Technology, Credit and Confidence during the Roaring Twenties

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Abstract

We compare and contrast alternative explanations of the Roaring Twenties. Starting with the RBC model as a benchmark, we also examine a model with indeterminacy and self-fulfilling expectations (SFE), and one with credit shocks. Historical and anecdotal evidence provides support for each of these set-ups. We use US data from 1889-1953 to estimate each of the relevant shocks, and the resulting model-driven output. Our results indicate that all three models replicate well the experience of the 1920s. We then estimate "horserace" regressions, which provide evidence of the explanatory power of each model above and beyond the others. Here the SFE model emerges as the winner, leading us to conclude that self-fulfilling confidence was the primary driving force behind the Roaring Twenties.

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1 Introduction

The boom of the 1990s has sparked interest among economists in studying unique episodes in the history of the US economy. Of interest to us is the literature on the Great Depression, led by Cole and Ohanian (1999, 2001) and including Bordo, Erceg and Evans (2000), among others, evaluating real business

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cycle or sticky price money models in this context. Harrison and Weder (2006) in particular assess the possibility that a neoclassical model in which self-fulfilling beliefs (aka sunspots) drive business cycles might explain the Great Depression. They provide evidence that extrinsic pessimism starting in 1930 turned what might have been a recession into the Great Depression. Here we carry out a similar analysis, this time studying the decade of the Roaring Twenties.

This paper differs from that of Harrison and Weder (2006) in various ways. We start with the standard real business cycle (RBC) model as a benchmark and assess the power of technology shocks at replicating the experience of the 1920s. We believe that the RBC approach is a potential candidate, not only because of its success in explaining the postwar cycle, but also in light of the introduction of many new goods during the first decades of the last century. For example, electricity had been extended to all but the most rural areas and telephones were becoming commonplace. In addition, we cite the introduction of new means of production, such as the assembly line. (See Delong, 1997.)

We then do the same for a modified version of the RBC model, where self-fulfilling expectations are added as a primary source of fluctuations (henceforth the SFE model). Optimism is cited widely as present during the 1920s:

> "... the bull market in stocks mirrored soaring American optimism about the future" (Friedman & Schwartz, 1963, p 296)

The SFE model is a modification of the RBC model in which the possibility of indeterminacy of equilibria arises, and is the same as that is used in Harrison and Weder (2006).[1] The indeterminacy occurs 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. In using this model, we have in mind a theory of the Roaring Twenties in which changes in expectations were extrinsic to the economy, or nonfundamental. Our theory is supported by Ginzberg (2004). He offers evidence of optimism on the parts of consumers during the 1920s. Relevant for us, he also observes that much of this optimism was not driven by fundamentals. He points to the "high wage doctrine" and the belief in the continuing stability of prices as the drivers of this optimism. The former refers to the belief that the prevailing high wages would continue, and were good for the economy. He observes that:

> "...the conviction became widespread that the prevailing prosperity could long continue...Depressions were perhaps a thing of the past...Today it is clear that the contemporary evaluation of the twenties was fundamentally incorrect, but it is not clear why contemporaries held firmly to the belief in economic balance...the populace must have been favorably predisposed to the gospel of enduring prosperity." (p 11)

Not only were contemporaries persistent in holding to their beliefs, but Ginzberg argues that

> "Doubtful was... the doctrine of high wages that sought to explain the dynamics of the era by virtues inherent in rising wage rates. The data were sparse, and the logic was weak." (p 132)

[1] See Benhabib and Farmer (1999) for a comprehensive review of such models.

and

> "Under the sway of the doctrine, optimism ran rampant; fundamental contradictions were politely denied." (p 68)

These quotes summarize well this view of the Roaring Twenties: nonfundamental optimism drove consumer demand.

Lastly, we examine a third model which includes credit and money shocks. Here we have in mind the theory that Olney (1991) advances. She asserts that the "consumer durables revolution" of the 1920s was supported by increases in the use of installment buying:

> "Changes in relative price and income cannot alone explain interwar patterns of household expenditure for durable goods...there was a vast expansion of consumer debt in the 1920s." (p 2-3)

Therefore, the credit shocks in our model represent the increased availability of credit during the period, facilitating the exchange of goods and services. There is also evidence of a change in the role of private banks during this time period, which we argue may be a force behind these credit shocks. In particular, Wheelock (1992) cites convincing evidence of "overbanking" due to the relaxation of regulations earlier in the century. Friedman and Schwartz (1963) state that:

> "Many banks engaged in sidelines in addition to making loans and investment – principally fiduciary functions and the underwriting and distributing of securities. These changes affected the number and size of banks." (p 245)

Our flexible price money and credit model (henceforth the MC model) is taken from Benk, Gillman and Kejak (BGK, 2005). Here, with constant returns to scale in the production of output, credit is produced as an alternative to money, and is subject to productivity shocks. Consumers operate under a cash-in-advance constraint. Our primary objective is to assess the role of the credit shocks.

In order to compare the efficacy of each of these three models, we estimate the technology shocks, sunspot shocks, and money and credit shocks in the RBC, SFE, and MC models respectively. To do this, we use annual data over the period 1889-1953. We then feed each of these shocks back in to the relevant model, and compare the resulting output to that in the data. We estimate two versions of the MC model, one with only money shocks and one with only credit shocks. Our results indicate that the RBC and SFE models replicate well the experience of the 1920s. Increases in total factor productivity during this time lend support to the RBC model, while the same is true for confidence and the SFE model. Increased credit does the same for the MC model, but the behavior of money (or the central bank for that matter) is not appropriate in this context for gaining an understanding of this period.

In addition, we carry out a quantitative analysis to compare these models. We estimate the ability of each model to explain output by running horserace regressions in the spirit of Fair and Shiller (1990). This method allows us to compare the explanatory power of each model above and beyond that of the

others. These results indicate that the SFE model provides the most significant power, but the RBC and, to a lesser extent, the credit model, follow closely behind. We therefore conclude that self-fulfilling expectations were the primary driving force behind the Roaring Twenties. However, technology and credit are also important to building an understanding of the experience of the Roaring Twenties.

The rest of this paper proceeds as follows. In Section 2 we outline both the RBC and SFE models. We do the same for the MC model in Section 3. In Section 4 we present our results; and in Section 5 we conclude.

2 The RBC and SFE models

In this section, we lay out a version of the RBC model that can be parameterized to display increasing returns to scale. When returns to scale are constant, we have the RBC model. When they are mildly increasing, it is the SFE model. The model is based on Greenwood, Hercowitz and Huffman (1988) and Wen (1998). It is a one-sector dynamic general equilibrium model with variable capital utilization and production externalities.[2] We assume that the economy is populated by identical consumer-worker households of measure one, each of which lives forever. The problem faced by a representative household is

$$\max_{\{c_t,l_t,u_t,k_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\varsigma)\log c_t + \varsigma(1-n_t)\right] \tag{1}$$

$$\text{s.t. } c_t + x_t = y_t = A_t^{\gamma} z_t (u_t k_t)^{\alpha} n_t^{1-\alpha} \qquad A_t = (\overline{u}_t \overline{k}_t)^{\alpha} \overline{n}_t^{1-\alpha} \tag{2}$$

$$k_{t+1} = (1-\delta_t)k_t + x_t; \qquad \delta_t = \frac{1}{\theta} u_t^{\theta} \tag{3}$$

and a given initial stock of capital, $k_0 > 0$. We restrict the parameters $0 < \alpha < 1$, $0 < \beta < 1$, $\gamma \geq 0$, $0 < \varsigma < 1$, and $\theta > 1$. The variables c_t, n_t, x_t, k_t, and u_t denote consumption, labor, investment, capital, and the capital utilization rate. Hours worked enter linearly into utility. This reduced form function reflects indivisibility of labor and that a lottery for employment allocates workers. As in most studies with variable capital utilization, the rate of depreciation, δ_t, is an increasing function of the utilization rate. A_t represents the aggregate externality, where bars over variables denote average economy-wide levels. The externality is taken as given for the individual optimizer. Deviations from constant returns to scale are measured by γ. In the RBC model, $\gamma = 0$. In the SFE model, $\gamma > \overline{\gamma} > 0$, where $\overline{\gamma}$ is a threshold above which expectations become self-fulfilling in the model. All markets are perfectly competitive. Stochastic total factor productivity is denoted by z_t and it follows the process

$$\ln z_t = \rho \ln z_{t-1} + \epsilon_t \qquad \epsilon_t \sim \mathcal{N}(0, \sigma_{\epsilon}^2),\ 0 < \rho < 1.$$

[2] Benhabib and Wen (2004) as well as Harrison and Weder (2006) report some further applications of this general model structure able to explain post- and prewar U.S. business cycles.

2.1 Equilibrium and dynamics

In symmetric equilibrium, the first order conditions entail

$$\frac{\varsigma}{1-\varsigma} n_t = (1-\alpha)\frac{y_t}{c_t} = (1-\alpha)\frac{z_t(u_t k_t)^{\alpha(1+\gamma)} n_t^{(1-\alpha)(1+\gamma)}}{c_t} \tag{4}$$

$$u_t^{\theta} = \alpha \frac{y_t}{k_t} \tag{5}$$

$$\frac{1}{c_t} = E_t \frac{\beta}{c_{t+1}} \left(\alpha \frac{y_{t+1}}{k_{t+1}} + 1 - \frac{1}{\theta} u_{t+1}^{\theta} \right) \tag{6}$$

$$k_{t+1} = (1 - \frac{1}{\theta} u_t^{\theta}) k_t + y_t - c_t. \tag{7}$$

Equation (4) shows that $1+\gamma$ measures the degree of increasing returns to scale. This is equal to one in the RBC model. In steady state, the parameter θ is pinned down by the steady state condition

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

where δ stands for the steady state rate of capital depreciation, and variables without time subscripts represent steady state values henceforth.

Turning to dynamics, we take log-linear approximations to the equilibrium conditions to obtain the following dynamic system:

$$\begin{bmatrix} \widehat{k}_{t+1} \\ E_t \widehat{z}_{t+1} \\ E_t \widehat{c}_{t+1} \end{bmatrix} = \mathbf{M}_Y \begin{bmatrix} \widehat{k}_t \\ \widehat{z}_t \\ \widehat{c}_t \end{bmatrix} \tag{8}$$

where hat variables denote percent deviations from their steady-state values; and $\mathbf{M}_Y$ is the 3×3 Jacobian matrix of partial derivatives of the transformed dynamic system evaluated at the steady state.

2.2 Calibration and Indeterminacy

We use annual data to calibrate these models. We set the capital share at $\alpha = 0.3$, the discount factor at $\beta = 0.96$ and $\delta = 0.1$. These imply $\theta = 1.417$. There is no need to calibrate ς as it does not appear in the log-linearized version of the economy. In the RBC model, $\gamma = 0$, returns to scale are constant, and there are no other solutions besides the unique steady state. The rest of this subsection is devoted to the SFE model.

Indeterminacy results when $\gamma > \overline{\gamma}$. Under our calibration, $\overline{\gamma} = 0.138$. Bernanke and Parkinson (1991) and Burns (1936) find evidence of significant increasing returns during the interwar years. We therefore set $\gamma = 0.2$ in the SFE model, implying returns to scale of 1.2, which cannot be rejected by Basu and Fernald (1997).

The condition for indeterminacy is easily understood from an economic perspective. Assume, for example, that households have optimistic expectations about the future and anticipate higher prospective income. Today's consumption expenditures will rise. As a consequence, the labor supply curve shifts in.

To understand the effect on employment, one must take into account that equilibrium labor demand may be unconventionally sloped, which can be seen from combining (4) and (5), which yields

$$y_t = \text{const} * k_t^{\frac{\alpha(1+\gamma)(\theta-1)}{\theta-\alpha(1+\gamma)}} l_t^{\frac{(1-\alpha)(1+\gamma)\theta}{\theta-\alpha(1+\gamma)}}. \tag{9}$$

The indeterminacy condition is that the reduced-form labor demand curve is upward sloping. Therefore, employment and investment rise today. The future capital stock, output and consumption will be high and initially optimistic expectations are self-fulfilled.

3 The MC model

In this section we present a model with money and credit. The model is based on that of Benk, Gillman and Kejak (BGK, 2005). Credit is intertemporal: it reflects the private banking sector's technology in aiding with the exchange of goods and services. That is, agents can either use money or credit when purchasing. It is assumed that the technology that produces credit is stochastic. Prices are flexible and money enters via a cash in advance constraint.

The representative household derives utility from the function

$$\sum_{t=0}^{\infty} \beta^t \left[(1-\varsigma)\log c_t + \varsigma \log x_t\right]$$

$$x_t = 1 - n_t - l_t.$$

Here x_t denotes leisure, where n_t denotes hours worked and l_t stands for the time devoted to credit production. Credit is produced using technology

$$c_t(1-a_t) = A\upsilon_t \left(\frac{l_t}{c_t}\right)^{\gamma} c_t \qquad\qquad A > 0,\ \gamma \in [0,1]$$

where $a_t \in [0,1]$ is the share of consumption expenditures that is bought via cash so that $(1-a_t)$ is the share purchased with credit. This share is a choice variable reflecting the trade-off between the opportunity cost of cash holdings, i.e. the rate of inflation, and time that is required for producing credit. $A\upsilon_t$ is the productivity shifter. We assume that

$$\ln \upsilon_t = \varphi_v \ln \upsilon_{t-1} + \epsilon_{vt} \qquad\qquad \epsilon_{vt} \sim \mathcal{N}(0, \sigma^2_{\epsilon v}),\ 0 < \varphi_v < 1.$$

The growth rate of money is represented by Θ_t and the government carries out transfers so that

$$T_t = \Theta_t M_{t-1} = (\Theta^* + u_t - 1)M_{t-1}$$

where Θ^* is the stationary growth rate of money. We further assume that the shocks to money growth follow:

$$\ln u_t = \varphi_u \ln u_{t-1} + \epsilon_{ut} \qquad\qquad \epsilon_{ut} \sim \mathcal{N}(0, \sigma^2_{\epsilon u}),\ 0 < \varphi_u < 1.$$

The cash in advance constraint of the household is:

$$M_{t-1} + T_t \geq a_t P_t c_t$$

where P_t is the current price level. Finally, its budget constraint is:

$$w_t P_t n_t + P_t r_t k_t + T_t + M_{t-1} = P_t c_t + P_t k_{t+1} + M_t.$$

The firms produce output, y_t, with a constant returns to scale production function:

$$y_t = z_t k_t^{\alpha} n_t^{1-\alpha} \qquad \ln z_t = \varphi_z \ln z_{t-1} + \epsilon_{zt} \qquad \epsilon_{zt} \sim \mathcal{N}(0, \sigma_{\epsilon z}^2),\ 0 < \varphi_z < 1.$$

3.1 Equilibrium and Dynamics

As do BGK, we represent the (unique) linear dynamics of the model with the system:

$$\widehat{k}_{t+1} = \Delta_1 \widehat{k}_t + \Delta_2 z_t + \Delta_3 v_t + \Delta_4 u_t$$

$$[X_t] = \Lambda_1 [\widehat{k}_t] + \Lambda_2 \begin{bmatrix} z_t \\ v_t \\ u_t \end{bmatrix}$$

where the Δ terms are scalars while Λ_1 and Λ_2 are matrices. Also, $[X_t] = [\widehat{c}_t\ \widehat{x}_t\ \widehat{n}_t\ \widehat{l}_t\ \widehat{a}_t\ \widehat{w}_t\ \widehat{r}_t\ \widehat{p}_t\ \widehat{y}_t]'$.

Of relevance here is the intratemporal condition

$$(1-\varsigma)\frac{1}{c_t} = \left(1 + \frac{1}{\gamma}\frac{a_t}{1-a_t}\right)\frac{\varsigma}{1-h_t-l_t}\left(\frac{1-a_t}{A v_t}\right)^{\frac{1}{\gamma}} + \frac{1}{w_t}\frac{\varsigma}{1-h_t-l_t} \qquad (10)$$

where the first term on right hand side drives in a wedge into the usual leisure-consumption trade-off. Weder (2006) discusses the importance of this wedge (sometimes referred to as a labour wedge, see Chari, Kehoe and McGrattan, 2007) during the 1920s.

3.2 Calibration

This model is also calibrated to annual data; and the calibration largely follows BGK. We set the capital share at $\alpha = 0.3$, the discount factor at $\beta = 0.96$ and $\delta = 0.10$. Credit production is assumed to have returns to scale of .21. That is, $\gamma = .21$. This is based on an estimate by Gillman and Otto (2003). We set the share of cash purchases, $a = .7$, as in Gillman and Kejak (2005). Leisure time in steady state, $x = .7055$, is similar to values used in previous studies, such as Gillman and Kejak (2005). This implies that the state value of time spent in credit production, $l = .00049$. We use data on M2 (see below), and estimate the growth rate of money, Θ^*, to be 6.1% per year.

4 Results

In this section we present our results from all three models. First we describe the data we use.

4.1 Data

Our data covers the period from 1889 to 1953. We use data on output, consumption, total hours worked, population and capital from Kendrick (1961). The GDP price deflator and monetary data are taken from Balke and Gordon (1986). All data is per capita.

4.2 The RBC model

In this section we present our results using the RBC model. We estimate the series of technology shocks as follows. There is no data for capital utilization available for the considered period. Hence, we first compute a series of model-consistent utilization from the first-order condition

$$u_t = \left(0.3\frac{y_t}{k_t}\right)^{1/1.41}$$

and given this calibration, total factor productivity is computed, accounting for variable utilization, by

$$z_t = \frac{y_t}{(u_t k_t)^{0.3} n_t^{0.7}}.$$

We Hodrick-Prescott detrend z_t (as well as all other data) and specify the parameter using the frequency power rule of Ravn and Uhlig (2002) (the number of periods per year divided by 4, raised to a power, and multiplied by 1600). We find that this resulting series is well-described by a first order autoregressive process with $\rho = 0.77$.

First, we plot TFP in Figure 1. Compared to the other decades in the sample, TFP experienced the highest growth during the 1920s. It was also the least volatile, and the highest on average. In Figure 2 we plot simulated model output compared to the data (both HP filtered). We adjust the volatility of shocks so that output's variance is the same for the model and the data over the whole sample.[3] The correlation between model and data is 0.85. Figure 3 shows this data for the 1920s and 1930s, where the correlation is slightly lower, at 0.78. The model misses the start of the Great Depression – it comes too late. We attribute this to the high TFP growth of the 1930s. The model also overestimates the speed of the recovery. This is consistent with Cole and Ohanian's (1999) recognition that changes in TFP cannot explain the weakness of the recovery. However, over the 1920s the model does quite well. There were three recessions, each lasting over a year, from 1920:I to 1921:III, 1923:II to 1924:III and 1926:III to 1927:IV. The model matches these, and does particularly well in the latter part of the decade. As with the other theories that we consider here, we will conduct a quantitative analysis of the model's performance in Section 4.5.

4.3 The SFE model

In this section, we use the SFE model ($\gamma = 0.2$). Here we have in mind an explanation of the 1920s in line with Allen (1931):

> "[The 1920s] represent nearly seven years of unparalleled plenty; nearly seven years during which men and women might be disillusioned about politics and religion and love, but believed that at the end of the rainbow there was at least a pot of negotiable legal tender consisting of the profits of American industry and American

[3] The reasoning here is twofold. First, the volatility of the sunspot shock in the SFE model is not pinned down, so a comparison of relative magnitudes is inappropriate. Second, our numerical analysis is an examination of statistical significance and goodness of fit, so that again relative magnitudes are not relevant.

salesmanship [...] For nearly seven years the prosperity band-wagon rolled down Main Street." (p 138)

In this case the model can be represented by:

$$\begin{bmatrix} \widehat{k}_{t+1} \\ \widehat{z}_{t+1} \\ \widehat{c}_{t+1} \end{bmatrix} = \mathbf{M}_Y \begin{bmatrix} \widehat{k}_t \\ \widehat{z}_t \\ \widehat{c}_t \end{bmatrix} + \mathbf{M}_\varepsilon \begin{bmatrix} \epsilon_{zt+1} \\ \eta_{t+1} \end{bmatrix} \tag{11}$$

Here η_t stands for expectational shocks or errors. Roughly speaking, given a sequence of fundamental shocks to agents' preferences and technologies, a solution to this linear rational expectations model is a sequence of rational expectations forecast errors under which the endogenous variables do not explode. Under indeterminacy the forecast errors can be decomposed in two components, one is due to the fundamental shocks, and the other one is caused by sunspot shocks. (See, for example, Sims, 2000 and Lubik and Schorfheide, 2003.)

Our procedure is similar in spirit to the business cycle accounting approach that has been recently advocated by Chari, Kehoe and McGrattan (2007). In a nutshell, they use an extended real business cycle model with various frictions (aka wedges) that are measured using various model equations (first order conditions and the production function). Then these shocks are fed back into the artificial economy in order to predict the fraction of cycles the frictions are able to account for. Unlike Chari, Kehoe and McGrattan (2007), here we test a real business cycle model with indeterminacy; i.e. we assume that the economy is best described by a model in which sunspots matter. Since the occurrence of sunspots is not manifested by single first order equations but rather by the complete model i.e. a combination of the first order and side condition, our accounting must rely on the reduced form of our artificial economy.

Now, we are ready to exploit the first rows of (10) and (14), which for our calibration is:

$$E_t\widehat{c}_{t+1} = -0.0768371\widehat{k}_t + 0.0183564\widehat{z}_t + 1.16526\widehat{c}_t,$$

as follows. We know that $\widehat{c}_{t+1} - E_t\widehat{c}_{t+1} = \eta_{t+1}$ hence

$$\widehat{c}_{t+1} = -0.0768371\widehat{k}_t + 0.0183564\widehat{z}_t + 1.16526\widehat{c}_t + \eta_{t+1}.$$

This is sufficient to generate a theory consistent series of expectations from data in the following sense: the expectational shock is constructed by subtracting expected consumption from the actual data.[4] With indeterminacy, agents have more information; and this new information is captured in the term η_{t+1} which, given the environment, is a function of state of technology and the sunspot, ζ_{t+1}. We restrict the sunspot to be orthogonal to the fundamental disturbance term. Hence, we run a regression:

$$\eta_{t+1} = \widehat{\beta}\epsilon_{t+1} + \zeta_{t+1}$$

over the complete annual sample period 1889 to 1953. (Again, data have been hp-detrended.) Unlike the RBC model, we assume increasing returns and accordingly, TFP is computed as

$$z_t = \frac{y_t}{(u_t k_t)^{0.36} n_t^{0.84}}.$$

[4] Our procedure is similar to Salyer and Sheffrin (1998) however, we do not use stock market data to construct the sunspots. We did this in an earlier version of this paper; and we found that the so constructed shocks simply are essentially the stock market movements.

The regression's residuals are plotted in Figure 4, and their values in the 1920s and 1930s in Figure 5. They are, of course, mean zero over the entire sample, while we see all shocks except one (1927) are positive during the 1920s. This indicates an optimistic attitude unrelated to fundamentals. This confidence may in fact be a reflection of Allen (1931):

> "The confidence had been excessive."(p 250)

We see negative shocks starting in 1930, and a recovery in 1934. To make the emerging picture clearer, we display an index of confidence constructed from the residuals over the sample, which is computed by chaining the measured innovations from year to year (a first-difference filter). This is in Figures 6 and 7, for the entire sample, and then for just the 1920s and 1930s. In Figure 7 we plot it with output from the data. We clearly see that the level of confidence rises steadily throughout the twenties, while somewhat leveling off around 1925 and plummeting after 1929. Furthermore, confidence makes a recovery after a trough in 1933. Confidence falls again with the recession of 1937. Overall, confidence very much follows the pattern of US output. This echoes Allen (1931):

> "Only when the memory of hard times has dimmed can confidence fully establish itself; only when confidence has led to outrageous excesses can it be checked. It was as difficult for Mr. Hoover to stop the psychological pendulum on its down-swing as it had been for the Federal Reserve to stop it on its up-swing." (p 299)

In figures 8 and 9 we display model output and the data. The model output is computed by feeding in only sunspot shocks, so that we can judge their efficacy alone. The standard deviation of the shock is again adjusted so that output's variance is the same for the model and the data over the whole sample. The correlations are 0.54 (whole sample) and 0.76 (20s and 30s). The model again captures the behavior of the 1920s quite well, especially after 1925. Note that this model better predicts the recovery from the Great Depression, due to the rebounding confidence.

4.4 The MC Model

Use of this model is motivated in part by the evidence in Olney (1991) about the credit expansion. She argues persuasively that the "consumer durables revolution" of the 1920s was accompanied by a significant expansion of credit:

> "Debt for buying cars increased phenomenally in the 1920s, with nearly five times as much debt outstanding in 1929 as in 1922...The combination of all other goods debt also increased markedly in the 1920s: it more than tripled." (p 92)

This refers to nominal debt. She notes that many prices of consumer durables were falling and that real measures reveal similar increases. Allen (1931) asserts that by the 1920s

> "people were getting to consider it old-fashioned to limit their purchases to the amount of their cash balances." (p 168)

In addition, evidence about important changes in the banking industry during this time supports the use of this model. Wheelock (1992) cites the creation of so many new banks during the first two decades of the 20th century so as to lead to "overbanking." Consequently, the number of banks fell starting in the mid-1920s, from 30,291 in 1920 to 24,970 in 1929, a fall of nearly 20%. He cites the Federal Reserve Board as saying there were

> "too many bank charters where there was no real need for them" (p 2)

He also cites the creation of deposit insurance for contributing to the problem. Friedman and Schwartz (1963) concur:

> "In an effort to attract banks to their respective jurisdictions, the state and national banking systems engaged in a competitive relaxation of charter requirements and of the limitations imposed on banking activities." (p 240)

They also offer, along with Ginzberg (2004), how this affected lending and deposits:

> "The high prosperity of the twenties and the spreading belief of a new era understandably led to an increasing optimistic evaluation of the prospects of repayment and hence to an increasing readiness to lend on a given project or collateral." (Friedman and Schwartz, p 246)

and

> "Total deposits in all banks amounted to approximately 36 billion dollars in 1922 and 52 billion dollars in 1929. The annals record only one parallel increase...during World War I." (Ginzberg, p 97)

Taken together, this points to (agnostically defined) positive productivity shocks in the banking sector during the 1920s.

In addition, the state of monetary policy in the 1920s was as follows. According to Bernanke (2002), amidst concerns about the rising stock market, monetary policy failed to be corrective. Instead, it was accommodative. Only in 1928, when influential Governor of the Federal Reserve Bank of New York Benjamin Strong died, did the Fed begin to raise interest rates.

Ideally we would like to use the intratemporal condition (10) to account for the sequence of v_t shocks. However, data for hours worked in banking sector is not available before the 1970s. Moreover it is not clear how to measure a_t. Hence, following BGK, we estimate the shocks as follows.[5] Recall the model's solution took on the form:

$$\widehat{k}_{t+1} = \Delta_1 \widehat{k}_t + \Delta_2 z_t + \Delta_3 v_t + \Delta_4 u_t$$

$$[X_t] = \Lambda_1 [\widehat{k}_t] + \Lambda_2 \begin{bmatrix} z_t \\ v_t \\ u_t \end{bmatrix},$$

[5] Thanks to Szilard Benk for assistance with this.

where the Δ terms are scalars while Λ_1 and Λ_2 are matrices. One can estimate sequences of shocks using the least squares formulae

$$\begin{bmatrix} z_t \\ v_t \\ u_t \end{bmatrix} = (\Lambda_2'\Lambda_2)^{-1}\Lambda_2'\left([X_t] - \Lambda_1[\widehat{k}_t]\right).$$

Here we use HP filtered consumption, total hours worked, the GDP deflator and GDP (all per capita) in $[X_t] = [\widehat{c}_t\ \widehat{n}_t\ \widehat{p}_t\ \widehat{y}_t]$. In our simulations, we produce model output in two ways. First we include only credit shocks, and then only money shocks. We call these the *credit model* and the *money model*. In neither case do we include technology shocks. Again, our goal is to assess the role that these changes played in isolation.

The results for the credit model are shown in Figures 10 and 11. Figure 10 shows the level of credit (the state of its technology) increasing starting in 1922, with negative values only in 1922 and 1927. This is well-supported by above mentioned authors. The level of credit falls at the start of the Great Depression. In Figure 11 we plot model output over the 1920s and 1930s with the data, where the correlation is 0.75. The increasing credit during the 1920s manifests itself in rising output, though the recessions are also replicated quite well.

The results for the money model are shown in Figures 12 and 13. Figure 12 shows the money shock over the 1920s. In contrast to both sunspot and credit shocks, most of these are negative. This is consistent with the above evidence of the response to "overbanking" in previous decades, but not with the accommodative policy until 1928. The result is the output shown in Figure 13. Here the correlation is -0.75, reflecting the effects of these shocks. In summary, the money model does quite poorly in replicating the data.[6]

These results indicate that the RBC, SFE and credit models all provide promising descriptions of what happened during the Roaring Twenties. However, money shocks fail to explain this experience. In the next section we quantify these comparisons with some tests.

4.5 The horserace

In this section we assess the explanatory of power of each of our models. Time series econometrics allows data to be distinguished in atheoretical ways. For example, modelling aggregate output as a low-order autoregressive or moving-average process generates reasonable fits (see also Salyer and Sheffrin, 1998). If any of our approaches conveys anything unique about the US economy it must provide some advantage relative to such atheoretical time series models. We implement this investigation by first estimating equations of the following form:

$$\ln y_t^{\mathrm{d}} = \sum_{i=1}^{n} \beta_i \ln y_{t-i}^{\mathrm{d}} + \gamma \ln y_t^{\mathrm{m}_i} + \epsilon_t. \tag{12}$$

Here y_t^{d} denotes per capita US GDP and y_t^{m} stands for simulated model output. The subscript i indexes our four models, RBC, SFE and the two versions of MC, one with credit shocks and one with money shocks. The data is once again

[6] We suspect that introducing price stickiness would improve upon these results.

HP-filtered. The idea behind conducting these tests is that by adding output from a model to the regression, one obtains a measure of to what extent the particular shocks in the model provide additional informational content.

Let us begin with the autoregressive model. A lag length of $n = 2$ was chosen since other lags were not significant. Furthermore, given the interests of this paper, we restrict the analysis to the interwar period (1920-1939). The AR(2) model is as follows (t-statistics in parenthesis)

$$\ln y_t^{\mathrm{d}} = \underset{(3.120)}{0.622} \ln y_{t-1}^{\mathrm{d}} - \underset{(-2.426)}{0.489} \ln y_{t-2}^{\mathrm{d}}.$$

In the regressions reported in Table 1, we check to what extent contemporaneous model realizations provide additional informational content. Each line contains the results from one regression. Row 1 corresponds to the AR(2) process. Row 2 considers the RBC model, row 3 the sunspot model, row 4 the credit model and row 5 the money model.

We notice that the sunspot model provides the most information, reducing the standard error of the regression by the most, and producing the highest adjusted R^2. The RBC model is next, and the credit model follows closely. The coefficient for the money model is negative, for reasons similar to those explained above.

Table 1
Regression results

Line	Variable	Coefficient (t-value)	$\overline{R}^2$	S.E.R.	p-value
1	-	-	0.353	0.046	-
2	y^{rbc}	1.056^* (3.818)	0.631	0.035	0.001
3	y^{sun}	1.076^* (3.872)	0.636	0.034	0.001
4	y^{credit}	0.795^* (3.292)	0.581	0.037	0.004
5	y^{money}	-0.569^* (-2.953)	0.547	0.038	0.009

Table 1 – Each line reports regression statistics of linearly detrended per capita output on a constant and on own lags using annual data 1920 to 1939. Dependent variable: loglinearly detrended per capita output. Coefficient = estimate when variable is added to regression, S.E.R. = standard error of regression, p-value = probability value of the null that the variable is zero. Row 1 corresponds to AR(2) process. Row 2 considers the RBC model, row 3 the sunspot model, row 4 the credit model and row 5 the money model. A * indicates significance at the 5% level.

In order to further ascertain the additional power that each model provides, we next estimate a horserace in the spirit of Fair and Shiller (1990). Our model is:

$$\ln y_t^{\mathrm{d}} = \sum_{i=1}^{n} \beta_i \ln y_t^{\mathrm{m}_i} + \epsilon_t.$$

We estimate all the possible versions of this equation, including different models, in order to fully compare the explanatory power of each model above and beyond that of the others. Table 2 summarizes. The money model continues to have a

negative coefficient throughout. When all models are included, the credit model also contributes negatively, though the coefficient is not statistically significant. When any other model (or models) is left out, the credit model's coefficient is positive, but it is only significant on line 7. In other words, these results indicate that the credit model provides no statistically significant additional help in explaining output above and beyond the other models in particular the sunspot model. The results for the RBC model are better, with 5 out of 11 significantly positive coefficients. The sunspot model is the only one with a significant coefficient in every regression. That is, it provides different information than the other models in every case. From these tests, we conclude that the sunspot model provides the best description of the experience of the Roaring Twenties.

Table 2
Regression results (t-values in parenthesis)

Line	RBC	Sunspot	Credit	Money
1	0.907* (3.203)	0.598* (3.485)	−0.495 (−1.922)	−0.624* (−4.862)
2	0.333 (0.848)	0.724* (2.792)	0.412 (1.521)	-
3	-	0.855* (4.535)	0.155 (0.786)	− 0.452* (−3.122)
4	1.369* (4.248)	-	−0.630 (−1.923)	−0.691* (−4.2233)
5	0.478* (2.548)	0.648* (3.547)	-	−0.445* (−4.677)
6	0.797* (3.102)	0.699* (2.610)	-	-
7	-	0.823* (3.583)	0.591* (3.480)	-
8	-	0.915* (5.350)	-	−0.533* (−5.264)
9	0.828 (2.01)	-	0.366 (1.152)	-
10	0.860* (4.361)	-	-	−0.465* (−3.821)
11	-	-	0.513 (1.965)	−0.416 (−1.989)

Table 2: Horserace regressions. Each line shows the results from a regression of the included variables. A * indicates significance at the 5% level.

Given that the RBC, sunspot and credit model provide the best explanatory power, we next extend this analysis for these models to the period from 1890 to 1939. The RBC and credit models each have positive and significant coefficients in 2 of their 3 regressions. However, and most importantly, again only the sunspot model is significant in every regression. This evidence concurs with our

conclusion that the sunspot model provides the most explanatory power.

Table 3 Regression results (t-values in parenthesis)			
Line	RBC	Sunspot	Credit
1	0.356 (1.851)	0.514* (3.296)	0.408* (2.327)
2	–	0.627* (4.254)	0.677* (6.704)
3	0.725* (6.435)	0.499* (3.061)	-
4	0.602* (3.098)	–	0.383 (1.992)

Table 3: Horserace regressions 1890 to 1939. Each line shows the results from a regression of the included variables. A * indicates significance at the 5% level.

5 Summary and Conclusion

> "What is frustrating to economists is the conventional view: that the economy was basically sound but that excessive speculation by the public at large brought old-time American capitalism to grief." [Hughes and Cain, 2007, 466]

In this paper, we have examined the ability of four different theories to explain the experience of the 1920s. Technological innovation during the period motivated the use of the RBC model as a benchmark. At the same time, the expansion of credit was clearly an important development during this period, enabling consumers to spend more than they earned. Of particular interest to us, however, are the results for the SFE model. Given the substantial evidence of persistent confidence not linked to fundamentals, and the results of our horserace, we conclude that sunspot shocks were the primary driving force behind the Roaring Twenties. The logical next phase of this research project is to produce a model in which both sunspot and credit shocks are relevant to the workings of the economy.

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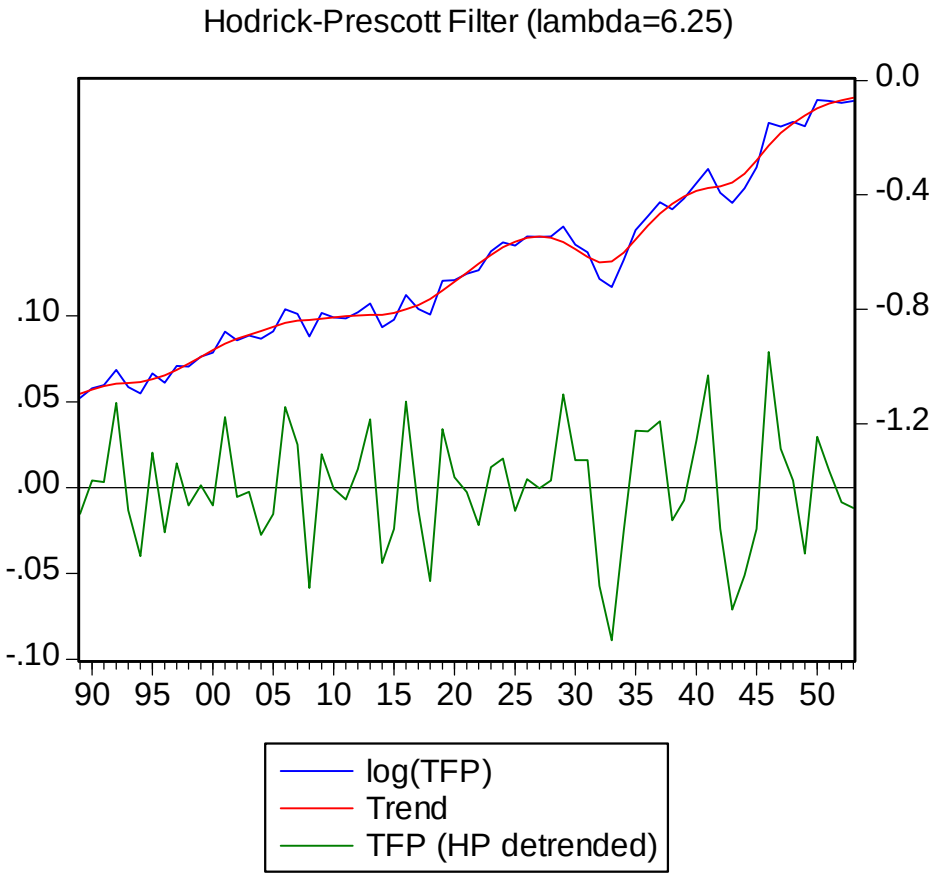
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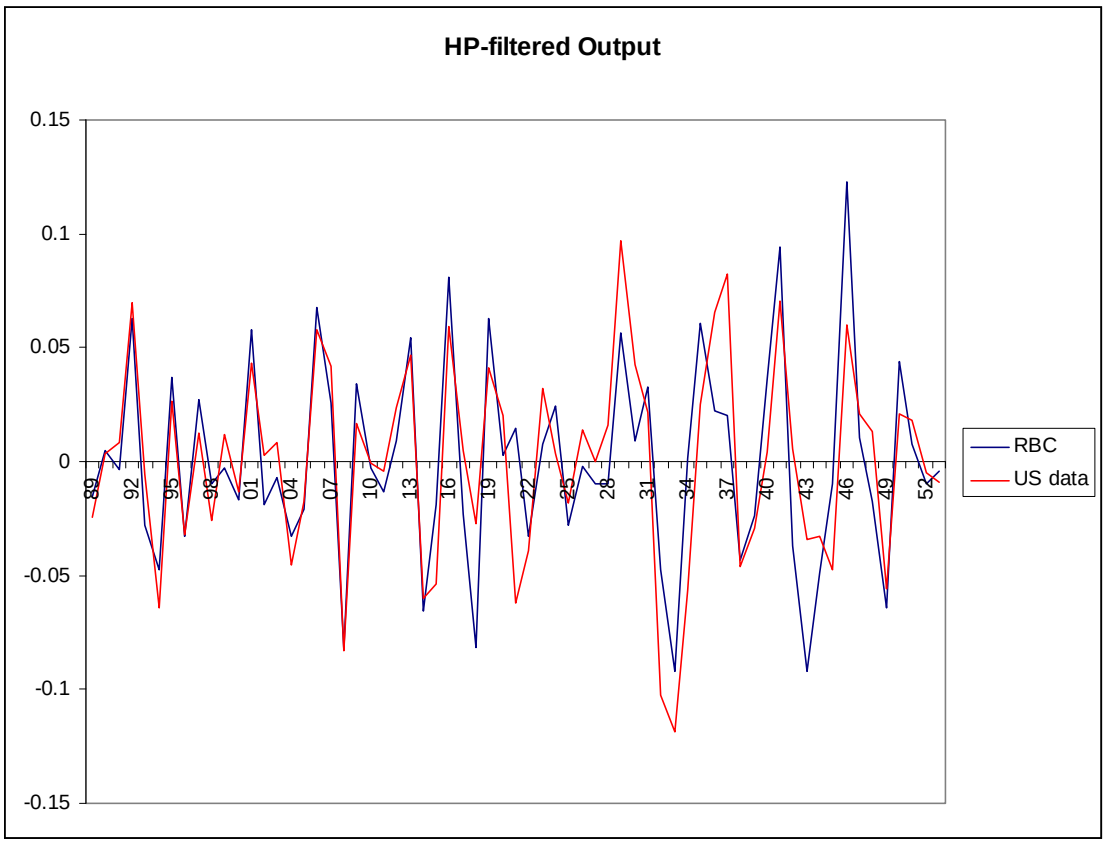
log(TFP)
Trend
TFP (HP detrended)

Figure 1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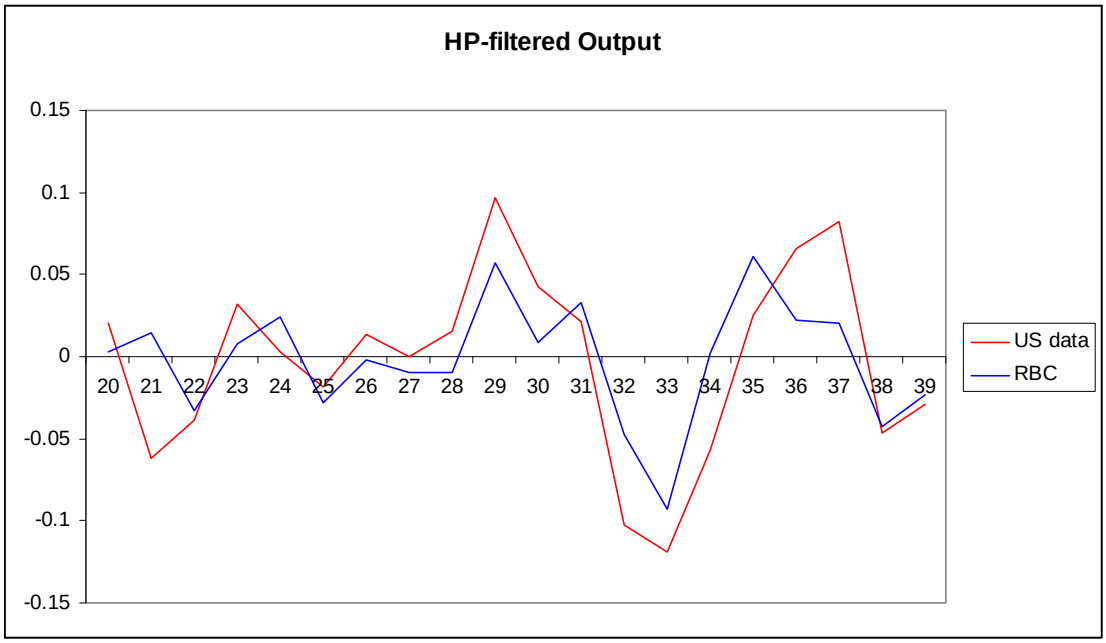
RBC
US data

Figure 2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22
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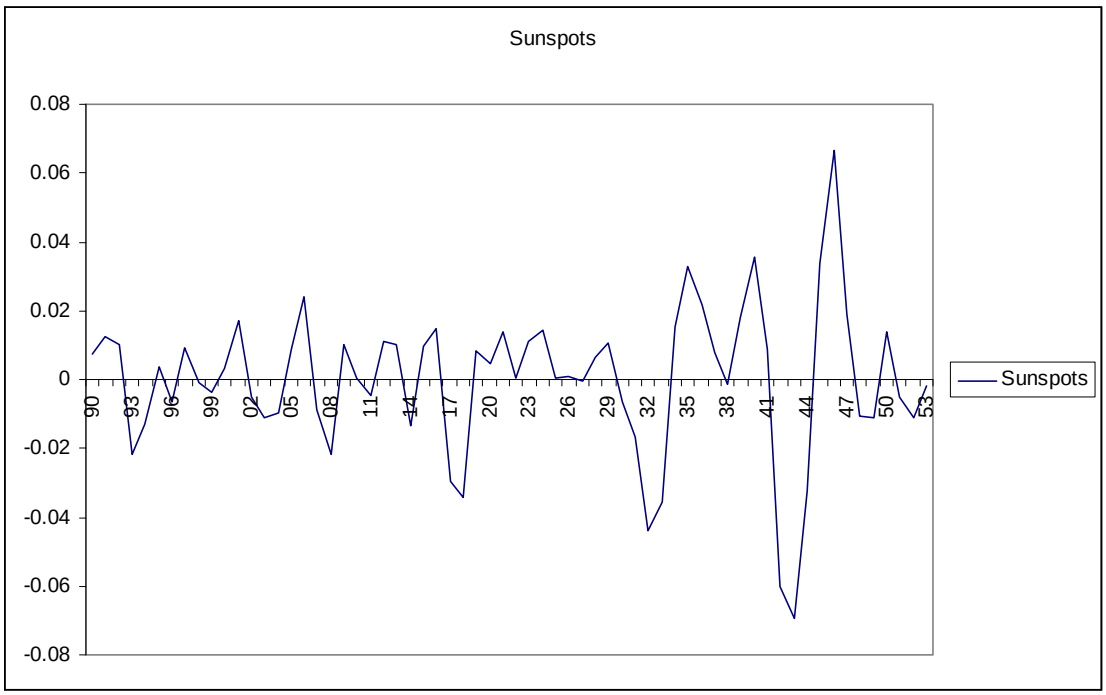
US data
RBC

Figure 3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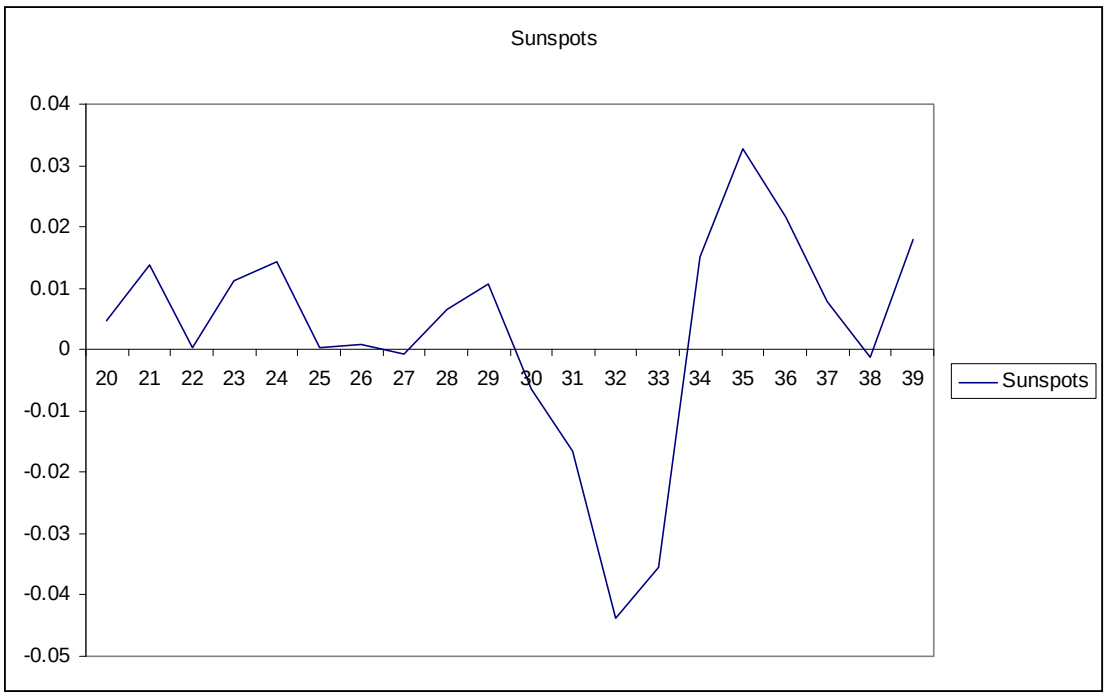
Sunspots

Figure 4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0.01
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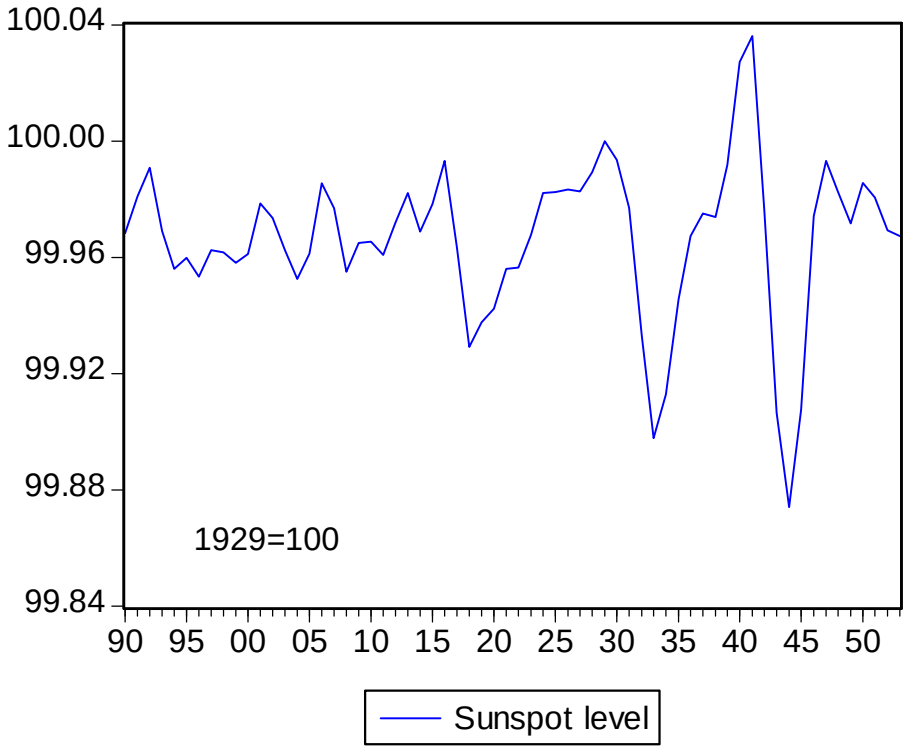
Sunspots

Figure 5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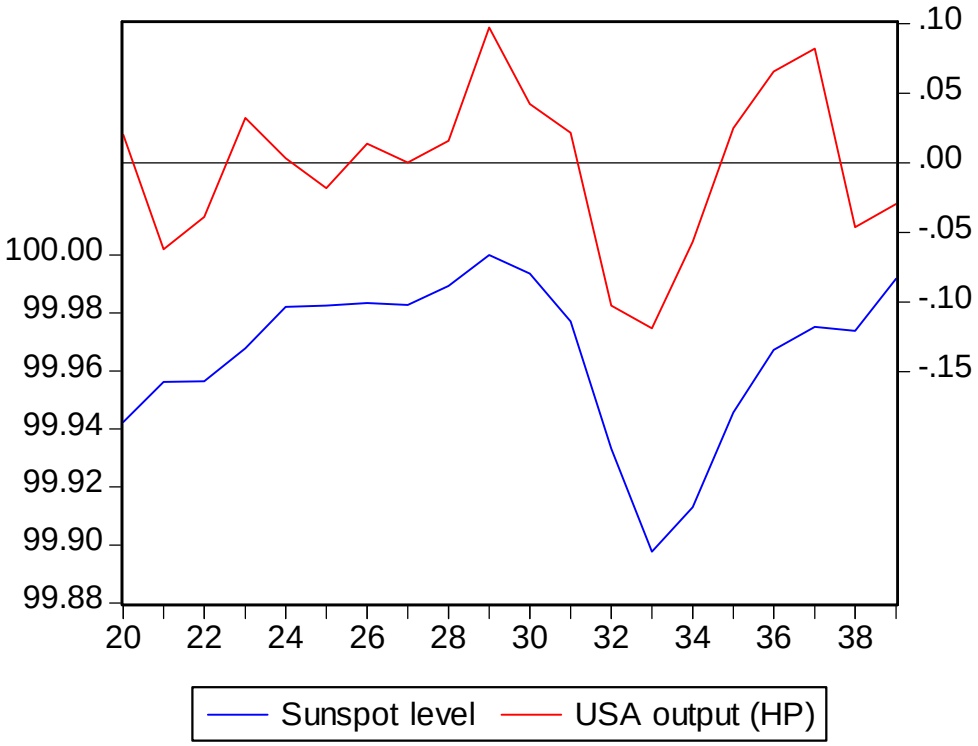
Sunspot level

Figure 6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22
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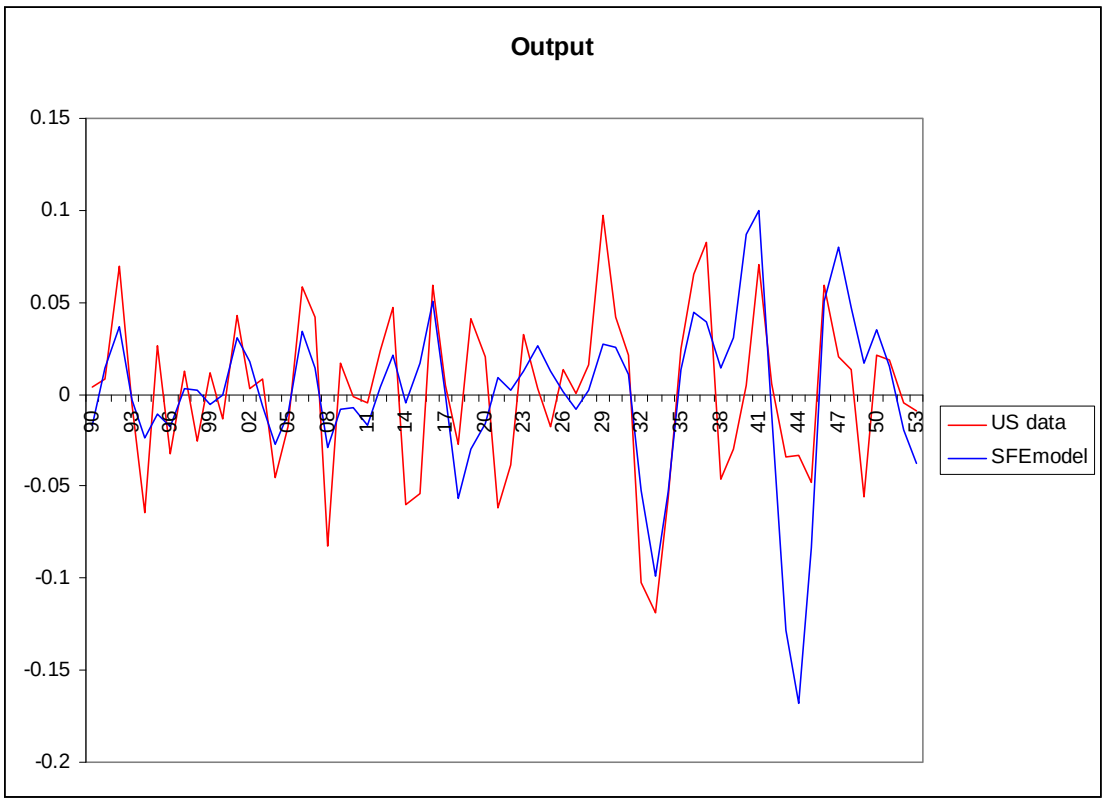
Sunspot level
USA output (HP)

Figure 7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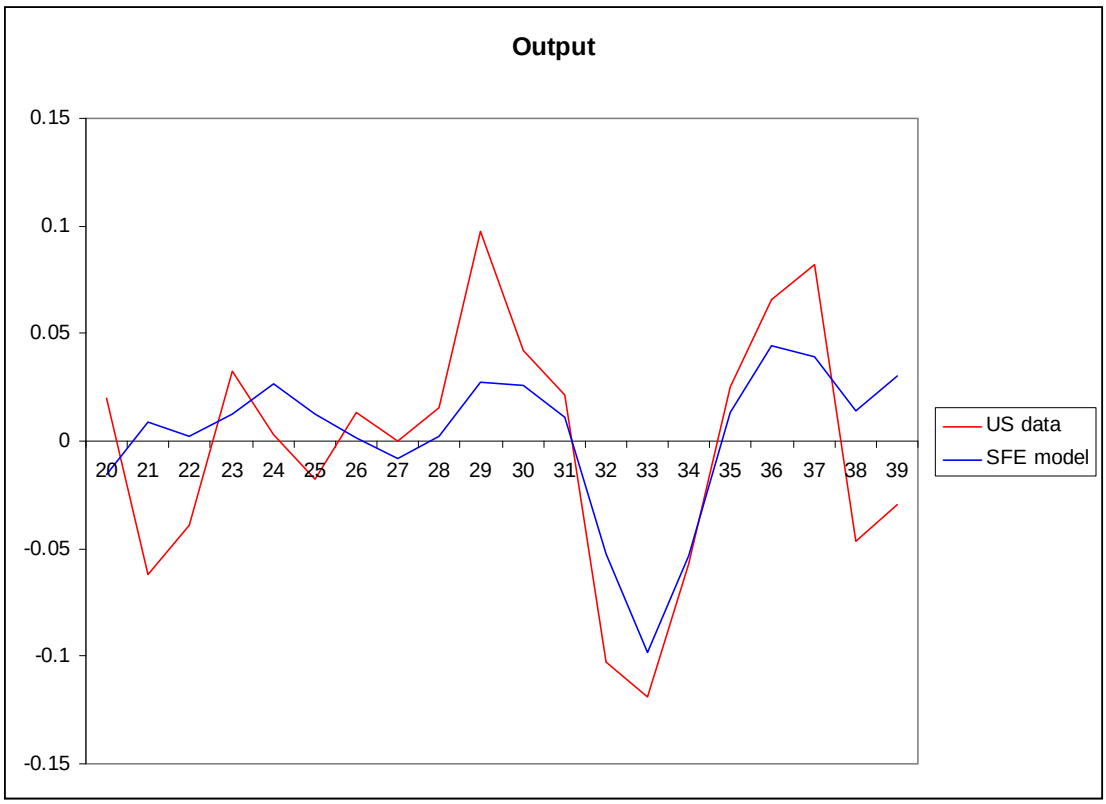
US data
SFEmodel

Figure 8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US data
SFE model

Figure 9

.

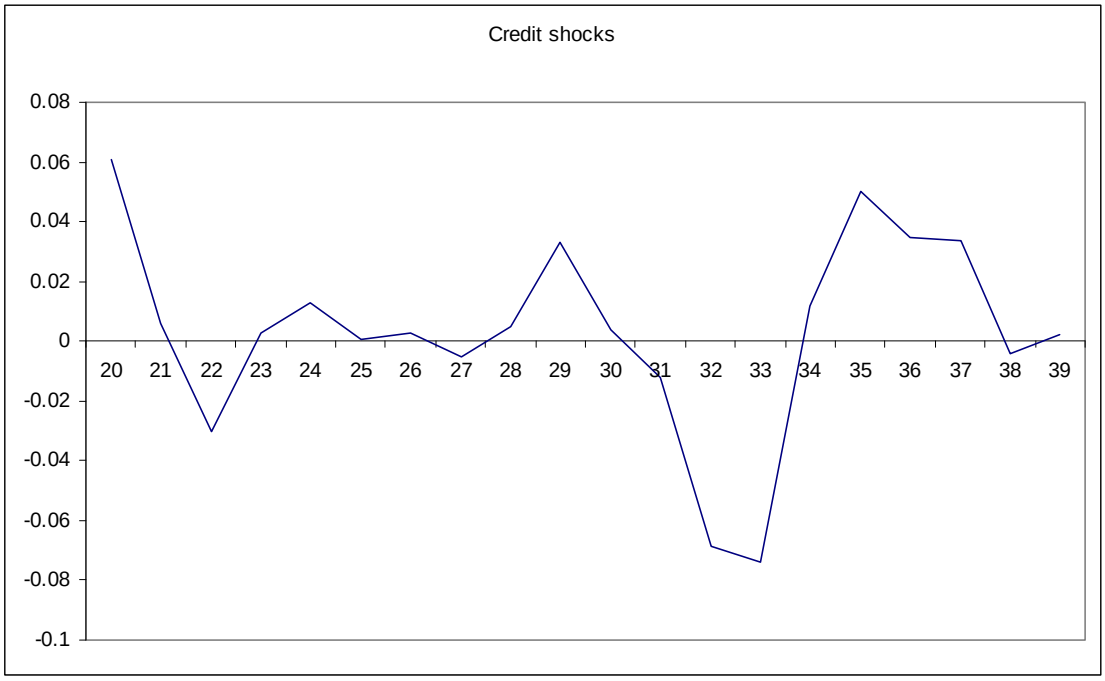
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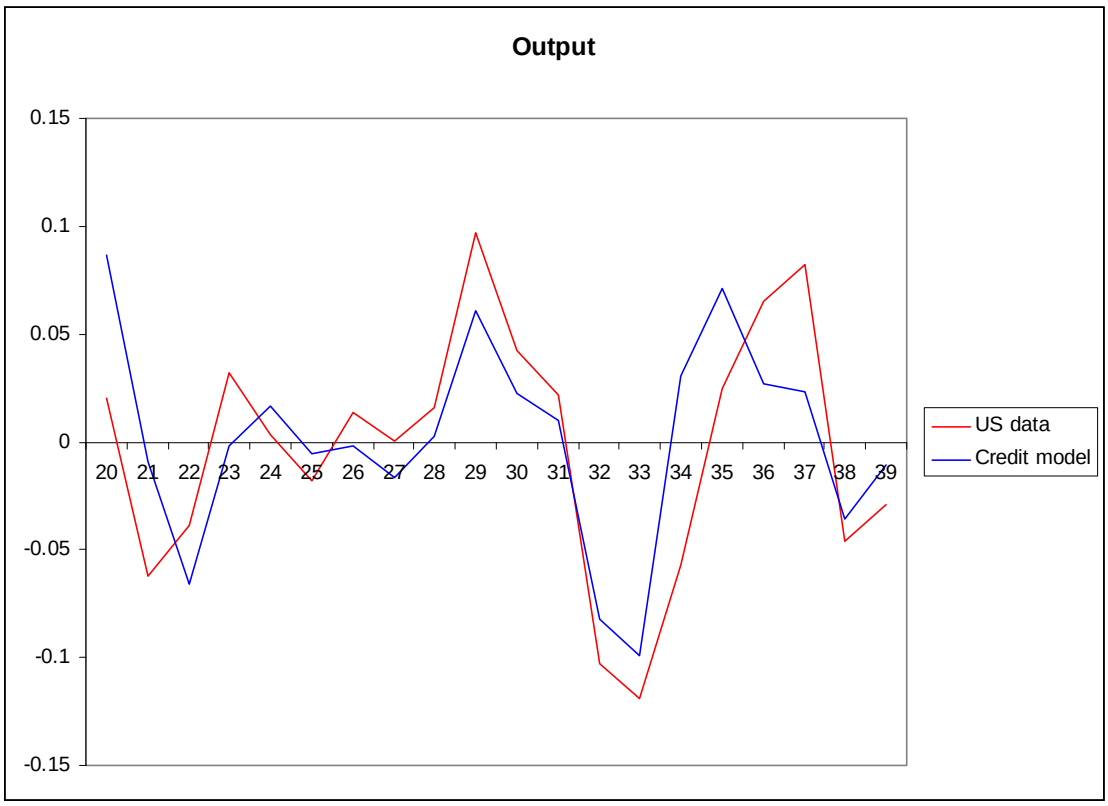
Figure 10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US data
Credit model

Figure 11

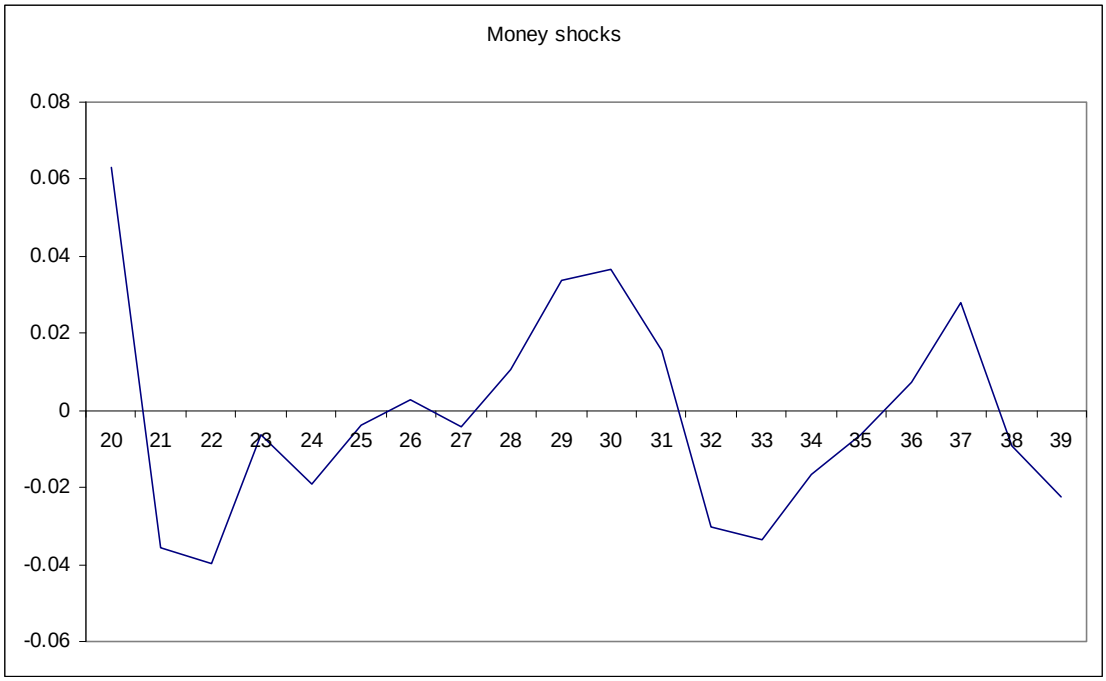
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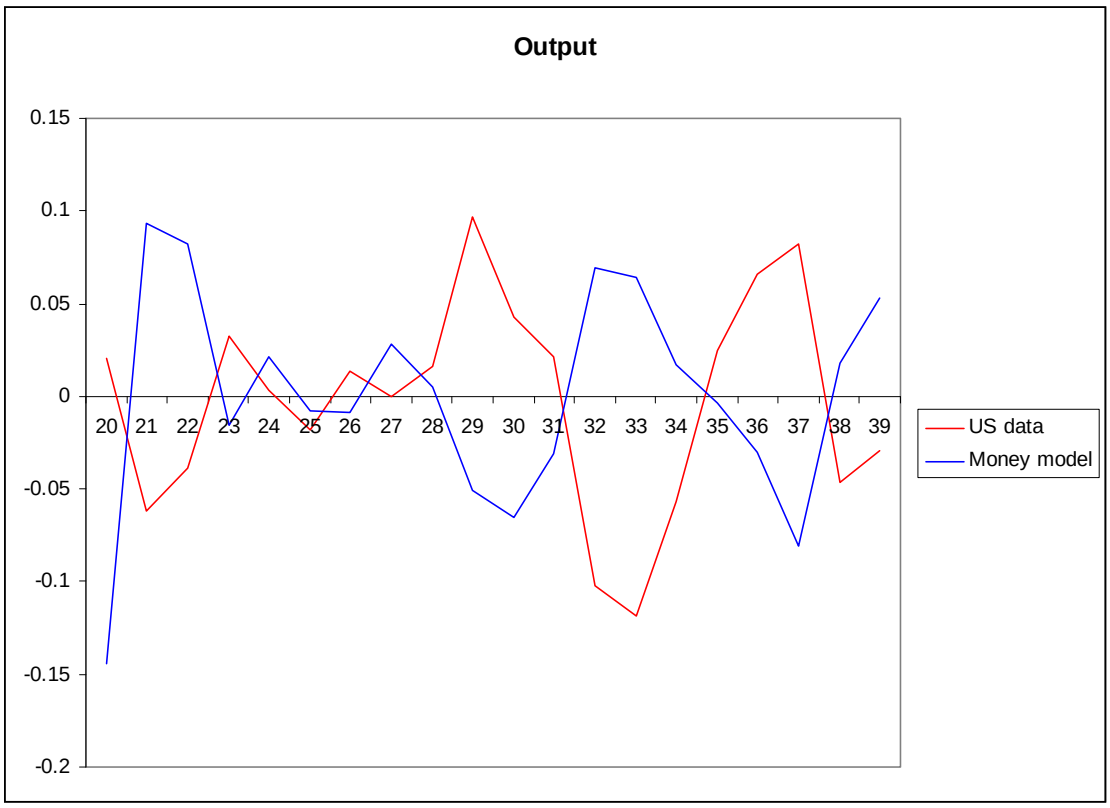
Figure 12


Output
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20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
US data
Money model

Figure 13