Did Sunspot Forces Cause the Great Depression?*

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Abstract

We apply a dynamic general equilibrium model to the period of the Great Depression. In particular, we examine a modification of the real business cycle model in which the possibility of indeterminacy of equilibria arises. In other words, agents' self-fulfilling expectations can serve as a primary impulse behind fluctuations. We find that the model, driven only by these measured sunspot shocks, can explain well the entire Depression era. That is, the decline from 1929-1932, the subsequent slow recovery, and the recession that occurred in 1937-1938.

1 Introduction

There has been a recent resurgence in interest among macroeconomists in the Great Depression. Perhaps because of the recent events in two leading industrial

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economies – the record-long boom in the U.S. and Japan's continual depression – curiosity about this unique episode has piqued. Of particular relevance to us is the application of neoclassical modelling techniques, which had previously only been applied to postwar episodes, to this historic period. For example, Cole and Ohanian (1999a) examine the efficacy of the real business cycle model at explaining both the decline from 1929 to 1933 and the subsequent slow recovery throughout the rest of the decade. While their model explains 40% of the decline, they are left with the puzzle of how to explain the weakness of the U.S. recovery. They suggest that some other type of shock must be responsible.

In this paper we identify such a shock. In particular, we examine a modification of the real business cycle model in which the possibility of indeterminacy of equilibria arises. The indeterminacy arises when, in the presence of relatively low increasing returns to scale in production, changes in agents' expectations are self-fulfilling and therefore serve as a primary impulse behind fluctuations. We find that such a model, driven only by these measured sunspot shocks, can explain well the entire *Depression era.* That is, the decline and subsequent slow recovery as well as the major recession that occurred in 1937-1938. Because of this, we believe that we have found the "other shock."

Most popular theories of the Great Depression stem from Friedman and Schwartz' (1963) monumental work blaming inept monetary policy, or reprehend bank failures for deteriorating the effectiveness of financial intermediaries (Bernanke, 1983). These findings are related to the often stressed viewpoint that the United States' adherence to the Gold Standard was a crucial element of the economic decline (Eichengreen, 1992). In more recent work, Bordo, Erceg and Evans (2000) identify a sequence of negative shocks to money growth dating from 1930:I to 1933:I, which coincides with the U.S. administration completely abandoning the Gold Standard in April of 1933. They evaluate these shocks in a model with nominal wage stickiness and find that these money growth innovations help to explain a large share of the decline in output experienced over that period.

However, both Bordo et al. (2000) and Cole and Ohanian (1999a) find that their models predict a swift recovery as well, when in fact output stayed depressed for the complete decade: per capita output still remained more than twenty percent below trend in 1939. In Bordo et al. (2000), expansionary policies by the Federal Reserve, in which money supply grew at spectacular rates after 1932, induce a quickly rebounding economy.[1] In Cole and Ohanian (1999a), it is total factor productivity that started to return to trend very quickly.

This all suggests that important nonmonetary, domestic forces kept the economy off track. Correspondingly, Bordo et al. (2000) and Cole and Ohanian (2001) shift attention to New Deal labor policy that facilitated inflating real

[1] Cole and Ohanian (2000), however, claim that the macroeconomic effects of the money and banking shocks of the 1930s appear to be small in general equilibrium.

wages. Still, Cole and Ohanian's (2001) technology-driven cartel-model closes the reported gap between the perfect markets real business cycle model and U.S. output by only a half. Perhaps even more important, it appears to miss the 1937-1938 recession – the third largest recession in American history in terms of output loss – altogether.[2]

Here, we look towards shocks to confidence as an alternative explanation for the entire Depression era, as we have defined it above. Of course, ours is not the first approach that highlights the effects of changes in confidence during the Depression. For example, Temin (1976) emphasizes a sudden contraction of aggregate demand after 1929. In conventional Keynesian jargon, he classifies this drop as a collapse of autonomous spending. Romer (1990) picks up on his observation and reports an increasing state of uncertainty following the October 1929 stock market crash. Indeed, she finds that this uncertainty led to delaying expenditures on durable goods. Both Temin (1976) and Romer (1993) note that expectations turn from uncertain to pessimistic during 1930. Temin writes:[3]

> "Sometime in the fall of 1930, then, businessmen became convinced that prosperity was no longer just around the corner. The timing of this change is not known with precision, but it came approximately one year after the stock market crash [...], and not everyone appears to have been conscious of it as it happened." [Temin, 1976, p. 79]

Moreover, Simons (1948) places great emphasis on the state of business confidence in explaining the Great Depression. Such evidence can also be found outside of the academic literature in economics. As exemplified in the following quote from *Business Week*, the public recognizes depressed expectations by as early as the Spring of 1930:

> "Business is now suffering chiefly from a pain in the expectations." [*Business Week*, May 14, 1930, p. 1]

We take these ideas a step further and propose that changes in nonfundamental confidence were the driving force behind all three events of the Great Depression era. That is, we hypothesize that the deep and prolonged extrinsic pessimism of agents can be explained by factors unrelated to fundamentals. In support of this idea, Hart (1933), a contemporary sociologist concludes:

> "[t]hat the depression has been fundamentally a psychological phenomenon has been reiterated at intervals in various magazines." [Hart, 1933, p. 677]

[2] Cole and Ohanian also do not provide a theory for the years 1929 to 1934 but rather simply calibrate their model to be 24 percent below its steady state in 1934.

[3] See also Schumpeter (1939, p. 911).

We propose, as did Temin, that the delayed fall in confidence caused what might have been a typical recession to worsen:

> "As the Depression deepened, adverse expectations kept [...] spending low." [Temin, 1976, p. 10]

In order to test this hypothesis, we apply the notion that *animal spirits* cause swings in economic activity by confronting a general equilibrium model to the Great Depression. In particular, we follow recent research in macroeconomics that focuses on models in which business cycles are driven by self-fulfilling changes in agents' beliefs.[4] In such models, a continuum of rational expectations equilibria, indexed by these beliefs, are possible. In the model we study, with varying capital utilization and externalities in production, indeterminacy obtains at empirically reasonable departures from constant returns.

To assess the accuracy of the model at replicating the facts, we feed in a series of sunspot shocks that we find to best reflect the behavior of nonfundamental confidence during the Great Depression era. As indices of confidence are not available for this period, we argue that an appropriately chosen interest rate spread, which widens when a recession is expected, serves as a proxy. In particular, we use the spread between the return on Baa rated bonds and Aaa rated bonds – an instrument widely used for default risk (see for example Bernanke, 1990, and Friedman and Kuttner, 1993). We then construct a vector autoregression model (VAR) in which the residual from a regression of the spread on fundamentals is taken to measure nonfundamental confidence.[5] Given these shocks, we find that our theory can account for important historical facts. In particular, our model predicts a fall in confidence after 1929, followed by a drastic decline in output. That is, in 1929 the economy appears to have been in a typical recession; and the fall in confidence caused the recession to deepen into a depression. The model also outperforms those in previously cited work by replicating well the recovery and the 1937-1938 recession.

Perhaps the most closely related work is that of Cooper and Ejarque (1995) and Cooper and Corbae (2000), who analyze the Great Depression from the standpoint of a monetary economy with increasing returns in the intermediation process. These scale economies imply multiple equilibria; and confidence in the financial system determines which of the solutions is realized. These authors find that nonfundamental shocks may have played an important role, particularly in connection with bank panics. However, the final banking crisis took place in January 1933. Thus their models also do not provide much insight for

[4] Early work includes Woodford (1991); and Benhabib and Farmer (1999) offer an excellent survey of the literature.

[5] We considered using the Euler errors from the model as the sunspot shocks. As this requires quarterly data, not all of which is available, and additional assumptions about the capital stock and the utilization rate, we chose instead to find a measure of confidence in the data.

the slowness of the recovery. Furthermore, the above papers neither estimate sunspots nor do they simulate the model.

The rest of this paper proceeds as follows. In section 2 we outline the model. In sections 3 and 4 we compute the sunspot shocks and feed them into the model. Section 5 examines the robustness of our results and section 6 concludes.

2 The model

In this section we present the model, discuss the calibration we use, and briefly report on qualitative dynamics. The model is based on Greenwood, Hercowitz and Huffman (1988) and Wen (1998). It is a standard one-sector dynamic general equilibrium model with variable capital utilization as in Burnside and Eichenbaum (1996) and production externalities.[6] Given a certain degree of externalities, the equilibrium of the model is indeterminate and the economy is subject to extrinsic uncertainty. We assume that the economy is populated by a large number of identical consumer-worker households, each of which lives forever. The problem faced by a representative household is

$$\max_{\{c_t, l_t, u_t, k_{t+1}\}} E \sum_{t=0}^{\infty} \beta^t \left[(1-\eta)\log c_t - \eta l_t\right] \tag{1}$$

$$\text{s.t. } c_t + x_t = y_t = A_t^{\gamma}(u_t k_t)^{\alpha} l_t^{1-\alpha}, \tag{2}$$

$$A_t = (\overline{u}_t \overline{k}_t)^{\alpha} \overline{l}_t^{1-\alpha}, \tag{3}$$

$$k_{t+1} = (1-\delta_t)k_t + x_t, \tag{4}$$

and

$$\delta_t = \frac{1}{\theta} u_t^{\theta}, \tag{5}$$

given an initial stock of capital, $k(0) > 0$. We restrict the parameters $0 < \alpha < 1$, $0 < \beta < 1$, $\gamma \geq 0$, $0 < \eta < 1$, and $\theta > 1$. The variables c_t, l_t, x_t, k_t, and u_t denote consumption, labor, investment, capital, and the capital utilization rate. As in most studies of variable capital utilization, the rate of depreciation, δ_t, is an increasing function of the utilization rate. The economy as a whole is affected by organizational synergies that cause the output of an individual firm to be higher if all other firms in the economy are producing more. A_t stands for these aggregate externalities where bars over variables denote average economy-wide levels. The production complementarities are taken as given for the individual optimizer and they cannot be priced or traded. Deviations from constant returns to scale are measured by γ. All markets are perfectly competitive.

[6] Bresnahan and Raff (1991) suggest that at least twenty percent of the aggregate capital stock was idle between 1929 and 1933. Thus, variable capital utilization may be an important factor for any model of the Great Depression.

In symmetric equilibrium, the first order conditions entail

$$\frac{\eta}{1-\eta} l_t = (1-\alpha)\frac{y_t}{c_t}, \tag{6}$$

$$u_t^{\theta} = \alpha \frac{y_t}{k_t}, \tag{7}$$

$$\frac{1}{c_t} = E_t \frac{\beta}{c_{t+1}} \left(\alpha \frac{y_{t+1}}{k_{t+1}} + 1 - \frac{1}{\theta} u_{t+1}^{\theta} \right), \tag{8}$$

$$k_{t+1} = (1 - \frac{1}{\theta} u_t^{\theta}) k_t + x_t, \tag{9}$$

$$c_t + x_t = y_t = (u_t k_t)^{\alpha(1+\gamma)} l_t^{(1-\alpha)(1+\gamma)} \tag{10}$$

and a transversality condition.[7]

Next we calibrate the model using parameter values, summarized in Table 1, that are typically found in the real business cycle and indeterminacy literatures. We choose parameters for our model economy so that it mimics certain ratios of the actual U.S. economy that are more or less constant. The fundamental period in the model is a quarter. The capital share, α, is 36 percent and the steady state rate of depreciation is 2.5 percent. The discount factor, β, is set at $1.03^{-1/4}$ which implies an annual steady state return of about three percent. The weight on utility of labor, η, has no influence on equilibrium dynamics and therefore need not be calibrated. Finally, increasing returns must be calibrated. Bernanke and Parkinson (1991) conclude that data suggest significant increasing returns during the interwar years.[8] Burns (1936) also points to some evidence for increasing returns during the depression years. Recent estimates for the U.S. economy (Basu and Fernald, 1997) indicate that scale economies are small. Our value of 1.25 cannot be rejected in their regressions, though it is likely near the ceiling of empirically plausible values.[9] In Section 5 we demonstrate the robustness of our results with respect to choice of this parameter.

Table 1: Model Calibration

α	β	δ	γ
0.36	$1.03^{-1/4}$	0.025	0.25

(11)

[7] Mulligan (2002) and Weder (2001) suggest that equation (6) may not have held during the Great Depression period (especially in the later part). Introducing shocks to account for this (potentially reflecting monetary or preference shocks) to our model would improve our results. However, we wish to isolate the effects of sunspot shocks; and so we therefore do not incorporate other shocks into this analysis.

[8] In addition, they find some evidence of varying capital utilization.

[9] Note that Cole and Ohanian (1999b) suggest a basic problem which implies that measuring increasing returns must remain imprecise: insufficient variations in factor inputs. They conclude that currently available methods are not adequate to return estimates of scale economies such that we can eventually draw a conclusive diagnosis against or in favor of models with indeterminacy.

2.1 Steady state and dynamics

Next we derive the steady state. Denoting steady state values with no time subscripts, the Euler equation becomes

$$\frac{1}{\beta} = \alpha \frac{y}{k} + 1 - \delta, \tag{12}$$

which allows us to compute y/k. Given our parameterization, on an annual basis, capital is 2.78 times that of output. This value conforms to the findings in Maddison (1991) who reports ratios of gross non-residential capital stock to GDP of 2.91 in 1913 and of 2.26 in 1950. The first order condition with respect to capital utilization together with the Euler equation imply:

$$\frac{1}{\beta} = 1 - \delta(1 - \theta), \tag{13}$$

which results in $\theta = 1.30$. The law of motion of the capital stock in steady state gives

$$\delta = \frac{x}{k}, \tag{14}$$

which yields a steady state investment share of 28 percent. This is close to the U.S. investment share in 1929.

Turning to dynamics, it is straightforward to show that our model possesses a unique interior steady state. We then take log-linear approximations to the equilibrium conditions to obtain the following dynamic system:

$$\begin{bmatrix} \widehat{x}_{t+1} \\ \widehat{k}_{t+1} \end{bmatrix} = \mathbf{J} \begin{bmatrix} \widehat{x}_{t} \\ \widehat{k}_{t} \end{bmatrix} + \mathbf{R} \begin{bmatrix} \omega_{t+1} \\ 0 \end{bmatrix} \tag{15}$$

where hat variables denote percent deviations from their steady-state values; and $\mathbf{J}$ is the 2×2 Jacobian matrix of partial derivatives of the transformed dynamic system.[10] Here $\omega_{t+1} \equiv E_t \widehat{x}_{t+1} - \widehat{x}_{t+1}$ is the expectational error, which is by definition serially uncorrelated and mean zero. Mathematically, indeterminacy requires then that both eigenvalues of $\mathbf{J}$ are inside the unit circle. In our model calibration, indeterminacy arises for external effects exceeding 1.1.

Indeterminacy in rational expectations implies that equilibria are possible in which fluctuations in economic activity are driven by arbitrary and self-fulfilling changes in people's expectations. It should be stressed that such sunspot equilibria are not based on agent irrationality – under the circumstances it is perfectly rational to believe in *crowd psychology*. The economic mechanism that creates the continuum of solutions in our particular model is closely related to the mechanism that creates the persistence. Let us elaborate with an example. Upon pessimistic expectations about the future, the household anticipates lower prospective income. Today's consumption expenditures will be reduced. As a

[10] See the Appendix for a more complete description of the linear model.

consequence, the labor supply curve shifts outwards. To understand the effect on employment, one must take into account that labor demand may be unconventionally sloped which can be seen from combining the first-order conditions (in symmetric equilibrium):

$$u_t^{\theta} = \alpha \frac{y_t}{k_t}$$
$$y_t = (u_t k_t)^{\alpha(1+\gamma)} l_t^{(1-\alpha)(1+\gamma)},$$

to get

$$y_t = \text{const} * k_t^{\frac{\alpha(1+\gamma)(\theta-1)}{\theta-\alpha(1+\gamma)}} l_t^{\frac{(1-\alpha)(1+\gamma)\theta}{\theta-\alpha(1+\gamma)}}. \quad (16)$$

Given our calibration, the effective labor-output elasticity exceeds unity,

$$\frac{(1-\alpha)(1+\gamma)\theta}{\theta-\alpha(1+\gamma)} = 1.18 > 1 \quad (17)$$

implying that the reduced-form labor demand curve is upward sloping.[11] Therefore, employment and investment slump today. The future capital stock, output and consumption will be low and initially pessimistic expectations are self-fulfilled. Sunspot movements remain stationary since decreasing utilization costs eventually bring the contraction to a halt. This is similar to the accelerator-multiplier mechanism that produces endogenous fluctuations in *ad hoc* models.

3 Computing Sunspots

The goal of this paper is to determine whether nonfundamental changes in expectations can explain the fluctuations that occurred during the Great Depression era, which we define as encompassing the decline from 1929-1933, the subsequent slow recovery from 1934-1936, and the recession of 1937-1938. In the context of our model, in other words, among the infinite number of possible sequences of the expectational error, ω_{t+1}, in (1), we seek the one that best describes the behavior of agents' extrinsic uncertainty during this historic period. We then evaluate the validity of our model by comparing the resulting model-generated sequences of output and other variables to true data from this era. Note that we are therefore working under the assumption that fluctuations are driven only by sunspot shocks.[12]

By definition, the shocks we choose must satisfy several properties. First, since we define them as sunspots, they must be purely nonfundamental. In other words, they are a measure of expectations or confidence that is determined independently of economic fundamentals. Second, they must be serially uncorrelated

[11] Simple algebra shows that it is always negatively sloped when $\gamma = 0$.

[12] Of course, we acknowledge that other shocks occurred this time, but this method allows us to isolate the effects of sunspot shocks.

and mean zero. In order to find a measure of nonfundamental confidence, we follow methods similar to those used in Matsusaka and Sbordone (1995) and Chauvet and Guo (2001), who work with postwar data. In particular, we construct a vector autoregression model (VAR) with a measure of confidence and several measures of fundamentals. The residual from the confidence equation will serve as our sunspot shock. Since the residuals from a regression are by definition mean zero, this property is easily satisfied. In addition, testing for serial correlation will be straightforward.

3.1 Data

In this subsection we describe our data. Though we seek to evaluate the role of sunspots in only the Great Depression Era, we theorize that the fundamental and nonfundamental determinants of confidence are the same during the period as both before and after. We were able to find consistent quarterly data on all of our variables for the period 1920 to 2000. In particular, we work with data from 1920:II to 2002:II for a total of 329 observations.[13]

The first variable of interest is a measure of confidence to use in the VAR system. While Matsusaka and Sbordone and Chauvet and Guo use the index published by the Survey Research Center at the University of Michigan, unfortunately such data is not available for the period of the Great Depression. Therefore, we must instead use another proxy.

Our idea is similar to that of Temin (1976), who quantifies the pessimism felt during the beginning years of the Great Depression. He constructs an index of expectations by taking into account changes in ratings of outstanding bonds. The particular quality boundary is just below Moody's Baa, following work by Hickman (1958). In particular, he interprets extensive net downgradings as reflecting anticipated greater risk and therefore predicting bad economic times. Similarly, Kindleberger (1989) suggests that interest spreads quantify confidence:

> "As it happened, interest rates declined sharply after the 1929 crash, except for instruments like second-grade bonds, which measure not the rate of interest but confidence." [Kindleberger, 1989, p. 78]

We therefore argue that an interest rate spread is an ideal candidate to measure confidence. In particular, if people fear a recession, for example, the spread would widen, since the anticipated risk of default on average hits lower rated companies first and foremost. Therefore, a rise in the spread represents

[13] Note that we checked the robustness of our results to sample size. Eliminating later data has a negligible effect.

a fall in confidence.[14] By turning to financial markets, we believe that we can extract a conclusive measure of investors' attitudes about the economy, and therefore their propensity to invest.[15]

In order to determine which interest rate spread to use, we focus on finding the difference between the returns on a low and a higher risk asset. We therefore use the difference between the returns on Baa rated bonds and Aaa rated bonds.[16] In this way, we eliminate any potential noise that may result from using different types (e.g. government and private) of assets. Indeed, Bernanke (1990) and Friedman and Kuttner (1993) use the same quality spread as an instrument for perceived default risk. Figure 1 plots this bond quality differential over the sample period.[17] Here we see that the spread increases after 1929 and it remains high during the 1930s. The delayed upward move may reflect the fact that confidence did not fall immediately following the stock market crash, but about a year later. In fact, the New York stock market leveled off in the first few months of 1930 and employment actually picked up from its December 1929 level. Along these lines, Dominguez, Fair and Shapiro (1988) find that even professional forecasters did not become pessimistic right away:

> "Harvard and Yale forecasting services [...] failed to anticipate the Depression and remained optimistic about economic performance following the crash." [Dominguez, Fair and Shapiro, 1988, p. 595]

Similarly, Temin (1976) and Romer (1993) find that expectations turned pessimistic during 1930. We also see that this spread's increase of more than 400 basis points during the Great Depression does not reoccur in any other recessions in recent times.[18] Our evidence therefore suggests that Baa-Aaa interest rate spreads during the Great Depression era may contain important information about non-fundamentals during this unparalleled episode in economic history.

We choose our measures of fundamentals with the following in mind. First, our variables must be good predictors of the spread. Second, if the residuals from the spread equation are to be taken to measure sunspot shocks, they must, by definition, be orthogonal to past values of the chosen fundamentals. We must

[14] Though confidence data is available after 1952, we still use the interest rate spread over our entire sample. There are two reasons for this. First, examining the interest rate spread during only the Great Depression Era, we found it to be nonstationary. Second, using the interest rate spread for the first part of the sample and a confidence index for the second would result in an inconsistent series.

[15] Our strategy is related to that of Salyer and Sheffrin (1998), in that they argue that financial markets involve expectations and therefore use financial data to compute sunspot shocks.

[16] Below we check our results for robustness to this measure of confidence.

[17] All data is from the NBER and the Federal Reserve.

[18] This stands in contrast to results in Cole and Ohanian (2000), who examine the behavior of several other short and long term spreads such as the spread between the short-run commercial paper rate and the rate on matched-maturity U.S. Treasury Bills (see Bernanke, 1990, and Friedman and Kuttner, 1993).

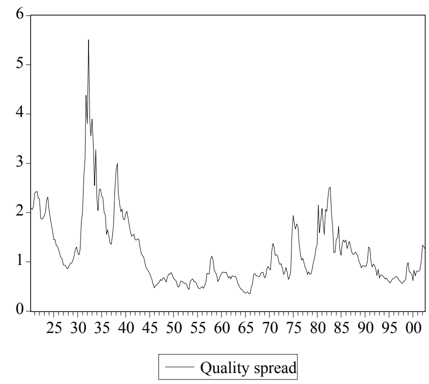

Figure 1: Baa-Aaa bond spread

therefore choose variables that capture as thoroughly as possible the state of economic activity over the sample period, so that changes in expectations due to fundamentals are accounted for in the regressions.

We use the following variables in the VAR[19]: the growth rate in real gross national product (y); the growth rate in real money supply, as measured by M2 (m); the rate of change of the GNP deflator (p); and the absolute change in the nominal return on prime commercial paper (cp).[20] Data on y provide a measure of the overall performance of the real economy. We use the widely defined real money supply to capture the effects of monetary policy. In particular, much of the literature on the Great Depression focuses on this variable, building on the work of Friedman and Schwartz (1963), who blame (non-)actions taken by the Federal Reserve as prime culprits. Money supply also reflects the workings of the intermediaries sector (i.e. the banking crises) as do interest rates (Bernanke, 1983).[21]

[19]In Section 5 we test for robustness to this set of fundamentals.

[20]Data on y, are from Balke and Gordon (1986) and NIPA. Data on m, p and cp are from Balke and Gordon (1986) and the Federal Reserve.

[21]Note that we also considered including government purchases and the leading economic indicators. However, these data are not available for the period 1940-1948, and so were eliminated from consideration. We considered using this data only for the period ending in 1939, but problems of nonstationarity arose.

3.2 Model and results

Our model is as follows:

$$\begin{bmatrix} m_t \\ cp_t \\ p_t \\ y_t \\ S_t \end{bmatrix} = [\mathbf{P}_1(\mathbf{L})] \begin{bmatrix} m_t \\ cp_t \\ p_t \\ y_t \\ S_t \end{bmatrix} + [\mathbf{P}_2] \begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^c \\ \varepsilon_t^p \\ \varepsilon_t^y \\ \varepsilon_t^s \end{bmatrix}, \tag{18}$$

where S is the interest rate spread. Dickey-Fuller-tests indicate that each of these variables exhibits stationarity over the considered sample. The matrix $\mathbf{P}_1(\mathbf{L})$ is of polynomials of length 4 so that we include four lags of each variable.[22] We also include a constant in each regression.

We consider two different specifications of $\mathbf{P}_2$, both of which are commonly applied in the empirical literature.[23] In the first, the matrix is upper triangular (UT).[24] In other words, the innovations to the spread are first in the causal chain so that other variables may respond contemporaneously to them, but they are exogenous. Here the spread innovations are in a sense the primary cause of fluctuations. In the alternative set up, $\mathbf{P}_2$ is lower triangular (LT). In other words, the innovation to the money supply is first in the causal chain and the spread is last. Here one can argue that the effects of any potential omitted variables are included in the spread equation. Figure 2 compares the two residuals from the spread equations over the Great Depression era. Overall the results are robust to specification of $\mathbf{P}_2$. The correlation between the two series is 0.91. In addition, their correlation over the entire sample is 0.90. Moreover, both series show pessimistic animal spirits from mid-1930 onward. The two series differ noticeably only in the last two quarters of 1929. As already discussed, our argument is that pessimism set in during 1930, so this is of little consequence to us. However, given that the LT series indicates optimism coincident with the stock market crash, we run the VAR assuming that P_2 is an upper triangular matrix with respect to identification.

The results of the spread regression are displayed in Table 2. Every variable is significant at the 5% level and the $\overline{R}^2$ indicates a very good fit.

[22] Inclusion of 4 lags was determined using the Akaike information criterion.

[23] See for example Christiano, Eichenbaum and Evans (1999) for a recent survey.

[24] With respect to the confidence equation, this is the standard approach taken by Matsusaka and Sbordone (1995) and Chauvet and Guo (2001).

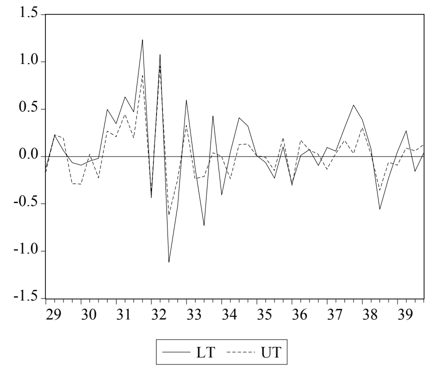

Figure 2: Alternative orderings of VAR

Table 2: Results of S Regression	
Variable or Statistic	Significance (S) or Value (V)
S	0.00 (S)
y	0.00 (S)
m	0.00 (S)
cp	0.00 (S)
p	0.05 (S)
$\overline{R}^2$	0.91 (V)
Breusch-Godfrey	0.98 (S)

(19)

The residuals from this regression are taken to measure nonfundamental confidence. The fourth-order Breusch-Godfrey LM test clearly indicates that we cannot reject the null hypothesis of no serial correlation.The Depression-era residuals $\{\varepsilon_t^s\}$ are plotted in Figure 3. A fall in nonfundamental confidence is indicated by a positive innovation. (The mean is .07, and is significantly different from zero.) It is useful to divide the analysis of the measured shocks between the decline of 1929-1933, the slow recovery of 1934-1936 and the recession of 1937-1938. With regards to the decline, we see that the residuals are positive (that is, pessimistic) from the last quarter of 1930 until 1932, peaking again in 1933. This again reflects the delayed fall of confidence, and also its continued persistence. Our sunspot sequence also indicates a slow initial decline in spirits, which should not be puzzling since a number of professional forecasters, including the Harvard Economic Society and Yale's Irving Fisher, remained optimistic well into 1930. Similarly, Hart (1933), again summarizing contemporaneous journal opinions, finds:

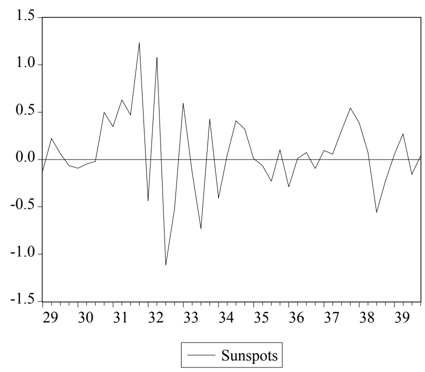

Figure 3: Depression-era residuals

> "The idea that the depression was due to a buyers' strike, or to unjustified withholding of buying power by consumers followed naturally from the conviction that conditions were essentially sound, and that the depression was psychological." [Hart, 1933, p. 678]

Overall, the tepid rise in the spread and the interpreted fall in extrinsic confidence coincides with Temin's (1976) and Romer's (1993) observations that expectations first turned "uncertain" following the months after the stock market crash and only later confidence became bruised to what we call pessimistic animal spirits. As Kindleberger (1986) puts it:

> "From August 1930 [...] the divergence between high and low quality issues reflects a drastic change in expectations and loss of confidence." [Kindleberger, 1986, p. 122]

We also see mostly positive residuals, and therefore pessimism, throughout the period of the recovery. This offers a possible explanation for the sluggishness of the recovery. Lastly, the residuals increase again at the onset of the 1937-1938 recession. This parallels Roose's (1954) interpretation of the 1937-1938 episode which attributes considerable importance to the uncertainty of business expectations partially based on a

> "[...] serious political conflict between New Deal and business." [Roose, 1954, p. 238]

In Figure 4 we display an index of confidence constructed from the residuals, which is computed by chaining the measured innovations from quarter to quarter

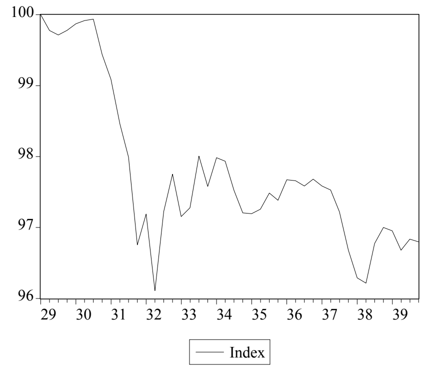

Figure 4: Computed extrinsic confidence index, 1929:I=100

(a first-difference filter). Here we clearly see confidence falling through the sample. As with the residuals, we see that confidence recovers only slightly after passing through a trough mid-1932[25]; and it reaches a low-level plateau during 1933. Confidence continues to fall through the mid-1930s and takes another dive in 1937.

Figure 5 plots the residuals for the entire sample. We observe that sunspot shocks are significantly smaller during the postwar period. This parallels findings reported by DeLong and Summers (1986) and by Farmer and Guo (1995) that the volatility of demand shocks becomes remarkably smaller in the postwar period.

In the preceding analysis, we identified a series of animal spirits shocks implied by the econometric model. In the next section, we will ask if these shocks explain the Great Depression era in deepness and in duration. We will particularly stress the sluggish recovery in the sense that detrended per capita output was still far from trend in 1939.

4 The Great Depression in the model

In this section, we use the sunspot shocks generated above to compute implied series for output, consumption, investment, the investment share, hours worked and labor productivity in our model. We then compare the results to data from the Great Depression era in order to determine the plausibility of the hypothesis that sunspot shocks were an important driving force behind the fluctuations that occurred during this period.

[25]The subsequent optimism may have set in upon Roosevelt's election.

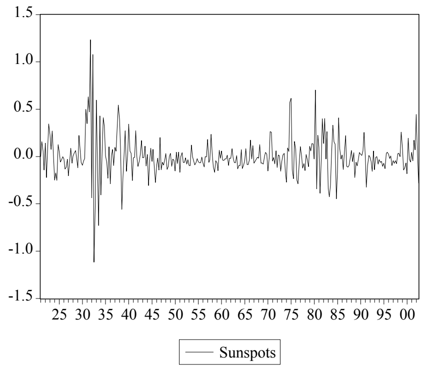

Figure 5: Entire sample residuals

4.1 Output

Figure 6 displays quarterly output in the US data with that implied by the model from 1929:I to 1939:IV. The U.S. data are detrended to allow for the absence of long-run technological progress and of population growth, as we abstract from these in the model. Cole and Ohanian (1999a) point out that the economy was at or very near trend in 1929 and the interpolated geometric trend computed by Balke and Gordon (1986) supports this. We therefore assume that our economy is in steady state in 1929:I and feed in sunspot shocks starting at this time.[26] For ease of presentation, we also rescale both model and U.S. data so that output is equal to 100 in 1929:I. Lastly, we are left with a degree of freedom in choosing the variance of our sunspot shock. This is due to the fact that models with indeterminacy and sunspots give definite predictions about relative variabilities as well as serial and cross correlations, but not about the amplitude of fluctuations.[27] It is common in the indeterminacy literature to choose the parameter so that the variance of model output is equal to that in the data (see for example Farmer and Guo, 1994). Here, instead, we use a similar methodology such that we scale the data so that the absolute decline of output at the trough coincide in model and in data.

Three important results emerge. First, the model economy predicts well the size and duration of the Depression. It is worth noting that output in the model falls with a lag. In particular, it is not until 1930:III that the economic run-down sets in. In the preceding year, the artificial economy appears to be leveling

[26] In Section 5 we test for robustness to this assumption.

[27] In terms of our our model, we do not have any guide in deciding the elasticity of investment with respect to sunspot shocks. Qualitatively, we set this elasticity such that a 100 basis point sunspot shock reduces investment by 0.4 percent.

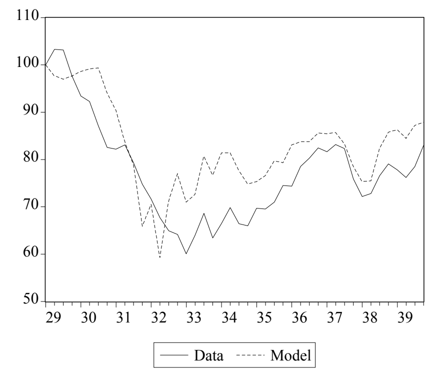

Figure 6: U.S. data and model-generated data (output), 1929:I=100

off.[28] This is most likely due to the previously cited evidence that confidence did not fall immediately following the 1929 crash and to the probability that other factors are chiefly responsible for the initial phase of the decline. This finding suggests the following interpretation of the role of sunspots in the Great Depression. The initial stages of the decline did not differ much from other recessions, but intensified pessimism during the summer of 1930 produced the slide into the abyss. This parallels Temin's narrative description of 1930:

> "[...] it would appear that businessmen's and probably also consumers' expectations built up during the 1920s about the normal state of business activity were not shattered immediately by the stock-market crash; they only dissolved a year after the crash." [Temin, 1976, p. 79]

The second finding is that the model also predicts a tepid recovery. This stands in sharp contrast to the prediction of the real business cycle model, in which there is a much faster recovery, due to the presence of large positive technology shocks (Cole and Ohanian, 1999a). Likewise, sticky price monetary models also predict a comparatively rapid recovery (Bordo et al., 2000) as the result of expansionary actions taken by the Federal Reserve and/or the abandonment of the Gold Standard in early 1933. In contrast, our results suggest that self-fulfilling changes in agents' beliefs played a significant role in much of the economic dive as well as in the lukewarm recovery. In 1939:IV, the U.S. and model economies remain 17 and 13 percent below trend respectively.

[28]While fhe sunspot model does not predict an immediate, dramatic decline after the 1929 stock market crash, the model does peak in 1929:I (a quarter ahead of the NBER's dating).

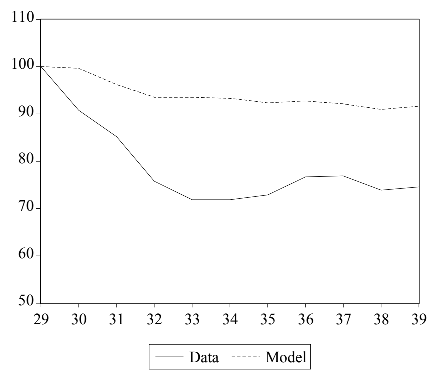

Figure 7: U.S. data and model-generated data (consumption), 1929=100

Lastly, the model does very well in predicting the recession from 1937:II to 1938:II. Note that it virtually coincides in both timing and deepness with the U.S. economy. In this respect the model is also superior to those mentioned above. Moreover, recall that when Cole and Ohanian (2001) take into account institutional changes arising from New Deal cartelization policies, which they claim as being essential for our understanding of the second half of the 1930s, their technology-driven model still misses the 1937-1938 recession.

There are some differences between the behavior of the model economy and the behavior of the U.S. economy during this episode. Most notably, the model predicts that the main cycle's trough occurs three quarters too soon. We interpret this as reflecting the fact that in the model, a change in expectations has an immediate effect on output whereas in the true economy, there may very well be a delay in the time it takes for such a shock to work its way through the real economy. One simple idea to improve the model in this respect would be to introduce adjustment costs.

4.2 Other variables

Next, we check the behavior of other variables. Since not all variables are available at quarterly frequency, we present only annualized values here.[29] Figures 7 to 12 display the patterns of consumption, investment, the investment share, employment, the real wage and labor productivity.

Starting with U.S. consumption, a striking aspect is that after its initial drop in 1932, it remains depressed until 1939. Cole and Ohanian (1999a) speculate that this behavior may reflect a convergence to a new growth path. However,

[29]Data for consumption, investment, and hours worked are from Cole and Ohanian (1999a).

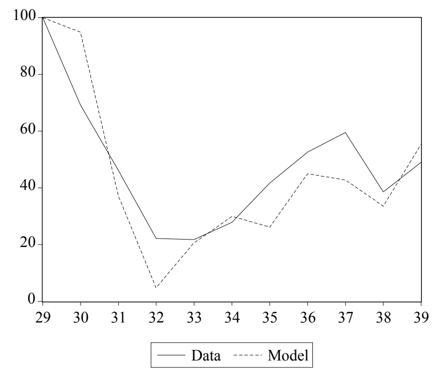

Figure 8: U.S. data and model-generated data (investment), 1929=100

the sunspot model can reproduce this general pattern while maintaining the single steady state assumption: model consumption was only 0.5% above its 1932 trough level in 1939. While the initial fall in consumption is less in the model than in the data, the smoothness and stability is replicated. Note that the smoothness of consumption in our model is caused by the inclusion of variable capacity utilization (Benhabib and Wen, 2000). That is, given the ability to leave some capital idle, agents do not have to change consumption as much when a given shock hits.

The behavior of investment, the investment share and employment (total hours) track quite well the Great Depression in timing and duration: all follow the "double dip character" that we see in the data. The behaviors of employment and investment are replicated especially well.[30] The model can also reproduce the procyclicality of the investment share.

In Figure 11 we depict the behavior of the real wage. Our model does well up until 1933, when the real wage in the data starts to rise. Bordo, Erceg and Evans (2000) and Cole and Ohanian (2001) attribute at least some of this increase to NIRA, which is of course not in our model.[31]

Figure 12 depicts the behavior of labor productivity, which we calculate as (detrended) real output divided by (detrended) total hours for both model and data. Though the trough in the model is not low enough, the initial fall and slight recovery are replicated.

[30]Note that model-generated investment becomes slightly negative in 1932:II. This results because we approximate the model around steady state in the presence of very large shocks.

[31]Our measure of the wage in the data is the total economy real wage (taken from Cole and Ohanian, 1999a). Manufacturing real wages increased during the entire Depression period. Incorporating both deflation and NIRA related labor market distortions into the current model would likely result in an even better match (see also Mulligan, 2002, and Weder, 2001).

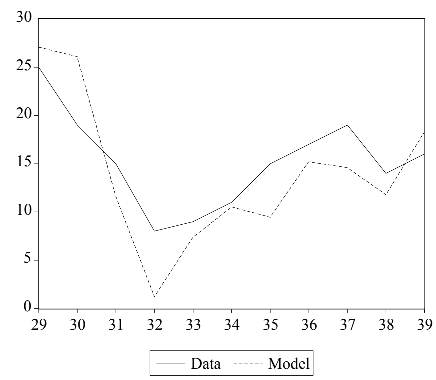

Figure 9: U.S. data and model-generated data (investment share)

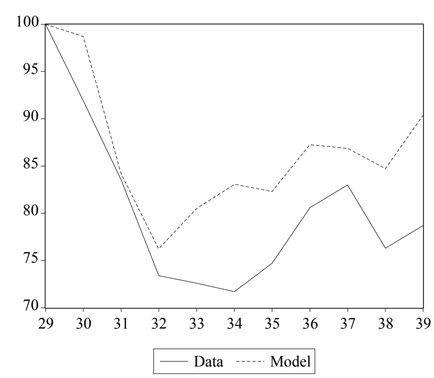

Figure 10: U.S. data and model-generated data (employment), 1929=100

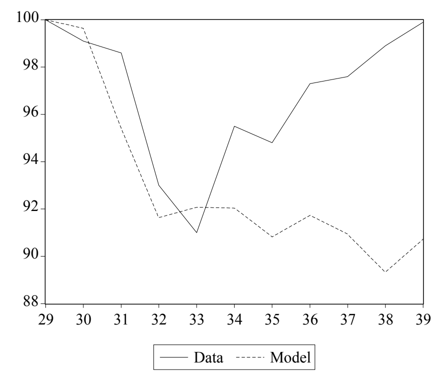

Figure 11: U.S. data and model-generated data (real wage), 1929=100

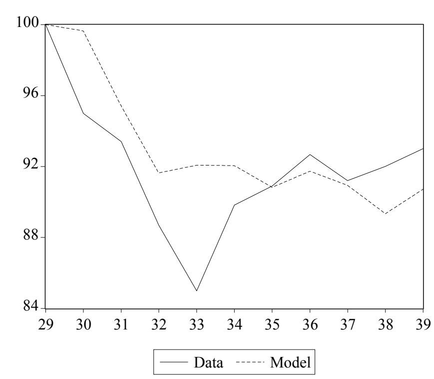

Figure 12: U.S. data and model-generated data (labor productivity), 1929=100

4.3 Intuition

Why does our model predict well the decline and especially the sluggish recovery? In order to understand this, let us reconsider why both the real business cycle model and the sticky price model do not. The real business cycle model is driven by technology shocks; and Cole and Ohanian (1999a) find that these were strong and positive during the recovery. Bordo et al. (2000) cite evidence of a large monetary expansion. Simply put, in this paper, we measure a sequence of negative domestic shocks that hit the U.S. economy during exactly the period in which existing theories fail to uncover any such effects.

In addition, our model exhibits more persistence than the real business cycle model. This is due to the presence of increasing returns to scale, which encourage "bunching" of periods of low output when agents are pessimistic. That is, once the economy is in state of low economic activity, agents prefer to wait until the economy moves to a higher productivity state to increase labor input, and therefore output. As a consequence, output can stay persistently low. We argue that this is another reason for the slow adjustments during the second half of the thirties. Thus, identified sunspots coupled with modest increasing returns appear to constitute an important ingredient of a theory of the Great Depression.

This endogenous persistence is seen in the model's ability to replicate total factor productivity (TFP), seen in Figure 13.[32] Cole and Ohanian (1999a) find that in the data in detrended form, it fell by 20% from 1929 to 1933, reflecting a procyclical movement like that observed in post-war cycles. While the real-business cycle model can explain this in the presence of technological regress, Ohanian (2001) suggests that there is no evidence of such regress. However, our model can explain the measured fall in TFP endogenously.

We derive the TFP as the residual from a naive Solow-residual accounting which attributes all of the movements in TFP to technology, Z_t. As do Cole and Ohanian, we assume constant returns to scale, and therefore calculate TFP as:

$$Z_t = \frac{Y_t}{K_t^{0.36} L_t^{0.64}}. \tag{20}$$

Because of the presence of increasing returns and of variable capacity utilization in our model, demand driven shocks, in particular sunspot shocks, lead to a procyclical series on TFP that closely matches that in the data. Figure 13 plots the computed model residuals vis-a-vis the data. At its trough, model productivity collapses by 13 percent versus 14 percent in U.S. data. The drop solely arises from the prolonged pessimism that led to dwindling labor and output, and therefore to a fall in the externality. Moreover, the model replicates total factor productivity's return to trend by 1936. The correlation between artificial and data series is 0.90 for the Depression period.[33]

[32]Thanks to Hal Cole for suggesting that we compute TFP.

[33]Chari, Kehoe and McGrattan (2002, p. 23) "find it uninteresting to view the efficiency

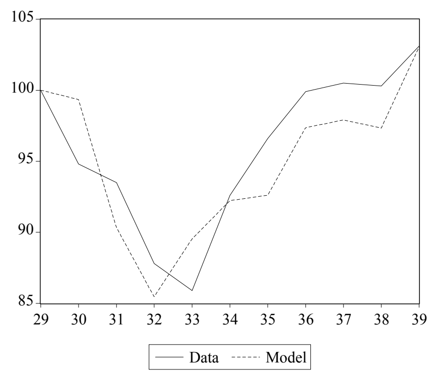

Figure 13: U.S. data and model-generated data (TFP), 1929=100

Cole and Ohanian (1999b) and Kamihigashi (1996) establish observational equivalence between sunspot and real business cycle models. The equivalence match of the models is only a partial one: here the procyclical pattern of TFP is driven by both the increasing returns to scale and variable capital utilization. In fact, when mismeasured as above, model TFP rises in large part due to the presence of variable capacity: if we correctly measure the model's capital input, then increasing returns can explain only a six percent decline and, more importantly, it does not recover after 1933. That is, it is then observationally equivalent to a real business cycle model with no (positive) technology shocks following the Depression's trough.[34]

Another factor driving the prolonged depression in the model is the low investment activity. Figure 14 plots model and data capital stock. The model reproduces the steady fall – while slightly overemphasizing the decline. In the model (and data) the decline itself caused businesses to put off expanding their capacity. With output about 40 percent below normal, excess capacity was widespread and hence there was no immediate incentive to invest at all. As a consequence, the low capital input kept the economy from recovering quickly – the model predicts that the smaller stock was used in increasing intensity after 1933 but not by enough to get output back to its potential. (At the artificial trough, utilization spiked to 25 percent below normal and from 1935 to 1939 it

wedge [i.e. TFP] as emanating from a loss of knowledge or a decline in the quality of blueprints" and suggest that alternative theories of TFP movements must be developed. In a sense, our finding of artificial TFP to fall endogenously, and in line with the data, gives support to calibration of the increasing returns.

[34]This echoes Burnside and Eichenbaum's (1996) finding that with variable capital utilization, a substantially smaller proportion of the standard deviation of output is due to the direct impact of technology shocks (or increasing returns).

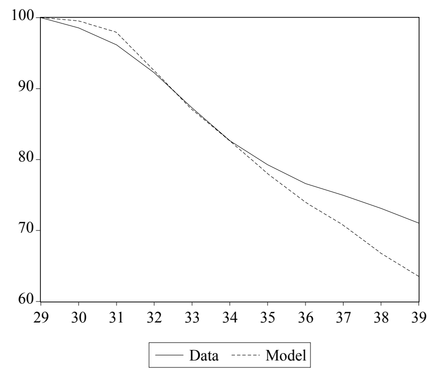

Figure 14: U.S. data and model-generated data (capital), 1929=100

averaged at about 10 percent above normal.)[35]

4.4 The Predictive Power of Sunspots

As further evidence of the success of our model, we examine the predictive power of sunspots using a method proposed by Salyer and Sheffrin (1998). Time series econometrics allows us to distinguish data in atheoretical ways. For example, modelling aggregate output as a low-order autoregressive process fabricates a reasonable fit. Therefore, if the sunspot approach to business cycles conveys anything new about the real economy it must provide some advantage relative to atheoretical time series models. Thus, the predictive ability of the sunspot approach can be evaluated by the simple regression

$$\ln y_t^d = \alpha + \sum_{i=0}^{n} \beta_i \ln y_{t-i}^d + \gamma \ln y_t^m + \epsilon_t. \tag{21}$$

We use data from 1929:I to 1939:IV. Here y_t^d is per capita output in the data and y_t^m that in the model. Adding output from the sunspot model to the richly parameterized regression, one obtains a measure of the extent to which sunspots provide informational content. The results are in Table 3. The time series model without sunspots explains over 87 percent of the variation in output one quarter hence.[36] However, the sunspot model adds incremental explanatory power. The

[35] Cole and Ohanian (1999, p. 10f) report that the strong recovery of the real business cycle model arises from (i) the capital stock falling less than in the data and (ii) predicted labor input being much higher than actual labor input. Both input series are well explained by the sunspot story.

[36] A lag length of $n = 4$ was used.

$\overline{R}^2$ increases and the t- and p-values indicate that the increment is statistically significant.

Table 3: Predictive Power of Sunspots: The Great Depression Era			
Variable	Coefficient (t-value)	$\overline{R}^2$	Log likelihood ratio (p-value)
-	-	0.88	-
y^m	0.250 (3.67)	0.91	13.37 (0.00)

(22)

5 Causality and Robustness

In this section we address and dismiss several potential criticisms of our analysis. First, we demonstrate that our measure of nonfundamental confidence Granger causes output, and not vice-versa. Second, we show that our results are robust to changes in several assumptions. The first is the relatively high returns to scale. When we decrease the size of the externality, persistence falls; but the model can still match important features of the Great Depression era. Second, we change the specification our VAR in several ways. We find robustness to using a different spread or different fundamentals. Third, we relax the assumption that the economy was in steady state in 1929 and assume overheating. Again, our results are not substantially affected. Lastly, our model does reasonably well at replicating postwar data.

5.1 Causality

First, given the evidence that both confidence itself and our empirical measure of it did not fall until 1930, we now present results from Granger causality tests on output and our measure of nonfundamental confidence.[37] That is, we examine the null hypotheses that our spread residuals (ε_t^s) do not Granger cause output growth (y) and vice versa. We carry out each test over the period 1929:I to 1939:IV using both 4 and 8 lags. The results of these tests are reported in Table 4. Results clearly indicate that the residuals Granger cause output growth, and not vice versa. Therefore we conclude that though confidence initially fell with

[37] Thanks to Jang-Ting Guo for suggesting we do this.

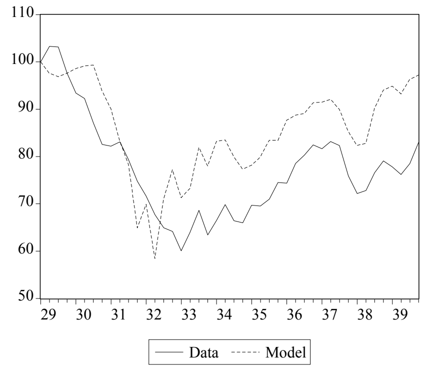

Figure 15: U.S. data and model-generated data (output), 1929=100, IRS=1.20

a lag, over the entire Depression era causality ran from confidence to output.[38]

Table 4: Results of Granger Causality Tests

Null Hypothesis (number of lags)	F-statistic	Significance
ε_t^s does not Granger cause y (4)	2.53	0.05
ε_t^s does not Granger cause y (8)	2.81	0.02
y does not Granger cause ε_t^s (4)	1.10	0.37
y does not Granger cause ε_t^s (8)	1.08	0.40

(23)

5.2 Returns to scale

Next we examine what happens when we lower the size of the externality. In Figures 15 and 16 we compare model-generated output to U.S. data using returns to scale of 1.2 and 1.15. Examining the figures, increasing returns appear to be important for achieving persistence in the fall in output, and therefore matching the anemic recovery – persistence rises and data matching improves as returns to scale increase. While the model still produces the sequential pattern of the Great Depression including the sharp recession of 1937-38, the recovery in the artificial economies is somewhat fast and too strong during 1933 and 1934 – after which the model and data move more or less in-synch.[39]

[38] Using our full sample or using real balances instead of output yields similar results.

[39] Adding shocks that Mulligan (2002) and Weder (2001) have identified as keeping the economy from recovering in the second half of the 1930s could solve the mismatch. These shocks may represent cartelization, monetary or preference (i.e. real demand) shocks (see also Chari, Kehoe and McGrattan, 2002).

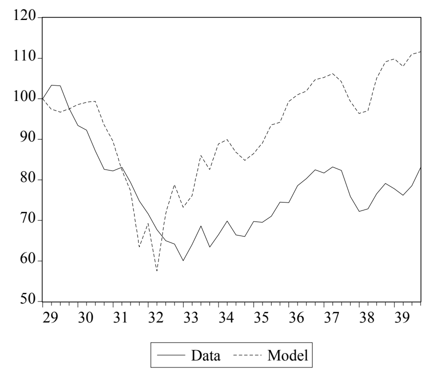

Figure 16: U.S. data and model-generated data (output), 1929=100, IRS=1.15

5.3 The VAR

There are several issues one might take with the specification of our VAR. First, one might wonder about our choice of Baa-Aaa instead of another spread. For example, instead of capturing confidence, by using the Baa-Aaa bond spread, we might be capturing the effects of monetary policy on economic activity. Friedman and Kuttner (1993), among others, have argued that such effects are captured by spreads such as that between the Prime Commercial Paper Rate and Treasury Bills (CP-Tbill) (hereafter denoted money spread). In fact, Bernanke finds evidence that the money spread measures the "stance of monetary policy" (Bernanke, 1990, p. 52), but both he and Friedman and Kuttner use Baa-Aaa to measure default risk. Evidence in Figure 17 illustrates that the money spread likely does provide a measure of monetary policy, while our spread does not. There we plot the residuals in level form that result from measuring S in (18) by the money spread along with our residuals. The shaded area represents the period of the NBER 1929-1933 Depression. Strikingly, the upward move in the Baa-Aaa spread lags the other (see also Bernanke, 1990): CP-Tbill starts to fall in 1928:II, Baa-Aaa shocks hit a peak in 1929:I. The pattern of the CP-Tbill residual is consistent with Hamilton's (1987) claim that the Federal Reserve started restrictive open market operation as early as January 1928.

Second, we repeat our analysis using the Baa-bond to T-Bill rate spreads as instrument for default risk.[40] The underlying idea for using government bonds is to utilize the asset with lowest possible risk of default.[41] For the time

[40] We would like to thank Hal Cole for suggesting this.

[41] This is certainly not the absolute case since some (private) prime rates involved a lower yield than U.S. government bonds (see for example Figure IV.2. in Temin, 1976). Moreover, even Aaa-TBill is negative for some sample observations.

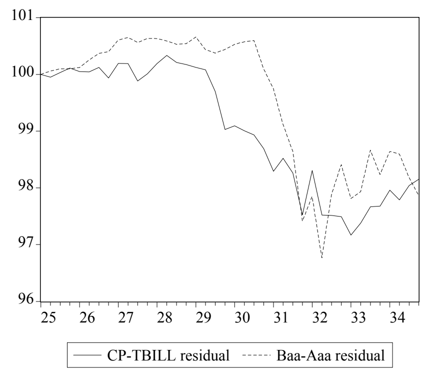

Figure 17: Two spread residuals

period considered, this is somewhat problematic since these assets were not regularly issued for given maturities and, therefore, the interest rate series must be constructed using various sources. Figure 18 plots the Baa-Tbill with Baa-AAA residuals over the Depression era. The two spreads display very similar patterns. When applying the first-difference filter to visualize the dynamic pattern of sunspots, the 1930s is again seen as a unique period in terms of loss of confidence. The sample correlation of the two sunspot indices, seen in Figure 19, is 0.76. More concretely, what makes the Great Depression unique is the complete absence of any signs of a recovery in confidence for an extended period. There is one important difference between the two spread residuals: the Baa-TBill spread suggests that the loss of confidence came about 6 months earlier. The slight difference in timing is likely the result of a composition effect arising from the downgrading of firms during recessions that was perhaps more pronounced during the Great Depression.[42] We also experimented with short-run spreads involving prime commercial paper and banker's acceptance rates – again suggesting that pessimism became an important aspect for the Depression.[43]

Figure 20 plots artificial output using Baa-TBill residuals with returns to scale equal to 1.15. The behavior of output is tracked quite well in terms of the timing and duration of the Great Depression. We therefore conclude that the persistent trend deviation of output is not a product of a specific quality

[42]Temin (1976) attempts to provide a better proxy for the decline in the value of bonds by constructing a fixed sample of bonds. The alternative spread opens sooner and, given his data, pessimistic expectations started to matter already by the end of 1929, well before the banking panics began.

[43]To economize space we do not report these results here. We also experimented with stock prices, which delivered parallel results.

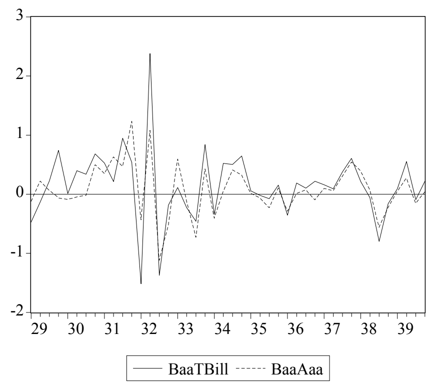

Figure 18: Depression era residuals using Baa-TBill versus Baa-Aaa spread

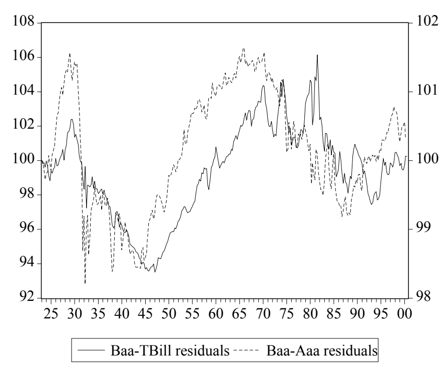

Figure 19: Two alternative spread residual confidence indices

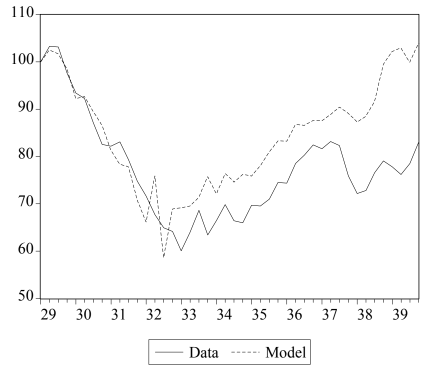

Figure 20: U.S. data and model-generated data (output), 1929=100, IRS=1.15 and Baa-TBill spread

spread.

The second set of issues involve the variables we use as fundamentals. The reader will notice that, though we include monetary variables in our VAR, the theoretical model is purely real. Therefore, the empirical sunspot shocks may not capture what we intended for the model. Figure 21 demonstrates that the sequence of Baa-Aaa spread residuals is essentially unaffected by money, inflation and interest rates. To see this, we consider four alternative VARs in which we vary variables: (i) (18), (ii) (18) without m/p (iii) (18) without m/p and p; and (iv) (18) without m/p, p and cp. The Depression era residuals are plotted in the figure. We note that the basic structure of the confidence meltdown and its slow recovery is similar in all cases. The contemporaneous correlation of the residuals from (i) and (iv) is 0.97. Put another way, adding real money or other nominal variables does not significantly help in predicting the evolution of the quality spread.[44]

Another objection is that it may be reasonable to expect the interest rate spread to reflect fundamental default risk in the economy. More concretely, since the interest rate spread measures default risk, an instrument for this risk should be included in the VAR. We therefore add the (first difference of the) number of commercial business failures, taken from *Dun's Review*. We estimate the new VAR over the available sample from the NBER's historical database, 1920:II to 1965:II. The two VAR residuals – one series containing the instrument, the other without it – are displayed in Figure 22. That is, the addition of the credit-market-instrument leaves our results relatively unaffected. Alternatively,

[44]We also experimented with adding a dummy variable during the period that NIRA was effective, 1933-1935. Results were again similar.

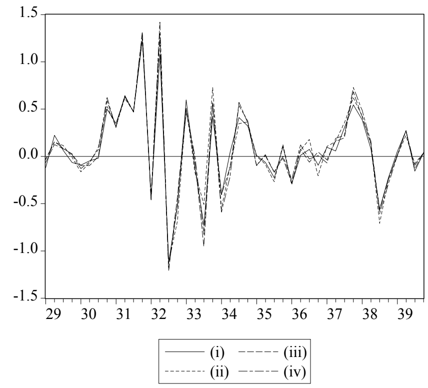

Figure 21: Alternative VARs

Bernanke (1983) proposes liabilities of failing business as an instrument for default; accordingly we GNP-price-deflate that series (also in first-differenced form, all commercial, published by *Dun's Review*, with a sample-period of 1920:II to 1967:IV). The corresponding VAR-residuals, seen in Figure 23, have a correlation of 0.96. We conclude that taking a broader view on how fundamentals related to default risk operate through the credit channel will not alter our results.

5.4 Overheating in the 1920s

Next, we examine the importance of our assumption that the economy was at steady state in 1929. Many interpretions of the *roaring twenties* have suggested that the economy was overheating by the end of the decade – specifically, it is argued that investment was so great that actual capital stocks were substantially above long-run desired levels, creating a capital overhang (DeLong, 2001). Therefore we (arbitrarily) select capital to be 10 percent above normal in the model's initial period. This generates an endogenous output decline setting in in 1929 and the whole of the Depression is captured by the sunspot model. In Figure 24 we set $\gamma = 0.15$ and use business failures-corrected Baa-Aaa residuals.[45] We view this result as encouraging, in the sense that with this correction the timing of the decline in the model closely matches that in the data.

[45] The result is somewhat general if trend deviations are more than five percent.

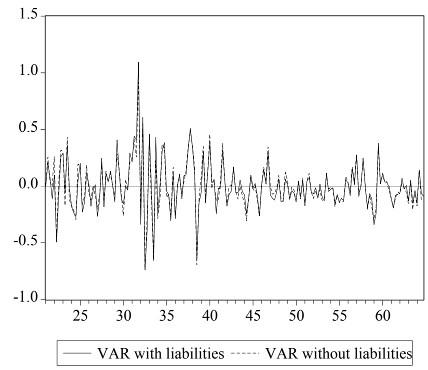

Figure 22: The effect of a default instrument

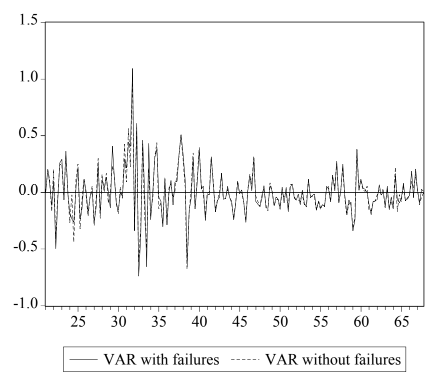

Figure 23: The effect of a default instrument

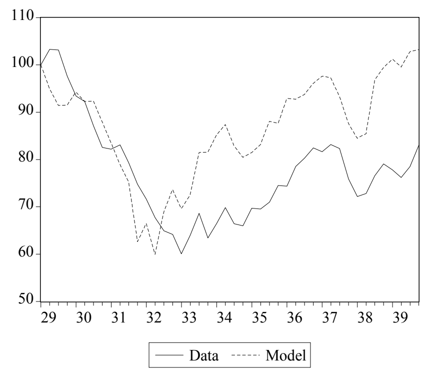

Figure 24: U.S. data and model-generated data (output), assuming overheating, $\gamma = 0.15$

5.5 The post-war period

Lastly, we look past 1939 and simulate the model for the post-war period.[46] We Hodrick-Prescott filter model-generated and US data on output and display them in Figure 25. Over the 1955:I to 2002:III period, the contemporaneous correlation of the two series is 0.55. However, the standard deviation of the model's series exceeds that of the U.S. by about 30 percent. This suggests that other factors were at work. Perhaps the demand shocks were partially neutralized by active fiscal and monetary policies. For example, the model predicts that the panic of 1998 involving LTCM should have triggered a (small scale) recession. But in October, the Fed jumped into action, surprising markets by sharply cutting interest rates. In any case, we take these results as evidence that our model can be applied outside the time frame of the Great Depression era with some success. Most notably, output in the model (i) shows all major recessions and (ii) is most volatile during the 1970s and 1980s.[47]

[46] Robert Solow suggested we also examine 1990s Japan. This is to be pursued in future research.

[47] For example, we find pessimistic animal spirits shocks dating from 1989:IV to 1991:I which essentially coincides with the NBER recession (1990:III to 1991:I) and parallels Blanchard's (1993) interpretation of the 1990-91 recession. Our model also provides some insight into the current recession resembling Bernanke (2003):

> "Clearly, an undercurrent of pessimism has persisted among business leaders for some time now, more so than can be accounted for by what seem to be the generally good fundamentals of the U.S. economy. For policymakers, the most troubling aspect of this pessimism is our inability to ascertain its cause (or causes): Is it geopolitical uncertainty? The aftermath of the accounting scandals of last summer? Concerns about the ultimate profitability of new technologies

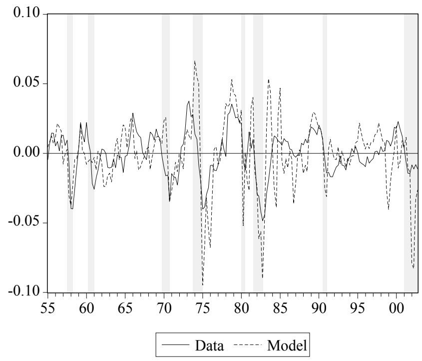

Figure 25: The postwar period

For the postwar period, seen in Table 5, the time series model outlined in section 4 explains over 75 percent of the variation in output one quarter hence. However, the sunspot model again contains incremental explanatory power on output. The $\overline{R}^2$ again rises; and y^m is statistically significant.

Table 5: Predictive power of sunspots

Variable	Coefficient (t-value)	$\overline{R}^2$	Log likelihood ratio (p-value)
-	–	0.756	–
y^m	0.103638 (4.23)	0.777	17.59 (0.00)

(24)

Overall, our findings suggest that shocks to expectations may have played an important role during the 1930s and beyond. The results can be interpreted as a compelling alternative to approaches that charge inept monetary policy or technology shocks.

6 Summary and Conclusion

In this paper, we have taken a novel approach to modelling the Great Depression. Instead of relying on technology or monetary shocks, we test the hypothesis

and products? The depressive side of Keynesian animal spirits? This pessimism does matter, if for no other reason than because it has the potential to become self-fulfilling."

that this historic episode can be explained by self-justifying pessimism. In the context of a neoclassical model in which indeterminacy of equilibria results with modest increasing returns to scale, we believe we have found the "other shock" needed to explain the slow recovery. Using an interest rate spread as a proxy for confidence, and a VAR to extract its nonfundamental part, we have constructed a series of sunspot shocks that, when fed into the model, predict a large and persistent fall in output. In particular, our model replicates well both the decline of 1929-1932 and the recession of 1937-1938. As such we feel our model represents considerable improvement over previous work that examines only fundamental and/or banking shocks.

Our results suggest the following interpretation of the Great Depression. The 1929 stock market crash was followed for about a year by what appeared to be the start of a normal recession. Only later, during the summer of 1930, did confidence began to deteriorate dramatically. Hence the recession was transformed into a depression. In 1932, faith in the economy hit bottom; and the continuing sequence of pessimistic animal spirits is a prime candidate in the quest to explain the subsequent stagnation that only ended with the onset of World War II. Our findings support DeLong's assertion:

> "The drop in demand produced by [the] shift in expectations helped bring on what people feared; it put America on the path to the Great Depression. The Great Depression happened in large part because people expected something bad to happen. Without the pessimistic shift in expectations [...], there would have been no Great Depression." [DeLong, 2001, p. 62]

Clearly, there were other forces at work during 1929 to 1939 as well, and a useful extension of the model would be to allow for this. In addition, a thorough examination of the relationship between the pessimism we observe here and the banking panics seems in order. Notwithstanding, our results can easily be reconciled with the banking view, although we stress a different propagation channel: the fall in pessimism certainly contributed to the banking failures both directly (a "contagion of fear" in Friedman and Schwartz' term) and indirectly through the drop in economic activity and the associated plunge in savings which likely intensified the intermediaries' distress.[48] While the results here are certainly not the final word on the origins of this unique episode, we believe that we have shed some light on this seemingly insoluble mystery.

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[48] We would like to thank Larry Christiano for pointing this out to us.

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7 Appendix

Let us denote $\widehat{y}_t \equiv (y_t - y)/y$ *et cetera*, then the linear model is given by[49]

$$\widehat{y}_t = \alpha(1+\gamma)\widehat{u}_t + \alpha(1+\gamma)\widehat{k}_t + (1-\alpha)(1+\gamma)\widehat{l}_t \tag{A1}$$

$$\widehat{l}_t = \widehat{y}_t - \widehat{c}_t \tag{A2}$$

$$\widehat{\delta}_t = \widehat{y}_t - \widehat{k}_t \tag{A3}$$

$$-\widehat{c}_t = -E_t\widehat{c}_{t+1} + \alpha\beta\frac{y}{k}\left[E_t\widehat{y}_{t+1} - \widehat{k}_{t+1}\right] - \beta\delta E_t\widehat{\delta}_{t+1} \tag{A4}$$

$$\widehat{k}_{t+1} = (1-\delta)\widehat{k}_t - \delta\widehat{\delta}_t + \frac{x}{k}\widehat{x}_t \tag{A5}$$

$$\widehat{\delta}_t = \theta\widehat{u}_t \tag{A6}$$

and

$$\frac{c}{y}\widehat{c}_t + \frac{x}{y}\widehat{x}_t = \widehat{y}_t. \tag{A7}$$

The model equations (A1)-(A7) can be compactly written as

$$\begin{bmatrix} \widehat{y}_t \\ \widehat{c}_t \\ \widehat{l}_t \\ \widehat{u}_t \\ \widehat{\delta}_t \end{bmatrix} = \mathbf{M}\begin{bmatrix} \widehat{x}_t \\ \widehat{k}_t \end{bmatrix} \tag{A8}$$

and

$$\begin{bmatrix} E_t\widehat{x}_{t+1} \\ \widehat{k}_{t+1} \end{bmatrix} = \mathbf{J}\begin{bmatrix} \widehat{x}_t \\ \widehat{k}_t \end{bmatrix}. \tag{A9}$$

[49] In an earlier version of the paper, we applied a slightly different approximation – at essentially the same results.