DO SUNSPOTS REFLECT CONSUMER CONFIDENCE?

AN EMPIRICAL INVESTIGATION

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INTRODUCTION

Much recent work in macroeconomics has focused on the problem of coordination among agents, and its implications. For example, starting from the work of Benhabib and Farmer [1994] and Farmer and Guo [1994], there is now an extensive literature examining business cycle models in which coordination on a belief can be self-fulfilling and therefore lead to indeterminacy of equilibria. One interpretation of such coordination is that it is driven by changes in confidence. In this paper, I assess the empirical plausibility of this idea in a particular model by examining the extent to which the measure of confidence implied by the model reflects that in the U.S. data.

The model I study is the same as that in Guo and Harrison [2001]. The evolution of the model can be traced as follows. In the one-sector Benhabib-Farmer-Guo model, indeterminacy results due to the presence of increasing returns to scale in production. This is because, for example, upon the expectation of an increased return on capital, agents invest more. The expectation will be fulfilled if the increase in the capital stock does in fact lead to an increase in its rate of return. However, in this model, the level of returns to scale for which this is the case is implausibly high, as evidenced by the empirical work of Basu and Fernald [1997] and Burnside [1996].

More recent work has addressed this issue and added features to the original model. Of particular note are Benhabib and Farmer [1996], Harrison [2001], and Weder [2000], who work with two-sector models and find that the level of returns to scale needed for indeterminacy is drastically reduced to one that is within the empirically plausible range. Here, the shifting of resources between sectors has dramatic effects on the return to capital, reducing the reliance on high returns to scale. Also, Wen [1998] adds variable capital utilization to the one-sector model and finds that this raises the elasticity of output with respect to labor, also reducing the necessity for high returns to scale. Guo and Harrison [2001] combine these features and study a two-sector model in which capital is utilized at a variable rate.

In this class of models, self-fulfilling changes in beliefs are often referred to as sunspots. These sunspots are assumed to be mean zero, serially uncorrelated, nonfundamental shocks. That is, they occur because of something orthogonal to the
A one interpretation of this is that they reflect changes in consumer confidence that occur as a result of nonfundamentals.

From an empirical standpoint, this interpretation has important implications. Applying it, there have been several studies in which authors assess whether changes in confidence, as measured by an index of consumer sentiment, in fact determine output or consumption, independent of fundamentals. For example, Matsusaka and Sbordone [1995] find that consumer sentiment, as measured by the University of Michigan’s index, explains 13 to 26 percent of the variation in GNP. Chauvet and Guo [2003] find that pessimism on the parts of consumers and investors played a role in several contractions. Oh and Waldman [1990] take a different approach and use revisions in the leading indicator to measure “mistakes” in agents’ expectations. They find that these mistakes explain between 8 and 20 percent of the growth in industrial production. However, these studies do not assess a particular model of the economy and instead only carry out empirical analyses.

Here I assess the plausibility of sunspot shocks in the context of the Guo-Harrison model. In doing so, I build upon the work of Farmer and Guo [1995] and Farmer and Ohanian [1999], who carry out similar studies using different models. In particular, using the intertemporal Euler equation and data for the U.S. economy, I construct a series of Euler errors that is implied by the model. I then separate this series into its fundamental and nonfundamental parts, taking the nonfundamental Euler error as a measure of the sunspot shock. Next, I take the analysis an important step further than previous authors. Since these sunspots are purported to measure nonfundamental confidence, I construct such a measure as the residual from a regression of the University of Michigan index of consumer sentiment on fundamentals. I then assess the relationship between the two series, and find a significant positive correlation. I therefore conclude that the measured sunspots in fact reflect consumer confidence derived from nonfundamentals.2

In addition, I also examine the likelihood that each of these measures actually serves as an impulse to business cycles as observed in the data. Both measures of nonfundamental confidence fall before some contractions, but they fail to rise before expansions. Therefore, the evidence that nonfundamental confidence causes business cycles is limited to contractions, and is weak at best.

The rest of this paper proceeds as follows. Section 2 reviews the related literature. Section 3 outlines the model. Section 4 describes both measures of nonfundamental confidence. Section 5 determines the relationship between these variables and Section 6 studies the possibility that each causes business cycles. Section 7 concludes.

RELATED LITERATURE

In this section I review both the theoretical and empirical work that motivates this paper. While the theoretical literature on sunspot equilibria is much broader than outlined here, I focus only on real models of the business cycle. The empirical work I describe assesses the plausibility of sunspots in these models.
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**Theoretical Work**

In the class of models in which business cycles are described by sunspot equilibria, a modification of a general equilibrium model of the business cycle leads to the possibility of indeterminacy of equilibria. The modification often involves some form of incomplete markets; in the model I study, this is accomplished by allowing for increasing returns to scale in production. The most widely studied one-sector version of this model is that of Benhabib and Farmer [1994] and Farmer and Guo [1994]. It is now well known that in the Benhabib-Farmer-Guo model, indeterminacy results only with very high returns to scale. One way to understand this is to examine the intertemporal Euler equation in the discrete-time case, assuming utility that is logarithmic in consumption, $C$:

$$
\frac{C_{t+1}}{C_t} = \beta [r_{t+1} + 1 - \delta].
$$

Here $r$ denotes the return on capital and $\delta$ its depreciation rate. Starting from the steady state equilibrium of the model, one can ask when another equilibrium, close to the steady state, is possible. For example, if agents expect the return on capital to rise next period, they will increase next period’s capital stock, sacrificing some consumption this period in order to consume more next period. Therefore the left hand side of this equation rises. In order for the economy to stay in equilibrium, so must the right hand side. Increasing returns must be high enough so that the return on capital rises with the capital stock. In this model, under a standard parameterization, this requires returns to scale of about 1.5. For example, if output is specified as $y_t = A^\theta k_t^\alpha l_t^{1-\alpha}$, where $k$ represents the capital stock, $l$ the supply of labor and $A$ the external effect (to be specified in more detail in the next section), indeterminacy requires that $\theta \approx 0.5$.

More recent work has incorporated new assumptions into this model that reduce the level of returns to scale necessary for indeterminacy. Most noteworthy here is the work of Benhabib and Farmer [1996], who study a two-sector version of the model where consumption and investment goods are produced separately. The intertemporal first order condition now becomes:

$$
\frac{C_{t+1}}{C_t} = \beta \left[ r_{t+1} + (1 - \delta) p_{t+1} / p_t \right],
$$

where $p$ is the relative price of the investment good. Now, telling the same story, the net return on capital is also dependent upon this relative price. The fall in this period’s consumption reduces the relative price of investment, as long as there is some amount of increasing returns to scale. (The best way to see this is to realize that the production possibilities frontier for this economy is convex.) Analogously, next period’s relative price rises. The net return on capital can therefore rise with lower returns to scale. In a similarly parameterized version of the model, indeterminacy results with returns to scale of less than 1.1.

Work on the two-sector model has been advanced by Harrison [2001] and Weder [2000], who both find that indeterminacy can result with returns to scale less than 1.1 in the investment sector, even if returns to scale for consumption are constant. That
is, they find that it is increasing returns in investment that drives the indeterminacy result.

Other work by Wen [1998] has incorporated variable capital utilization into the one-sector model. This also reduces the level of returns to scale necessary for indeterminacy by increasing the elasticity of output with respect to labor. The rise (fall) in next (this) period's consumption is accompanied by a rise (fall) in labor, and this causes larger movements in output and the interest rate when capital utilization is allowed to vary. Wen [1998] finds indeterminacy with returns to scale of about 1.1.

Guo and Harrison [2001] incorporate variable capital utilization into the two-sector model and find indeterminacy with returns to scale as low as 1.02. This model is outlined in Section 3.

Empirical Work

The empirical work that motivates this paper can be divided into three categories. Each strand of the literature assesses the empirical plausibility of sunspots and indeterminacy in a different way.

The first set of papers is the literature that focuses on the required amount of returns to scale necessary for indeterminacy and therefore estimates production functions using U.S. data. Early work focuses on aggregate estimate of returns to scale. Basu and Fernald [1995a] and Burnside [1996] find little or no evidence of significant increasing returns to scale for the economy as a whole. This is the work upon which indeterminacy in the original Benhabib-Farmer-Guo one-sector model was deemed implausible.

In line with the advancements in theoretical work, the empirical work also progressed by disaggregating the economy. Burnside [1996] rejects the hypothesis that returns to scale are the same across industries while Basu and Fernald [1995b, 1997] observe that reallocations of resources between types of goods over the business cycle can cause aggregation bias in estimates of returns to scale at the aggregate level. Clearly, allowing for disaggregation is essential.

Recent work by Harrison [2003] estimates returns to scale for the consumption and investment sectors. Results indicate that returns to scale for investment are slightly increasing, while those for consumption are constant so that indeterminacy in the two-sector model is plausible. Harrison [2003] also provides estimates that control for variable capital utilization.

The second strand of literature tests the idea that confidence causes output or consumption. While Leeper [1992] and Fuhrer [1993] find that consumer confidence has almost no power in predicting output once financial variables and other fundamentals are included, several authors do find evidence that nonfundamental confidence causes output or consumption. For example, Matsusaka and Sbordone [1995] find that consumer sentiment explains 13 to 26 percent of the variation in GNP. As measures of fundamentals they use the leading economic indicator, a Treasury bill rate, and government spending. Each of these studies uses the University of Michigan's index of consumer sentiment to measure confidence. Oh and Waldman [1990], however, take a different, ingenious approach to capturing the effect of expectations. They
hypothesize that revisions in the leading indicator can measure “mistakes” in agents’ expectations and find that these mistakes explain between 8 and 20 percent of the growth in industrial production. Chauvet and Guo [2003] model expectations of consumers and investors as Markov switching processes, moving between periods of optimism and pessimism. They find that periods of pessimism are associated with higher volatility and that probabilities of pessimism rise before or at the start of slowdowns and recessions. They also find some evidence of recessions and slowdowns following periods of relatively strong fundamentals paired with pessimism. In these cases, nonfundamental falls in confidence can be interpreted as contributing to the contractions.

Lastly, papers by Farmer and Guo [1995] and Farmer and Ohanian [1999] examine the plausibility of sunspots and indeterminacy in a different way. It is these papers to which the work here is most closely related.

Farmer and Guo [1995] study the one-sector Benhabib-Farmer-Guo model and pose an alternative to calibration of parameters. Instead, they linearize the model and use regression techniques to estimate the parameters. The goal of their study is to assess the relative importance of the different shocks in the model: supply, or productivity, shocks and demand, or sunspot, shocks. By estimating the variance-covariance matrix of the residuals from the production function and Euler equation, they find that demand shocks are roughly twice as important as supply shocks over their entire sample. Their parameter estimates also put the economy in the range of indeterminacy.

Farmer and Ohanian [1999], borrowing from the work of Bennett and Farmer [2000], add nonseparable utility to the one-sector model and carry out a similar exercise. With nonseparable utility, the condition for indeterminacy changes and their parameter estimates imply that our economy is best described by a model with a single equilibrium path.

In this paper, I carry out analysis similar to that of Farmer and Guo [1995] and Farmer and Ohanian [1999]. However, I work with a different model and examine more carefully the validity and proposed interpretation of the sunspot shocks.

THE MODEL

In this section I describe the model that I use, which is the same as that in Guo and Harrison [2001]. There are two types of firms, which produce consumption and investment goods, each with variable capital utilization and the possibility of increasing returns to scale in production. Recall that it is the presence of increasing returns that drives the indeterminacy result.

Firms

The model incorporates variable capital utilization into the discrete-time version of the two-sector real business cycle (RBC) framework as in Benhabib and Farmer [1996]. In the consumption sector, output is produced by competitive firms using the following technology:

\[ Y_{ct} = A_t \left( u_t K_{ct} \right)^\alpha L_{ct}^{1-\alpha}, \quad 0 < \alpha < 1, \]
where $u_t$ denotes the rate of capital utilization that is endogenously determined by the representative household and $K_t$ and $L_t$ are the capital and labor inputs used in the production of consumption goods. In addition, $A_t$ represents productive externalities that each individual firm takes as given, and is specified as

$$A_t = \left(\frac{\overline{u_tK_{ct}}}{\overline{L_{ct}}}\right)^{\alpha L_{ct}^{1-\alpha}}, \theta > 0,$$

where $\overline{u_tK_{ct}}$ and $\overline{L_{ct}}$ denote the economy-wide average capital and labor services used in producing the consumption good and $\theta$ measures the degree of sector-specific externalities in the consumption sector.

Similarly, investment goods are produced by competitive firms using the technology:

$$Y_{It} = B_t(u_tK_{It})^{\alpha L_{It}^{1-\alpha}},$$

where $K_{It}$ and $L_{It}$ are capital and hours worked in the investment sector and $B_t$ represents a productive externality that is an increasing function of the economy-wide average levels of productive capital and labor devoted to producing investment goods. Following Benhabib and Farmer [1996], the degree of sector-specific externalities in the investment sector is also measured by $\theta$.

Under the assumptions that factor markets are perfectly competitive and that capital and labor inputs are perfectly mobile across the two sectors, the first-order conditions for the firms’ profit maximization problems are

$$r_t = \alpha Y_{ct}/K_{ct} = p_t(\alpha Y_{It}/K_{It}),$$

$$w_t = (1-\alpha)Y_{ct}/L_{ct} = p_t[(1-\alpha)Y_{It}/L_{It}],$$

where $r_t$ is the rental rate of capital, $w_t$ is the real wage rate, and $p_t$ denotes the price of investment goods relative to consumption goods.

**Households**

There is a unit measure of identical infinitely lived households, each of which maximizes its present discounted lifetime utility:

$$\sum_{t=0}^{\infty} \beta^t E_t[\log C_t - \zeta L_t], \quad 0 < \beta < 1 \text{ and } \zeta > 0,$$

where $C_t$ and $L_t$ are the representative household’s consumption and hours worked and $\beta$ is the discount factor. The budget constraint faced by the representative household is

$$C_t + p_tI_t = Y_t = r_tK_t + w_tL_t,$$
where $I_t$ is investment, $Y_t$ is GDP, and $K_t$ is the household's capital stock. The law of motion for the capital stock is given by

$$K_{t+1} = (1 - \delta_t)K_t + I_t,$$

where $\delta_t \in (0,1)$ is the time-varying capital depreciation rate. As in Wen [1998], I postulate that $\delta_t$ takes the form

$$\delta_t = (1/\gamma)u^\gamma_t, \quad \gamma > 1,$$

which states that more intensive capital utilization accelerates its rate of depreciation. I assume that there is no fundamental uncertainty present in the economy.

The first-order conditions for the household’s optimization problem are

$$(2) \quad \zeta C_t = w_t,$$

$$(3) \quad E_t \left[ \frac{1}{C_{t+1}} \left( (r_{t+1} + (1 - \delta_{t+1})p_{t+1})/p_t \right) \right] = 0,$$

$$(4) \quad \alpha(Y_t/u_t) = p_tu_t^\gamma - 1 K_t,$$

$$(5) \quad \lim_{t \to \infty} \beta^t(K_{t+1}/C_t) = 0,$$

where Equation (2) equates the slope of the household’s indifference curve to the real wage and Equation (3) is the consumption Euler equation. Moreover, Equation (4) equates the marginal gain (more output) and marginal loss (higher capital depreciation) of a change in the capital utilization rate and Equation (5) is the transversality condition.

**Equilibrium and Local Dynamics**

I focus on symmetric perfect-foresight equilibria that consist of a set of prices $\{p_t, r_t, w_t\}_{t=0}^\infty$ and quantities $\{C_t, L_t, u_t, K_t, I_{t-1}\}_{t=0}^\infty$ that satisfies the household's and firms' first-order conditions. In addition, the aggregate consistency condition requires that $u_t = \bar{u}_t$, $K_{ct} = \bar{K}_{ct}$, $L_{ct} = \bar{L}_{ct}$, $K_{lt} = \bar{K}_{lt}$, and $L_{lt} = \bar{L}_{lt}$, for all $t$. The equalities of demand by households and supply by firms in the consumption and investment sectors are given by $C_t = Y_{ct}$ and $I_t = Y_{lt}$. Finally, factor markets clear whereby

$$K_{ct} + K_{lt} = K_t,$$

$$L_{ct} + L_{lt} = L_t.$$

It is straightforward to show that the model possesses a unique interior steady state. Then, taking log-linear approximations to the equilibrium conditions in a neighborhood of this steady state results in the following dynamic system:
\[
\begin{bmatrix}
\hat{K}_t \\
\hat{p}_t
\end{bmatrix}
= J \begin{bmatrix}
\hat{K}_{t+1} \\
\hat{p}_{t+1}
\end{bmatrix}, \quad \hat{K}_0 \text{ given},
\]

where hat variables denote percent deviations from their steady-state values and \( J \) is the Jacobian matrix of partial derivatives of the transformed dynamic system. The model exhibits saddle path stability when one eigenvalue of \( J \) lies inside and the other outside the unit circle. When both eigenvalues are outside the unit circle, the steady state is indeterminate and thus a sink. When both eigenvalues are inside the unit circle, the steady state becomes a totally unstable source.

**The Euler Equation and Indeterminacy**

In this model, indeterminacy results with very low increasing returns to scale because of the combined effects, described above, of the existence of two sectors of production and of variable capital utilization. The Euler equation can be satisfied by an infinite number of sequences of prices and quantities even with returns to scale as low as 1.02, under a standard parameterization.

Now, to incorporate formally the possibility of sunspot shocks, we rewrite the intertemporal Euler equation, Equation (3), as:

\[
E_t[V_{t+1}] = 0,
\]

where

\[
V_{t+1} = \frac{1}{C_t} \left\{ \frac{(1/C_{t+1})[r_{t+1} + (1 - \delta_{t+1})p_{t+1}]}{p_t} \right\}.
\]

That is, on average the Euler equation is satisfied. We can therefore write:

\[
V_{t+1} - E_t[V_{t+1}] = \omega_{t+1},
\]

where

\[
E_t(\omega_{t+1}) = 0.
\]

I refer to \( \omega_{t+1} \) as the sunspot shock or the Euler error. As sunspot equilibria are rational, and the sunspot is assumed to represent agents’ expectations, the Euler error is assumed to be mean zero and also serially uncorrelated. In the next section I describe in more detail how I compute this series.

**MEASURES OF NONFUNDAMENTAL CONFIDENCE**

In this section, I describe how I compute both measures of nonfundamental confidence. First, I use the Euler equation of the model to compute the Euler error, and calculate its nonfundamental part as the residual from a regression on fundamentals. Then, I calculate the measure of nonfundamental confidence in the data as the residual from a regression of the University of Michigan index on the same fundamentals.
The Nonfundamental Euler Error

I use Equation (6) to calculate the Euler errors in the model. In contrast to Farmer and Guo [1995] and Farmer and Ohanian [1999] (FGO), I directly calculate them, as opposed to estimating them as the residual from a linear regression. I use quarterly data (as opposed to annual) in order to capture more precisely any fluctuations at the frequency of the business cycle. The sample is from 1968:2 to 1996:3 for a total of 114 observations. For example, the Euler error for 1968:2 is:

$$\omega_{1968:2} = \left(1/C_{1968:1}\right) - \left(\beta/C_{1968:2}\right) \left[\left(r_{1968:2} + (1-\delta_{1968:2})p_{1968:2}\right)/p_{1968:1}\right].$$

Data on consumption, $C$, is the sum of personal and government consumption expenditures (see FGO) from National Income and Product Accounts (NIPA) data. The relative price of investment, $p$, is calculated as the ratio of the price of investment to consumption goods, also using NIPA data. The rate of capital depreciation for each period is derived as it is assumed in the model. That is,

$$\delta = (1/\gamma)u^\gamma .$$

I choose $\gamma = 9.72$, for which the mean rate of utilization in the data (82 percent) implies $\delta = .015$, a value common in the RBC and indeterminacy literatures. Data on capacity utilization, $u$, is from economagic.com. Following FGO, I use the model equations to compute $r$. In particular, I use

$$r = \alpha C/K_c = \alpha C/\mu K ,$$

where I set $\alpha = .3$ and $\mu$ is the share of resources used in production of the consumption good. I compute a series for the capital stock, $K$, as do FGO, using Equation (1). This data was found to perform better than conventional measures, which are only available at the annual frequency. Lastly, I calculate $\mu$ as:

$$\mu = C/(C + pI),$$

where investment, $I$, is also taken from NIPA data and includes government investment. The average value of $\mu$ in the data is .8. The parameter $\beta$ is fixed at .99.

Of course, this Euler error contains information both fundamental and nonfundamental. In order to create a measure of the nonfundamental Euler error, I regress the Euler error, $E$, on fundamental variables. The residual from this regression therefore measures the nonfundamental part of the Euler error. The regression is:

$$E_t = \begin{bmatrix} P_1(L) & P_2(L) & P_3(L) & P_4(L) \end{bmatrix} \begin{bmatrix} l_t \\ T_t \\ m_t \end{bmatrix} + \epsilon_t ,$$

where $E_t$ is the Euler error and $\epsilon_t$ is the residual. This regression allows us to estimate the nonfundamental part of the Euler error, which can then be used in further analysis.
where \( l \) is the growth in the leading economic indicator, \( T \) is the change in the three-month Treasury bill rate, and \( m \) is the growth in the real money supply as measured by M2 (economagic.com). Dickey-Fuller tests indicate that each of these variables is stationary over the sample period. The \( P(L) \)'s are each polynomials that include a constant and are of length four in the lag operator. That is, four lags of each variable are included in the equation.\(^7\) \( \varepsilon_t^E \) is taken to measure the sunspot shock. The results of this regression are reported in Table 1. In this regression, only the change in the Treasury bill rate is not significant. The Durbin Watson statistic indicates that the null hypothesis of no first-order serial correlation cannot be rejected while the high significance levels for the Ljung-Box statistics indicate the same for higher orders.\(^8\) This latter result stands in contrast to Farmer and Guo [1995], who do find serial correlation in their Euler errors and conclude that the Euler equation in their model may be misspecified. On the contrary, I conclude that the nonfundamental Euler errors computed from this model do in fact represent sunspot shocks.

**TABLE 1**

Results of \( E \) Regression

<table>
<thead>
<tr>
<th>Variable or Statistic</th>
<th>Significance or Value (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E )</td>
<td>.09</td>
</tr>
<tr>
<td>( l )</td>
<td>.00</td>
</tr>
<tr>
<td>( T )</td>
<td>.43</td>
</tr>
<tr>
<td>( m )</td>
<td>.09</td>
</tr>
<tr>
<td>( \bar{R}^2 )</td>
<td>.43 (V)</td>
</tr>
<tr>
<td>Durbin Watson</td>
<td>2.03 (V)</td>
</tr>
<tr>
<td>Ljung-Box with 4 lags</td>
<td>.99</td>
</tr>
<tr>
<td>Ljung-Box with 8 lags</td>
<td>.86</td>
</tr>
<tr>
<td>Ljung-Box with 12 lags</td>
<td>.85</td>
</tr>
</tbody>
</table>

**Nonfundamental Confidence**

I construct a measure of nonfundamental confidence using the University of Michigan index of consumer sentiment. Bram and Ludvigson [1998] provide a thorough discussion of this index.\(^9\) I regress the index on the same fundamentals as above. The regression is therefore:

\[
S_t = [P(L)] \begin{bmatrix} S_t \\ l_t \\ T_t \\ m_t \end{bmatrix} + \varepsilon_t^c,
\]

where \( S \) denotes the confidence index and the residual, \( \varepsilon_t^c \), or confidence residual, is the measure of nonfundamental confidence.
Table 2 reports the results of this regression. Only the growth in the leading indicator is not significant at the 10 percent level, and there is again clearly no serial correlation in errors.

**TABLE 2**

<table>
<thead>
<tr>
<th>Variable or Statistic</th>
<th>Significance or Value (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$</td>
<td>.00</td>
</tr>
<tr>
<td>$l$</td>
<td>.40</td>
</tr>
<tr>
<td>$T$</td>
<td>.03</td>
</tr>
<tr>
<td>$m$</td>
<td>.10</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.82 (V)</td>
</tr>
<tr>
<td>Durbin Watson</td>
<td>1.99 (V)</td>
</tr>
<tr>
<td>Ljung-Box with 4 lags</td>
<td>.97</td>
</tr>
<tr>
<td>Ljung-Box with 8 lags</td>
<td>.98</td>
</tr>
<tr>
<td>Ljung-Box with 12 lags</td>
<td>.94</td>
</tr>
</tbody>
</table>

**DOES THE SUNSPOT REFLECT CONFIDENCE?**

In this section, I examine the relationship between these two series in order to determine whether the model’s sunspot represents a measure of confidence that may be observed in the data. First, recall that by definition, since they are residuals from a regression, both series are mean zero. In addition, the Durbin Watson and Ljung-Box statistics reported in Tables 1 and 2 clearly indicate that the null hypothesis that there is no serial correlation cannot be rejected for either series. Therefore, both satisfy the necessary properties of sunspot shocks.

Figure 1 plots the confidence residuals together with the nonfundamental Euler errors. They appear to be highly correlated. Table 3 reports the results of a regression of the nonfundamental Euler errors, $\varepsilon_t^E$, on the confidence residuals, $\varepsilon_t^s$. Given the coefficient on $\varepsilon_t^s$ and its standard error, there is clearly a statistically significant relationship between the two.10

**TABLE 3**

<table>
<thead>
<tr>
<th>Variable or Statistic</th>
<th>Coefficient or Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_t^s$</td>
<td>.319 (.090)</td>
</tr>
<tr>
<td>$\bar{R}^2$</td>
<td>.11</td>
</tr>
</tbody>
</table>

Note: Standard errors are reported in parentheses.
Of course, there are a variety of other variables that may explain $\varepsilon_t^E$. By construction, this variable is orthogonal to the fundamentals in Equation (7), but the possibility always exists that other relevant variables have been omitted. However, assuming that the computed confidence residual, $\varepsilon_t^s$, is truly nonfundamental, it is by construction orthogonal to any excluded relevant variables. In this case, the exclusion of such variables does not affect the consistency or standard error of the coefficient on $\varepsilon_t^s$. In order to test the exogeneity of $\varepsilon_t^s$, Table 4 presents the results of a regression of $\varepsilon_t^s$ on other fundamentals. The fundamentals are the Standard & Poor 500 index ($sp500$), the unemployment rate ($unemp$), and the growth rate of real GDP ($gdpgr$). Dickey-Fuller tests indicate stationarity of these variables over the sample period. Four lags of each variable, and a constant, are included. Since none of the variables are significant and the $R^2$ is negative, it appears that the confidence residual is truly nonfundamental. Therefore, exclusion of other variables from the regression in Table 3 is of no consequence.
DO SUNSPOTS REFLECT CONSUMER CONFIDENCE?

TABLE 4
Results of $\varepsilon_t$ Regression

<table>
<thead>
<tr>
<th>Variable or Statistic</th>
<th>Significance or Value (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_t$</td>
<td>.99</td>
</tr>
<tr>
<td>sp500</td>
<td>.64</td>
</tr>
<tr>
<td>unemp</td>
<td>.48</td>
</tr>
<tr>
<td>gdpgr</td>
<td>.87</td>
</tr>
<tr>
<td>$R^2$</td>
<td>–.09 (V)</td>
</tr>
</tbody>
</table>

DOES EITHER SERIES CAUSE FLUCTUATIONS?

Given evidence of a significant correlation between the two series, I now examine the possibility that either captures a measure of confidence that has served to cause fluctuations in the U.S. economy. I first examine the behavior of each series before business cycle turning points. In particular, falling (rising) confidence before a peak (trough) suggests that the pessimism (optimism) may have caused the subsequent contraction (expansion).

Consumer Sentiment and the Confidence Residual

Before examining the behavior of the confidence residual, it is useful first to study the variable from which it is derived, the University of Michigan index of consumer sentiment. The time series behavior of the index is displayed in Figure 2. Also included in the figure are National Bureau of Economic Research (NBER) contractions, indicated by the shaded areas. This figure demonstrates the relationship between sentiment and business cycles. Keeping in mind that correlation does not imply causation, if the index falls before the start of a contraction, this can be interpreted as evidence that the fall in sentiment contributed to the contraction. If it rises before the end of the contraction, optimism may have contributed to the recovery. Of course, this index is likely highly influenced by fundamentals and so is not the measure in which I am ultimately interested. However, this analysis provides a useful exercise for thinking about the relationship between confidence and output.

By examining the figure, one observes that the index was falling preceding four of the five contractions. The only exception is the slowdown of the early 1980s, during which confidence fell only as the contraction started. Before each upturn, however, it does not appear that confidence rose. This provides preliminary evidence that the index may be a good predictor of contractions, but not necessarily of expansions. (See also Chauvet and Guo [2003], who focus on contractions.)
Table 5 identifies the NBER peaks and troughs that occurred during the sample. In addition, it reports the average growth rate of the index during the 3 quarters preceding each turning point. The number of quarters, out of three, for which the index fell (rose) before each peak (trough) is reported in parentheses. When the sign is as predicted, the number is in boldface. As discussed above, the average growth rate is negative before four of the five peaks, but positive before only one of the troughs. Chauvet and Guo [2003] find that the probability of pessimism is higher in recessions, so perhaps this explains the latter result.

TABLE 5
Behavior of Consumer Sentiment

<table>
<thead>
<tr>
<th>Peak</th>
<th>Trough</th>
<th>Growth Rate Before Peak</th>
<th>Growth Rate Before Trough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1969</td>
<td>Nov. 1970</td>
<td>-.02 (2)</td>
<td>-.01 (1)</td>
</tr>
<tr>
<td>Nov. 1973</td>
<td>Mar. 1975</td>
<td>-.07 (3)</td>
<td>-.03 (1)</td>
</tr>
<tr>
<td>Jan. 1980</td>
<td>July 1980</td>
<td>-.04 (3)</td>
<td>-.05 (1)</td>
</tr>
<tr>
<td>July 1981</td>
<td>Nov. 1982</td>
<td>.05 (1)</td>
<td>.01 (2)</td>
</tr>
<tr>
<td>July 1990</td>
<td>Mar. 1991</td>
<td>-.01 (3)</td>
<td>-.18 (0)</td>
</tr>
</tbody>
</table>

Note: Numbers in parentheses are number of quarters, out of three, that the measure fell (rose) before each peak (trough). Results with the expected sign are in boldface.
Figure 3 depicts the confidence residuals, computed as the part of the index orthogonal to the chosen fundamentals, with NBER contractions again shaded. These residuals do not appear to fall before peaks as consistently as did the sentiment index itself. To see this more clearly, in Table 6 I again report the peaks and troughs with average growth rates of the confidence residuals before each turning point. The evidence indicates that pessimism contributed to two of the five contractions, but that optimism was not present before any of the expansions.

**FIGURE 3**

Confidence Residuals

![Graph showing confidence residuals with shaded areas indicating NBER contractions.]

Note: Shaded areas are NBER contractions.

**TABLE 6**

Behavior of Confidence Residuals

<table>
<thead>
<tr>
<th>Peak</th>
<th>Trough</th>
<th>Growth Rate Before Peak</th>
<th>Growth Rate Before Trough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1969</td>
<td>Nov. 1970</td>
<td>3.96 (1)</td>
<td>–.95 (0)</td>
</tr>
<tr>
<td>Nov. 1973</td>
<td>Mar. 1975</td>
<td>–2.83 (2)</td>
<td>–1.05 (1)</td>
</tr>
<tr>
<td>Jan. 1980</td>
<td>July 1980</td>
<td>.155 (1)</td>
<td>–1.85 (0)</td>
</tr>
<tr>
<td>July 1981</td>
<td>Nov. 1982</td>
<td>.047 (1)</td>
<td>–.10 (1)</td>
</tr>
<tr>
<td>July 1990</td>
<td>Mar. 1991</td>
<td>–2.87 (3)</td>
<td>–3.71 (1)</td>
</tr>
</tbody>
</table>

Note: Numbers in parentheses are number of quarters, out of three, that the measure fell (rose) before each peak (trough). Results with the expected sign are in boldface.
In summary, using the University of Michigan’s index of consumer sentiment, there is evidence that pessimism on the part of consumers may have contributed to contractions during the sample period. After controlling for fundamentals, the same is true of the confidence residuals. However, neither seems to capture a cause of any expansions. It seems that at the end of expansions, consumers turn pessimistic, which may contribute to the subsequent contraction, but the opposite is not true at the end of contractions. Consumers do not become optimistic, either as measured including the effects of the economy on their behavior, or without such effects.\textsuperscript{12}

**Nonfundamental Euler Errors**

Figure 4 plots the nonfundamental Euler error over the sample period and in Table 7 I assess its properties around turning points. With respect to peaks, average growth rates indicate that, if the nonfundamental Euler error is a reflection of sentiment, like the confidence residual, it contributed to two contractions. As far as expansions are concerned, this shock performs better than the two measures of confidence in the data, though still with only two positive average growth rates.

![FIGURE 4](image-url)
DO SUNSPOTS REFLECT CONSUMER CONFIDENCE?

TABLE 7

Behavior of Nonfundamental Euler Errors

<table>
<thead>
<tr>
<th>Peak</th>
<th>Trough</th>
<th>Growth Rate Before Peak</th>
<th>Growth Rate Before Trough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1969</td>
<td>Nov. 1970</td>
<td>-3.14 (3)</td>
<td>-1.43 (0)</td>
</tr>
<tr>
<td>Nov. 1973</td>
<td>Mar. 1975</td>
<td>-1.19 (3)</td>
<td>-3.22 (0)</td>
</tr>
<tr>
<td>Jan. 1980</td>
<td>July 1980</td>
<td>.98 (2)</td>
<td>3.06 (2)</td>
</tr>
<tr>
<td>July 1981</td>
<td>Nov. 1982</td>
<td>63.15 (2)</td>
<td>-3.49 (0)</td>
</tr>
<tr>
<td>July 1990</td>
<td>Mar. 1991</td>
<td>3.76 (1)</td>
<td>1.99 (2)</td>
</tr>
</tbody>
</table>

Note: Numbers in parentheses are number of quarters, out of 3, that the measure fell (rose) before each peak (trough). Results with the expected sign are in boldface.

In summary, similar to the confidence residuals, the sunspot shocks implied by this model may have contributed to contractions. In addition, in contrast to the confidence residuals calculated using the index of consumer sentiment, the model’s measure of expectations implies that optimism may also have contributed to some expansions. In this respect, the implied sunspot shocks may be a better measure of changes in confidence than those represented by the data.13

CONCLUSION

In this paper I have examined a model of business cycles in which indeterminacy is possible. In the model, self-fulfilling changes in agents’ expectations, represented by sunspot shocks, are a driving force behind fluctuations. That is, indeterminacy of equilibria is possible. This is the case due to the presence of increasing returns to scale in production.

I have used the intertemporal Euler equation to estimate the sunspot shocks implied by the model, and found that the computed series in fact satisfies the necessary properties of such shocks. I have also constructed a measure of nonfundamental confidence using data on consumer sentiment and found that this series also qualifies as a sunspot shock. Comparing the two series, I have found a statistically significant correlation between them. I therefore conclude that the sunspot shock in the model is an accurate reflection of nonfundamental confidence. Evidence, however, that either of these series measure a shock that has contributed to business cycles is weak.

Results in this paper indicate that, in models with indeterminacy of equilibria, the sunspot shock can be interpreted as reflecting changes in nonfundamental confidence. In future work I will allow for fundamental shocks as well, in order to assess the relative importance of each in driving business cycle fluctuations. I will also address the issue of changes in nonfundamental confidence more deeply by asking what in particular causes such changes. Potential candidates include political factors as well as influence from the media.

NOTES

I thank Marina Felman, Julie Muchnik, and Maya Rosenthal for excellent research assistance; and Marcelle Chauvet, Jang-Ting Guo, an anonymous referee, and the participants at the Conference on Macroeconomic Coordination Failures for helpful comments and discussion. All remaining errors are, of course, my own.
1. See Benhabib and Farmer [1999] for an excellent survey of this literature.

2. Chauvet and Guo [2003] and Eudey and Perli [1999] are both able to fit measures of consumer sentiment to a Markov switching process, moving between states of optimism and pessimism. Here neither series was found to follow such a process. See also Hamilton [1989].

3. Harrison [2001] considers different sizes of sector-specific externalities and finds that indeterminacy occurs when externalities in the investment sector are sufficiently high, even when there is none for consumption. Weder [2000] obtains the same finding in a monopolistic competitive setting in which the two sectors exhibit different markups of prices over marginal costs.

4. I adopt the period utility function with indivisible labor, as in Hansen [1985], whereby the labor supply elasticity is infinity. See Table 2 of Schmitt-Grohé [1997], which shows that the higher the labor supply elasticity, the lower the increasing returns needed to obtain indeterminacy in RBC models.

5. See Christiano and Harrison [1999] for a more detailed notation for including sunspot shocks.

6. Results are robust to altering the definition of consumption so as not to include government consumption or as not to include spending on durable goods.

7. The use of four lags is standard in the literature (See, for example, Matsusaka and Sbordone [1995] and Chauvet and Guo [2003].)

8. I also considered fundamentals such as the growth in GDP and the Standard & Poor 500 stock index. Results were similar.

9. Thanks to Sydney Ludvigson for making data on consumer sentiment available to me.

10. The series have been scaled so that their variances are equal. Therefore, the reported coefficient is equal to the correlation between the two series.

11. Thanks to Gautam Tripathi for pointing this out to me.

12. I also cannot reject the null hypothesis that the confidence residuals do not Granger cause output growth for the entire sample and for the subsample of observations around business cycle turning points.

13. However, I also cannot reject the null hypothesis that the nonfundamental Euler errors do not Granger cause output growth for the entire sample and for the subsample of observations around business cycle turning points.

REFERENCES


