similar to those reported in Table 4 for the Shapiro and Watson formulation. The estimates of the contribution of aggregate demand to output variation falls by one-half.

Figure 2A: Components of Forecast Error for Output – Aggregate Supply
Hours, Output, Price and Interest Rate Model, 1920–1940
Bias Adjusted with One Std. Error Bands

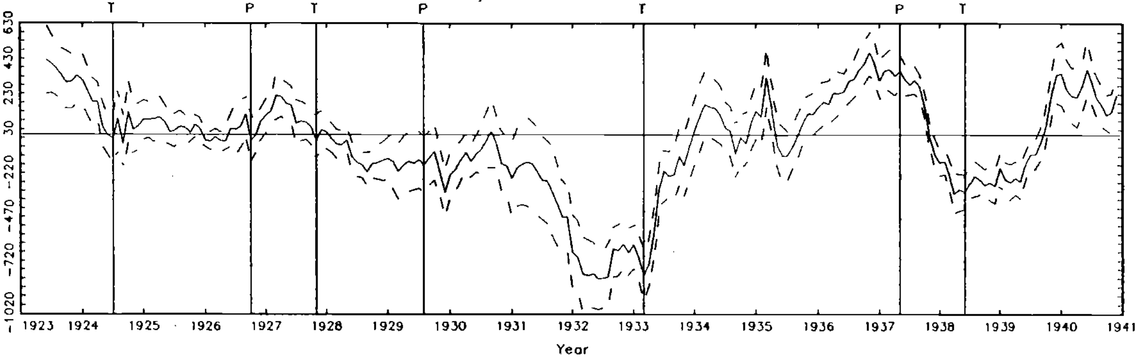
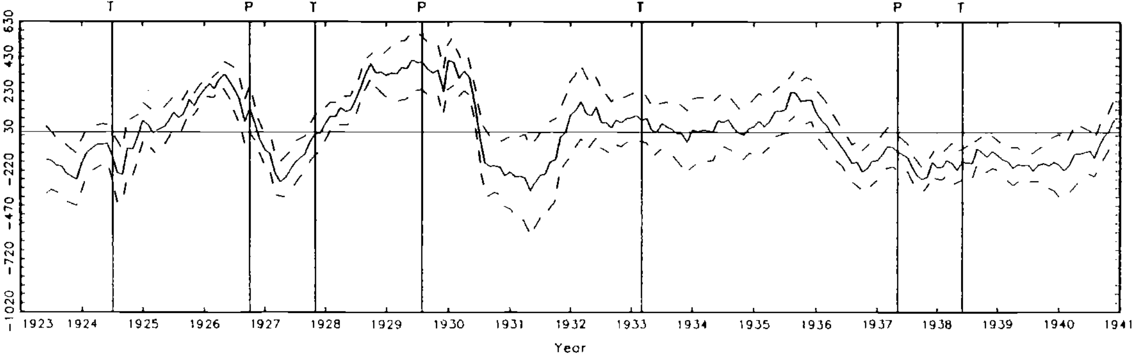


Figure 2B: Components of Forecast Error for Output – Aggregate Demand
Hours, Output, Price and Interest Rate Model, 1920–1940
Bias Adjusted with One Std. Error Bands



output beginning in 1929 and continuing through mid-1931, and that, beginning in mid-1931, aggregate supply contraction is the major cause of the continued decline. Finally, these results reinforce the conclusion that aggregate demand shocks cannot fully account for the 1937–38 downturn.

Using the Shapiro–Watson identification, we can decompose output fluctuations into a portion due to the labor supply shocks and one resulting from technological innovations. The results, bias-adjusted along with standard errors, are plotted in Figures 3A–C. The estimates imply that the bulk of the decline in output from July 1931 to March 1933 can be accounted for by negative labor supply innovations. This very unappealing result causes us to question the relevance for our sample period of the assumption used by Shapiro and Watson to identify labor supply shocks.

While we present evidence for two specific models, we have examined numerous other specifications in order to insure the robustness of the conclusions stated above. These alternatives included using both M1 and M2 in place of the interest rate in the both models, replacing the commercial paper rate with either the stock market time loan rate or a Treasury security rate, substituting the wage for hours in the Shapiro–Watson model, and changing the sample period for the estimation, including estimating the three variable model using data from 1910 to 1990. Regardless of the specification, the major results for the historical decompositions always survive: (1) there was a very large negative innovation to aggregate demand immediately following the stock market crash of October 1929, (2) aggregate demand accounts for the bulk of output fluctuations from August 1929 to mid-1931, and (3) aggregate supply contraction accounts for the continued decline in output from mid-1931 to early 1933.

5.3 IS-LM Decomposition: The Galí Model

We now move to the results implied by the Galí estimation procedure discussed in Section 2.2. Restricting two contemporaneous effects allows us to separate aggregate demand shocks into three components. Table 5 reports the variance decomposition when the model is estimated using data on output, the nominal interest rate, the

Figure 3A: Components of Forecast Error for Output – Labor Supply
Hours, Output, Price and Interest Rate Model, 1920–1940
Bias Adjusted with One Std. Error Bands

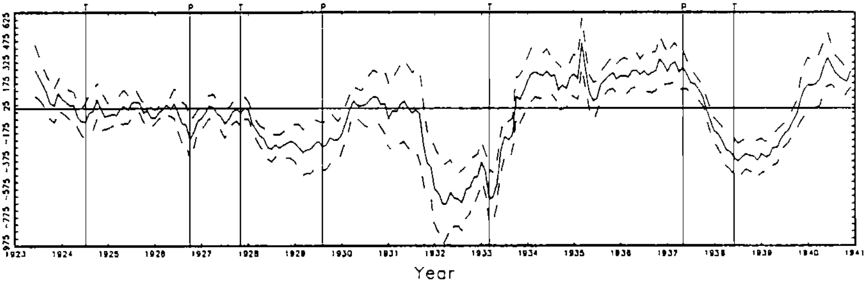


Figure 3B: Components of Forecast Error for Output – Technology
Hours, Output, Price and Interest Rate Model, 1920–1940
Bias Adjusted with One Std. Error Bands

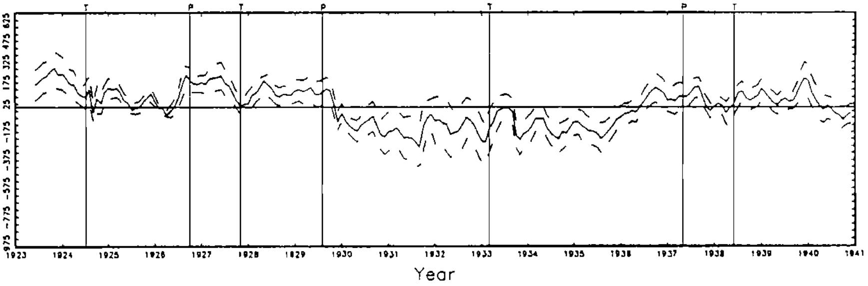
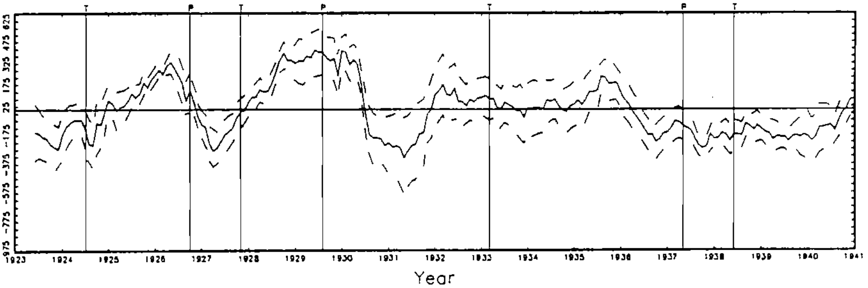


Figure 3C: Components of Forecast Error for Output – Aggregate Demand
Hours, Output, Price and Interest Rate Model, 1920–1940
Bias Adjusted with One Std. Error Bands



real interest rate, and real M2 from 1910 to 1940. The table reports the impact of money supply shocks, money demand shocks, and IS shocks on the four variables in the model. We omit the impact of aggregate supply innovations, as this is simply 100 minus the three values that are reported.

Aggregate demand shocks now account for roughly one-half of the output forecast error variance at horizons of less than twelve months. Of this, IS shocks appear substantially more important as LM shocks. For example, at a twelve month horizon, 43.6% of the variance in output forecasts is accounted for by IS innovations, 3.2% by money supply innovations and 2.2% by money demand innovations. It is also interesting to note that the variance of nominal interest rate forecasts is accounted for almost entirely by a combination of money supply and IS shocks, while it is money demand shocks that are important in accounting for real interest rate variability. This last finding differs substantially from the Galí estimates derived using quarterly post-WWII data and reported in his Table 4. He finds that the nominal interest rate is substantially affected by money supply shocks at short horizons but the impact dies off rapidly, falling to 15% after 5 quarters. At longer horizons it is IS shocks that dominate. Finally, Galí finds that money supply innovations are largely responsible for real interest rate fluctuations, accounting for 88% of the forecast error variance at 1 quarter, falling to 58% at a 10 quarter horizon.

Figures 4A, 4B and 5A through 5D present the bias-adjusted estimates and standard errors of the historical decomposition of output forecast errors using the Galí framework. Figure 4 provides the aggregate supply and aggregate demand components together, while Figure 5 plots aggregate supply and the three identifiable components of aggregate demand separately.

The results in Figures 4A and 4B are very similar to those in Figures 1A and 1B, although the estimates contain more noise and the standard error bands are somewhat wider beginning in 1931. But again, the figures reveal a large aggregate demand decline following the stock market crash, with a continued decline through the middle of 1931. Beginning in mid-1931 aggregate supply begins to fall, bearing the bulk of the responsibility for the continued output contraction through 1932 and

Table 5: Variance Decomposition, Galí Model
(Output–Nominal Interest Rate–Real Interest Rate–Real M2,
Monthly, 1910 to 1940, Standard Errors are in Parentheses)

Source of Innovation	Horizon in Months				
	1	6	12	24	36
	Fraction of Variance in Output				
Money Supply	0.00	0.61	3.21	5.47	5.62
	(0.00)	(2.27)	(4.06)	(6.74)	(7.83)
Money Demand	0.00	0.83	2.21	1.59	1.52
	(0.00)	(1.59)	(2.70)	(3.16)	(3.57)
IS	52.5	53.3	43.6	26.8	21.0
	(29.0)	(29.5)	(28.5)	(25.8)	(24.1)
	Fraction of Variance in Nominal Interest Rate				
Money Supply	6.53	3.68	2.89	5.77	10.2
	(31.4)	(31.1)	(28.0)	(22.5)	(18.0)
Money Demand	33.5	33.9	27.8	18.8	14.1
	(19.4)	(19.2)	(16.3)	(12.5)	(10.6)
IS	17.4	25.0	39.2	54.4	60.1
	(15.7)	(17.4)	(18.6)	(19.6)	(19.9)
	Fraction of Variance in Real Interest Rates				
Money Supply	4.47	3.57	4.43	10.0	11.6
	(2.28)	(2.68)	(3.55)	(4.70)	(5.11)
Money Demand	48.4	47.8	50.3	46.2	45.3
	(26.7)	(23.0)	(19.2)	(15.9)	(15.1)
IS	36.3	37.9	34.1	30.3	29.4
	(20.5)	(19.1)	(16.0)	(13.6)	(13.0)
	Fraction of Variance in Real M2				
Money Supply	66.6	51.4	39.2	39.1	39.2
	(50.6)	(42.8)	(35.9)	(37.3)	(37.8)
Money Demand	14.7	11.0	10.5	6.90	5.16
	(37.8)	(36.1)	(36.2)	(31.8)	(29.4)
IS	3.28	10.6	15.4	14.1	13.7
	(19.1)	(21.5)	(22.7)	(22.5)	(22.5)

Variance decomposition computed from estimation of the Galí model, (5), subject to the constraints described in the text. Numbers in parentheses are standard error computed using the Monte Carlo procedure described in Section 3 with 2500 draws.

Figure 4A: Components of Forecast Error for Output – Aggregate Supply
Gali Model, Monthly 1910–1940, SA
Bias Adjusted with One Std. Error Bands

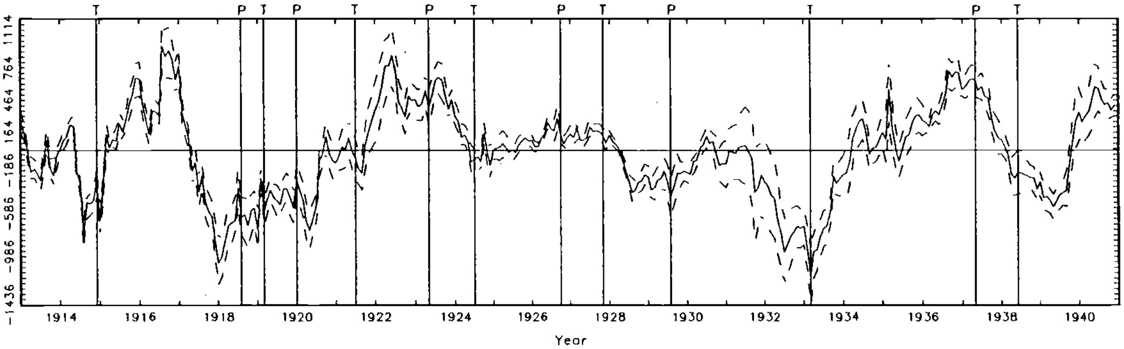


Figure 4B: Components of Forecast Error for Output – Aggregate Demand
Gali Model, Monthly 1910–1940, SA
Bias Adjusted with One Std. Error Bands

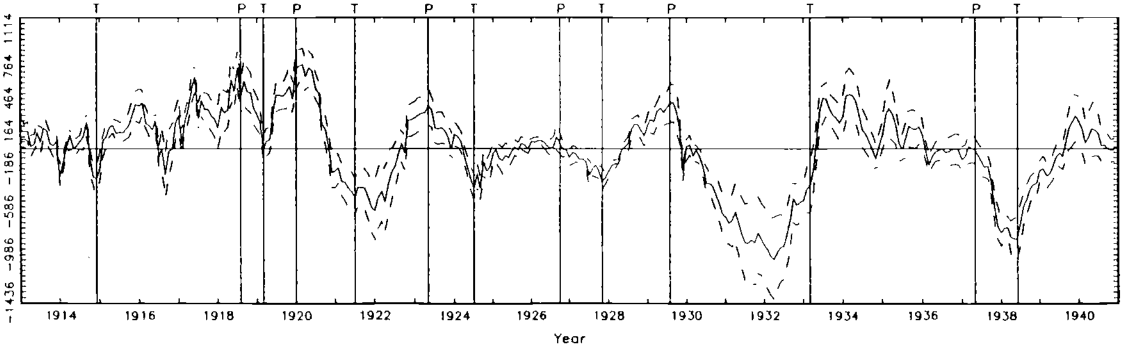


Figure 5A: Components of Forecast Error for Output – Aggregate Supply
Gali Model, Monthly 1910–1940
Bias Adjusted with One Std. Error Bands

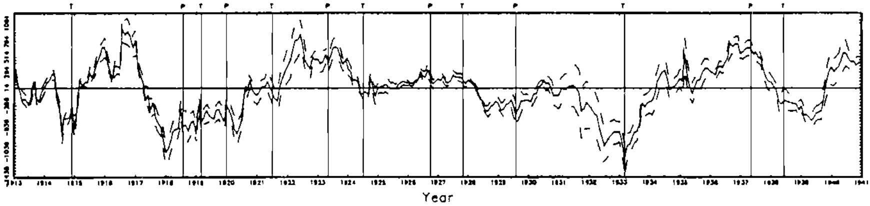


Figure 5B: Components of Forecast Error for Output – Money Supply
Gali Model, Monthly 1910–1940
Bias Adjusted with One Std. Error Bands

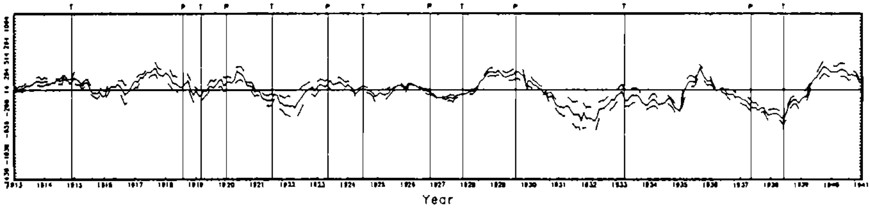


Figure 5C: Components of Forecast Error for Output – Money Demand
Gali Model, Monthly 1910–1940
Bias Adjusted with One Std. Error Bands

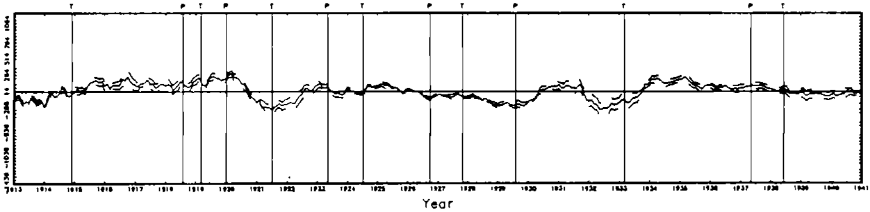
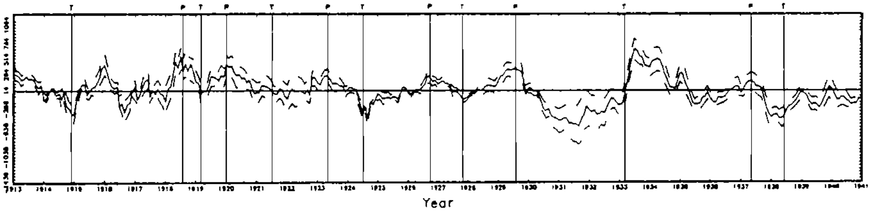


Figure 5D: Components of Forecast Error for Output – IS
Gali Model, Monthly 1910–1940
Bias Adjusted with One Std Error Bands



into 1933.

Figures 5A-D report the components of the output forecast error that can be accounted for by aggregate supply, money supply, money demand, and the IS component separately. Several features of these plots are worth noting. First, the decline in output from the peak in August 1929 until late 1931 is entirely due to money supply and IS shocks. Money demand and aggregate supply shocks bear responsibility for the continued decline during 1932. Furthermore, the money supply and IS components are of roughly equal magnitude in their contributions to the output decline during the entire Depression period, while their sum is approximately the same size as that attributable to aggregate supply. The plots also reveal that negative IS shocks are present during all of the recessions in the sample, and that, with the exception of a sharp fall during the 1920–22 recession, money demand is relatively unimportant.

These results suggest several conclusions. First, they substantiate Romer's (1990) hypothesis that the stock market crash created an immediate decline in aggregate demand that was nonmonetary in its origin. Second, there is clearly evidence that monetary shocks, both demand and supply, contributed to the output decline beginning in late 1929 and going through mid-1932, and that the magnitude of the effects was large. Taken as a whole, these results suggests that the simplest form of the Friedman and Schwartz (1963) monetary hypothesis must be supplemented in order to explain the full extent of the contraction in the early 1930s.[23]

6 Robustness

The results presented thus far all point to the same conclusions. The historical decompositions show the same pattern, and the estimates are for the three variable output-price-interest rate model for the Galí model are very precise. But the estimates all rely on the use of the long run identifying restrictions suggested by Blanchard and

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[23] These results are also supported by a three variable model with output prices and interest rates in which we identify IS from LM shocks by assuming that only IS shocks can affect the real interest rate in the long run. Estimation of this model over the 1910 to 1940 sample yields results that are very similar to those reported for the Galí model above.

Quah, in which only aggregate supply shocks have permanent effects.

In a recent paper, Galí and Hammour (1991) estimate the *long run* effects of aggregate demand fluctuations. By assuming that aggregate demand shocks have no contemporaneous influence on productivity, they are able to identify the long run effect of both aggregate supply and aggregate demand shocks on output. Their findings suggest that the two shocks have long run impacts that are roughly of the same magnitude, but of opposite sign.

Using these results, we can study an alternative identification. Concentrating on the three variable model of Section 2.1, we examine the implication of assuming that $a_{y2} = 0$ and that $a_{y1} = \rho a_{ys} < 0$. This identification implies that the first aggregate demand shock, v_t^1, has a permanent negative impact on output that is ρ times the magnitude to the long run impact of the aggregate supply shock. In addition, the second aggregate demand shocks, v_t^2, has a purely temporary effect on output. This new restriction allows estimation of the model in a manner analogous to that described in Section 3.

Figures 6A and 6B report the results of the historical decompositions for the base case of $\rho = 0$ and for the case of $\rho = -1$.[24] In both plots the solid line represents the aggregate demand component and the dashed line plots the output movements that are attributed to aggregate supply shocks. The general character of the conclusions is unchanged. There is a large negative aggregate demand shock following the stock market crash, and aggregate demand contraction ceases to be an important component of the Great Depression by the middle of 1931.

7 Conclusion

This paper has used long run restrictions to decompose output fluctuations during the interwar period into components resulting from aggregate supply and aggregate demand shocks. We provide estimates of both the relative importance of aggregate supply and demand on average — the variance decomposition — as well as an account-

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[24] We obtain similar results for ρ equals -0.5 and -0.25.

Figure 6A: Components of Forecast Error for Output
Output, Price and Interest Rate Model, Monthly 1910–1940
RHO = 0

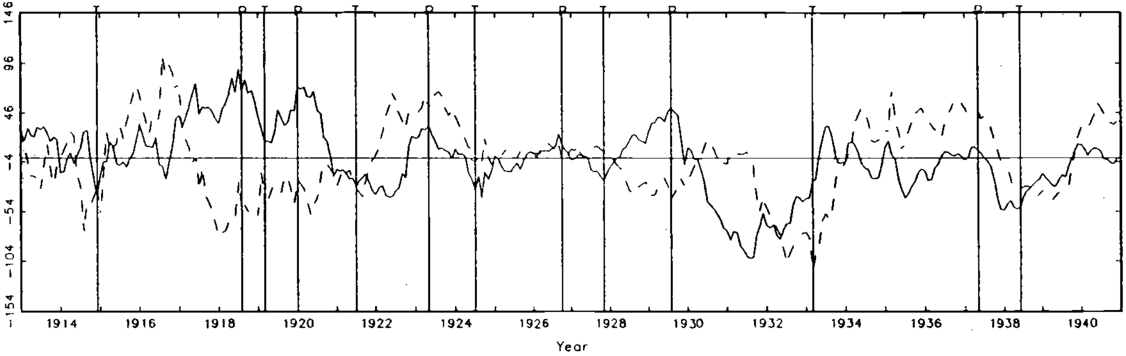
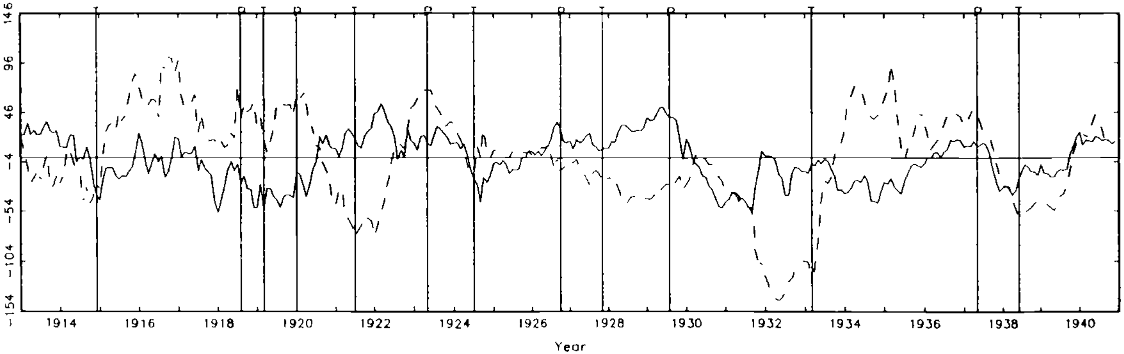


Figure 6B: Components of Forecast Error for Output
Output, Price and Interest Rate Model, Monthly 1910–1940, NSA
RHO = -1



Solid Line - Aggregate Demand, Dashed Line - Aggregate Supply ing of the likely source of specific movements in output — an historical decomposition of the output forecast errors. This historical decomposition allows us to draw conclusions about the empirical importance of competing hypotheses about the causes of the length and depth of the Great Depression of the 1930s.

We present estimates of three models that all support the following conclusions. First, there was a large, negative aggregate demand shock in November 1929, immediately following the stock market crash. In addition, continued negative aggregate demand shocks are largely responsible for the decline in output through mid to late 1931. This is consistent with the Romer (1990) version of Temin's (1976) hypothesis that a consumption collapse contributed greatly to the depth of the Depression. Finally, beginning in mid to late 1931, there is an aggregate supply collapse, including a very large negative shock in October of 1931. The timing of the aggregate supply decline coincides with the onset of severe bank panics, providing evidence for Bernanke's (1983) view that the collapse of financial intermediation bears a large responsibility of the extent for the decline.

Our aggregate supply – aggregate demand decompositions are based solely on the restrictions that encompass a broad class of economic models in general use today. While the bulk of our results assume that aggregate demand shocks do not have long run real effects, we also provide evidence that our conclusions are the same when demand shocks have permanent negative effects on output. Any explanation of output movements during the 1930s that employs one of these models must account for the pattern of shocks that we find. In particular, any theory primarily based on monetary policy errors must explain the very large aggregate demand decline that began in November of 1929. By the same token, theories based solely on aggregate demand contractions must be augmented to include some explanation of the aggregate supply contract that began in 1931 and ended in 1933.[25]

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[25] These findings are consistent with those in Fackler and Parker (1990). Using Bernanke's (1986) structural vector autoregression (VAR) procedure, they conclude that no single theory is capable of explaining the Depression by itself.

Data Appendix

This appendix describes the data used in the paper. For the three variable model of Section 3.1, and the Galí model of Section 3.3, the sample period is from January 1910 to December 1940. For the Shapiro and Watson model of Section 3.2, we use data from June 1920 to December 1940. All data are seasonally unadjusted, and are available in machine readable form upon request.

Industrial Production:

Prior to 1919, the data are the new series collected by Miron and Romer (1990). Beginning in January 1919, we use the Federal Reserve index of industrial production for manufacturing. Since it has wider coverage, we use the FRB index for the period when it is available.

Hours:

The monthly data on hours from the various publications of the National Industrial Conference Board. The numbers measure total manhours worked for all wage earners in twenty-five manufacturing industries. From June 1920 to December 1921, and July 1922 to December 1933, the data are from Beney (1936) Table 2, pages 44 to 47. From January 1934 to December 1938 the data are from Sayre (1940) Table 1, pg. 115 to 116. From January 1939 to December 1939, the data are from Sayre (1941a) pg. 17. And, for 1940 the data are from Sayre (1941b) pg. 144. To construct the six missing observations from January to June 1922, we constructed an index by multiplying total production worker employment from U.S. Department of Labor (1991), pg. 56 times NBER (1991) Series *M08628*, average hours of work per week, production workers, manufacturing.

Prices:

The monthly consumer price series was constructed by splicing together three series. From January 1910 to January 1912, the data are NBER (1991) Series *M04055*, the cost of living index for the Massachusetts. For the period 1913 to 1940, this series has correlation 0.988 with the level of price series described below, and a correlation of 0.728 with the growth rates. From January 1913 to December 1919 the raw data are the U.S. Department of Labor, Bureau of Labor Statistics Consumer Price Index. From January 1920 to December 1940 the raw data are the National Industrial Conference Board all-items consumers' price index published in Sayre (1948) Table 1. It does not appear that the BLS collected and published a monthly series on the prices of consumer goods during the 1920's and 1930's. The all items CPI data that are currently available for this period seem to have been created from data sampled at a lower frequency and then interpolated using some component series. The quarterly consumer price series is then constructed by taking the last observation of each quarter of the monthly series.

Interest Rates:

The interest rate data are the sixty to ninety day commercial rate, NBER (1991) Series *M13024*. From January 1910 to January 1937, these are from Macaulay (1938) pp. A142–161. From February 1937 to December 1940, the data are computed by the NBER from weekly data in the *Commercial and Financial Chronicle.*

Money Stock:

All data on money are from Friedman and Schwartz (1963) Appendix A. Data on M2 are taken Table A-1.

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