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The Role of Preference Shocks and Capital Utilization in the Great Depression*

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ABSTRACT

The paper investigates the notion that preference shocks play a central role in our understanding of the Great Depression. I identify a series of universally large negative shocks which destabilized the U.S. during the 1930s. When the artificial economy is paired with variable capital utilization and mildly increasing returns to scale in production, it is able to account for most of the decline in economic activity and it is able to predict realistic persistence.

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> "In other words, what happened to the United States in the 1930s was a severe attack of contagious laziness!" [Franco Modigliani, 1977, p. 6]

1 Introduction

The Great Depression in the United States, in all its many dimensions, remains unparalleled. Real output cumulatively declined by about 30 percent between 1929 and 1933, which dwarfs the drop in any post-war business cycle. Perhaps the most perplexing aspect of the Great Depression, however, is that the economy remained depressed for so long. Economic activity remained at levels that seem too low to square with the normal business cycle. More specifically, real GNP did not reach its pre-Depression value until 1936 and per capita output still remained about twenty-five percent below trend in 1939. The recovery phase lasted seven years – four times the average post-war recovery period.

The current paper identifies atemporal preference shocks as chief culprits for the Great Depression. This is carried out using a modified version of the real business cycle model with variable capital utilization, mildly increasing returns to scale and driven by stochastic preferences. I find that the artificial economy can explain most of the decline in economic activity from 1929 to 1933 and it can replicate the subsequent lukewarm recovery throughout the rest of the decade as well as the 1937-1938 recession. Consequently, the conundrum that puzzled Cole and Ohanian (1999) as well as Bordo, Erceg and Evans (2000), namely that technology and money-driven models fail to reproduce the depressed second half of the 1930s, does not present itself in the current model.

The strategy of estimating the taste shocks from data originally stems from Hall's (1986) analysis of the role of consumption in the U.S. business cycle. Baxter and King (1991) furthered Hall's concept by constructing a dynamic general equilibrium model that includes stochastic preferences. These atemporal shocks represent shifts in the marginal rate of substitution between consumption and leisure; hence, they reflect a mix of changes in the demands for consumption and for leisure.

The remainder of the paper evolves as follows. The next Section will present the model and will show how the preference shock can be derived from first-order conditions. This is followed by the estimation of the shocks including robustness checks along various dimensions. Section 4 returns to the artificial economy and evaluates the effects of the shocks in general equilibrium. Section 5 concludes.

2 The environment

The model is based on Baxter and King (1991) as well as on Greenwood, Hercowitz and Huffman (1988). Essentially, it is a standard one-sector dynamic general equilibrium model augmented by stochastic preferences. There are two further departures from the standard model. Bresnahan and Raff (1991) suggest that at least twenty percent of the aggregate capital stock was idled between 1929 and 1933. Thus, a variable capital utilization model is a tenable framework for any theory of the Great Depression. Another departure from the standard model is the assumption of mildly increasing returns to scale in production.

The economy that I examine is populated with a large number of identical consumer-workers households, each of which will live and grow forever. Households own the capital stock. Time evolves in discrete units, called periods, which are specified to be one year long.

2.1 Technology

On the production side, competitive firms, indexed by i, choose how much labor, $l_{i,t}$, and capital services, $\square_{i,t}$, to hire and how much output, $y_{i,t}$, to produce. Capital services are defined as the intensity (or employment rate), $u_{i,t}$, by which the capital stock is operated times the amount of capital, $k_{i,t}$, i.e. the number of machines. Each of the individual firms produces an identical final commodity using the technology

$$y_{i,t} = A_t^{\gamma} \square_{i,t}^{\alpha} l_{i,t}^{1-\alpha} \qquad 0 < \alpha < 1$$
$$A_t = \square_t^{\alpha} l_t^{1-\alpha}.$$

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. The term A_t stands for these aggregate externalities (eliminating the index i denotes aggregate values). The production complementarities are taken as given for the individual optimizer and they cannot be priced or traded. The increasing returns hypothesis is represented by $\gamma > 0$. The firm sells output to consumers on competitive markets and buys capital and labor services from the households at competitive prices r_t and w_t. Thus, the profits of the firm equal

$$\pi_{i,t} = y_{i,t} - r_t \square_{i,t} - w_t l_{i,t}.$$

The firm's profit maximization condition implies

$$r_t = \alpha \frac{y_{i,t}}{\square_{i,t}} \qquad \text{and} \qquad w_t = (1-\alpha)\frac{y_{i,t}}{l_{i,t}},$$

that is, firms are renting effective capital units.[1] Phrased alternatively, one way to increase output is to operate a given plant more intensively, i.e. machines run faster. Another way is to put into operation a marginal machine. The firms do not care how the increase is realized; the decision is made by the household who own the capital stock and who can decide on the utilization rate.

2.2 Household

A representative household, indexed j, solves

$$\max_{\{c_{j,t},l_{j,t},u_{j,t},x_{j,t}\}} E_0 \sum_{t=0}^{\infty} \beta^t (1+n)^t \left[(1-\eta)\log(c_{j,t}-\Delta_t)+\eta\log(1-l_{j,t})\right]$$

$$\text{s.t. } c_{j,t}+x_{j,t}=w_t l_{j,t}+r_t u_{j,t} k_{j,t}$$

$$(1+g)^{\frac{(1-\alpha)(1+\gamma)}{1-\alpha(1+\gamma)}}(1+n)k_{j,t+1}=(1-\delta_{j,t})k_{j,t}+x_{j,t}$$

$$\delta_{j,t}=\frac{1}{\theta}u_{j,t}^{\theta}$$

including the usual initial condition. Here $0<\beta<1$, $0<\eta<1$ and $\theta>1$. $c_{j,t}$, $x_{j,t}$, and β represent consumption, investment, and the discount factor. All variables are in detrended per capita terms. The random variable Δ_t is zero in its stationary state. The variable alters preferences to allow for shifts to the marginal utility of consumption. The dynamics for Δ_t are described by an autoregressive process of maximal order two and the realizations of this process are assumed to be the same for every agent. The parameter n is the deterministic rate of population growth and g denotes the deterministic rate of labor augmenting technical progress. As in most studies of variable capital utilization, the rate of depreciation, $\delta_{j,t}$, is an increasing function of the utilization rate: higher utilization causes faster depreciation.[2] The household is assumed to make three kinds of choices: it chooses both labor supply and the amount of physical capital in each period and it chooses the

[1] Technology displays internal increasing returns if the usual commodity point is employed. An alternative commodity point is needed if I am to use competitive analysis. My approach is to assume that firms demand effective capital units, i.e. □ $= uk$.

[2] Basu and Kimball (1997) use the more general formulation $\delta_t=\delta_0+\delta_1 u_t^{\theta}$. Their work suggests that the rust part dominates. It is easy to show that if δ_t stays more or less constant, then the current model's propagation mechanism becomes stronger. Thus, the current formulation errs on the conservative side with respect to the importance of preference shocks.

capital stock's employment rate per period. The household's optimal plan involves

$$\frac{\eta}{1-\eta}\frac{c_{j,t}-\Delta_t}{1-l_{j,t}} = w_t \tag{1}$$

$$\frac{(1+g)^{\frac{(1-\alpha)(1+\gamma)}{1-\alpha(1+\gamma)}}}{c_{j,t}-\Delta_t} = E_t\frac{1}{c_{j,t+1}-\Delta_{t+1}}\left(r_{t+1}u_{j,t+1}+1-\delta_{j,t+1}\right) \tag{2}$$

$$u_{j,t}^{\theta-1} = r_t \tag{3}$$

plus the transversality condition. Equation (1) equates the household's indifference curve to the real wage, (2) is the consumption Euler equation and (3) equates the marginal loss and the marginal gain of a change in the capital utilization rate.

2.3 Symmetric equilibrium and calibration

In symmetric equilibrium, aggregate and individual values of the various variables coincide. Hence, the economy's aggregate consistency requires that $c_{j,t} = c_t$, $\delta_{j,t} = \delta_t$, $k_{i,t} = k_{j,t} = k_t$, $\Box_{i,t} = \Box_t$, $l_{i,t} = l_{j,t} = l_t$, $u_{j,t} = u_t$, $x_{j,t} = x_t$, and $y_{i,t} = y_t$. The five equations that describe the aggregate economy are laid out below:

$$u_t^{\theta} = \alpha\frac{y_t}{k_t} = \alpha(u_t k_t)^{\alpha(1+\gamma)} l_t^{(1-\alpha)(1+\gamma)} k_t^{-1} \tag{4}$$

$$\frac{\eta}{1-\eta}\frac{c_t-\Delta_t}{1-l_t} = (1-\alpha)\frac{y_t}{l_t} \tag{5}$$

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

and

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

Hence, the alternative commodity point selection does not change the usual forms of the intertemporal Euler equation (6).

Next, I will describe the parametric specification of the model and assign parameter values. Table 1 reports the calibration which brings the model in line with long-run averages of the U.S. economy. Capital's share is a third which matches national accounts data. The discount factor is set so that the steady state net return to capital is three percent. The labor force grows at a rate of one percent per year; the number conforms to trend growth of the population (see Maddison, 1991). Technology expands at an annual 1.9 percentage rate. The number coincides with the United States' long-run per-capita output growth (from Cole and Ohanian, 1999). The parameter η will be set such that households supply 20 percent of their time endowment to labor and the annual rate of depreciation is eight percent. Taken together, this calibration implies a capital-output-ratio of 2.57. This value matches Maddison's (1991) who reports ratios of gross non-residential capital stock to GDP at 2.91 (in 1913) and at 2.26 (in 1950). The calibrated economy's steady state investment share of output amounts to 28 percent. I set the increasing returns to scale parameter to zero for the time being. Lastly, the calibration implies – from the first-order conditions – that $\theta = 1.624$ which is consistent with the corresponding GMM estimate that is reported in Burnside and Eichenbaum (1996).

The model is solved by Taylor-approximating (4) through (7) and the second-order process of Δ_t around the unique steady state. Let us denote the two variables $\widehat{k}_t \equiv (k_t - k)/k$ and $\widehat{\Delta}_t \equiv (\Delta_t - c)/c$ where omitting time indices on variables indicates steady state values (the preference shifter is zero in the stationary state). Given the calibration, the linear rational expectations model has enough initial conditions to uniquely determine the stationary equilibrium.[3] The model can be reduced to the stochastic matrix difference equation

$$\begin{bmatrix} \widehat{k}_{t+1} \\ \widehat{\Delta}_{t+1} \\ \widehat{\Delta}_t \end{bmatrix} = \mathbf{M} \begin{bmatrix} \widehat{k}_t \\ \widehat{\Delta}_t \\ \widehat{\Delta}_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ d_{t+1}/c \\ 0 \end{bmatrix} \tag{8}$$

which describes the evolution of the economy as a Markov process in the state variables. The coefficient matrix $\mathbf{M}$ is 3×3 (Weder, 2001, presents the complete solution of the model). The next Section will discuss the computation of the sequence of d_t-innovations which will be used to shock the dynamical system (8) and to derive output realizations for the artificial economy in Section 4.

3 Preference shock realizations

This section discusses the derivation of an empirical sequence of the taste-shocks and it will check for robustness.

[3] In fact, one needs to limit $\gamma < 0.4$ to rule out indeterminacy of rational expectations. See Harrison and Weder (2002) for a sunspot based interpretation of the Great Depression.

3.1 Backing out preferences

Technology shocks are customarily estimated as residuals from a Solow decomposition. In other words, these shocks are not directly observable and measurement takes place within a particular model – a production function. The methodology used here to measure preference shocks is similar to Hall (1986, 1997), Parkin (1988), Bencivenga (1992) and Baxter and King (1991).[4] In particular, the above authors use the intratemporal first-order conditions to back out a sequence of preference shocks. To understand this concept, note that the intratemporal optimality condition (1) implies that a positive innovation to Δ_t represents a positive shock to consumption demand for a given wage and labor supply: the urge to consume increases. Accordingly, Baxter and King (1991) refer to shifts in Δ_t as demand shocks. However, in another interpretation, Δ_t thwarts the equalization of the marginal rate of substitution between goods and work, hence, it is a shock to the propensity to leisure: a fall in Δ_t requires a decline of labor supply at given levels of consumption and of the remuneration of labor. Thus, the best interpretation of Δ_t-shifts will be to assume that they represent changes in taste; they reflect a mix of shifts in consumption demand and in the propensity to consume leisure.

Given data on consumption, wage and labor input, shifts of the preference parameter can be estimated. Annual data on real consumption expenditures on nondurables and services are from Balke and Gordon (1986) and the National Income and Product Accounts. Data were divided by the working-age population (16 years and older). Wage data are average hourly earnings. Earnings data are not available for all sectors in the beginning decades of the sample. To maintain continuity of overall series, I use wages in the manufacturing sector. In particular, I employ Hanes' (1996) compilation of National Industrial Conference Board and Bureau of Labor Statistics (BLS) data. For missing World-War II years, I employ the BLS data on hourly wages directly – by chaining it into Hanes' series. The GNP deflator takes out inflation. Lastly, labor input is measured as total nonfarm employment times average weekly hours per employee (manufacturing hours for the pre-war era).

Note that in (8), preferences occur in percentage deviations from steady state consumption. Thus, any shock series that is fed into the model for simulation must be in equivalently detrended units for making the key prediction of how much of the depression is caused by preference shocks. This is done by using the Taylor-approximated household's intratemporal opti-

[4] In New Keynesian models, preference shocks are also widely used (see for example Ireland, 2002).

mality condition as in Baxter and King (1991):

$$\widehat{\Delta}_t \simeq \widehat{c}_t - \widehat{w}_t + \frac{l}{1-l}\widehat{l}_t. \tag{9}$$

Equation (9) backs out a sequence of preference states $\left\{\widehat{\Delta}_t\right\}$.[5] Of course, one could have computed a series for Δ_t directly – in fact, this is done in Subsection 3.2.5. – but then this series must be transformed as well before it can be fed into the model.

Figure 1 displays the computed series of the state of preferences, $\widehat{\Delta}_t$, over the 1919 to 1980 period. The series centers around zero which mimics the construction of preferences in the model. One readily notices a striking plunge that distinguishes the early years of the Great Depression. Furthermore, around 1937-1938 the economy appears to have experienced another drop. After 1950, the preference shifter settled on (what looks like) its trend level. Figure 1 also plots NBER recessions. Most recessions coincide with a drop in $\widehat{\Delta}_t$. Moreover, for the years 1919 to 1939, the correlation of $\widehat{\Delta}_t$ and linearly-detrended output is 0.95 and it amounts to 0.56 for the whole sample – likely reflecting a lesser importance of preference shifts during the post-1940 years (or the effect of effective macroeconomic polices). Of notable exception were negative comovements during the 1940s. During World-War II, output exhibited excessive growth rates that reflected the dramatic increase of war-related government expenditures. The second half of that decade (the Reconversion-period after 1945 to 1947 which is associated with a dramatic increase of measured $\widehat{\Delta}_t$) is characterized by the opposite pattern.

Where do the shocks come from? The consumption-component of (9) produces 71 percent of the volatility of $\widehat{\Delta}_t$. The correlation of $\widehat{\Delta}_t$ and $\widehat{c}_t$ is 0.93. Thus, by a large factor, the shocks appear to represent changes in the urge to consume.[6]

There has been little work done in the way the dynamic process of preferences should realistically be modelled, especially for the interwar period. This differs from technology for which a simple first-order process is routinely assumed which is widely applied within the real business cycle approach. For the postwar period, Baxter and King (1991) find that a first-order autoregressive process (AR) including a constant and trend provides a good fit

[5] Since the variables are measured as deviations from the stationary state, an estimate of the steady state values is necessary to convert data. Data were rendered stationary by deflating each variable by its long run (sample) trend growth. I estimate a variable's x_t "steady state" (or trend) by regressing

$$\ln x_t = c + \beta t + \varepsilon_t.$$

[6] I arrive at this number by computing the individual standard deviation of the components in relation to the volatility of the preference-shifter. The remaining volatility is a mix of wages (20 percent) and labor (less than 10 percent).

for the evolution of the preference state. I experimented with a number of possible low-order processes – various AR processes and random walk specifications. I find that when the dynamic process is of first-order, the process displays clear evidence of serial correlations of residuals. This is no longer the case when I assume that preferences are described by a second-order autoregressive process.[7] Lags beyond the second do not contribute important explanatory power. I conclude that a second-order autoregressive process provides a good description of the evolution of preferences (absolute t-statistics in parenthesis, sample period 1919 to 1980):

$$\begin{aligned}\widehat{\Delta}_t &= \underset{(10.03)}{1.23}\,\widehat{\Delta}_{t-1} - \underset{(2.83)}{0.33}\widehat{\Delta}_{t-2} + d_t/c \qquad (10)\\ \overline{R}^2 &= 0.90, \quad SE = 0.043, \quad DW = 1.83.\end{aligned}$$

Figure 1 also plots the computed shocks $\{d_t/c\}$ of (10). The process yields an enormous bunching of large negative shifts in the early thirties. From 1929 to 1934, the preference shocks are negative. Moreover, the 1930s is the only period in which I measure negative shocks of that magnitude. The volatility of the shocks becomes remarkably smaller in the post-war period. Figure 1 also shows that the (smoother) upward shift that occurred during the 1960s did not yield sequences of large shocks – unlike the exceptional reconversion year 1946, in which the level of preferences returned to their pre-Depression level.[8]

3.2 Robustness

In the following, alternative formulations for the preference process are tested. The intend is to see if the results are sensitive to the choice of data and methods of detrending.

3.2.1 Detrending

Relationship (1) could be transformed to

$$\widetilde{\Delta}_t \simeq \widetilde{c}_t - \widetilde{w}_t + \frac{l}{1-l}\widetilde{l}_t$$

where a tilde denotes the variables deviation from the sample mean. It is virtually coincident with the sequence calculated earlier. The correlation of both series is 0.97.

[7] A Breusch-Godfrey serial correlation test suggests the same lag length.

[8] Francis and Ramey's (2003) four years with the largest negative nontechnology shocks are 1919, 1921, 1932 and 1938. The latter three all fall into the top five of negative shocks here (unlike Francis and Ramey's SVAR-based series, my sequence of empirical shocks does not start until 1921).

3.2.2 Price deflating

Employing the CPI instead of the GDP deflator to deflate wages also leaves the picture unchanged. The correlation of both preference series is 0.96.

3.2.3 Wage data

One may question whether the use of manufacturing wages distorts the results. However, manufacturing real wages and aggregate real wages moved parallel during the whole Depression except for the year 1933 in which manufacturing real wages diverged upwards (see for example Bordo et al., 2000, Figure 1). I repeat the calculation of preferences using aggregate real wages and total hours. In particular, I use Kendrick's (1961) measure of total hours and the total economy real wage (see Cole and Ohanian, 1999, for construction). The new sequence moves notably parallel to the original through the 1930s. The correlation of both series is 0.97. Hence, the shift in preferences is independent of using sectoral or aggregate wage data since it is predominantly driven by consumption. In the end, I decided in favor of using the manufacturing wage mainly because of its higher quality and since it is consistently available over a long time span.

An alternative check would be to replace the real wage by average labor productivity – constructed by dividing real GDP by total hours worked. Given the Cobb-Douglas production function, labor productivity is proportional to real wages. The correlation of this new series with the original preferences is 0.98.

3.2.4 Out-of-sample estimation

Is the estimation of the dynamic process of preferences sensitive to the unique episode of the 1930s? To answer this question, I re-estimate the dynamic process for preferences using 1950 to 1980 data only. The estimated dynamic process is almost identical to the original version:

$$\begin{aligned}\widehat{\Delta}_t &= \underset{(8.03)}{1.24}\widehat{\Delta}_{t-1} - \underset{(1.88)}{0.29}\widehat{\Delta}_{t-2} + d_t/c \\ \overline{R}^2 &= 0.93, \quad SE = 0.013, \quad DW = 1.59.\end{aligned}$$

I then compute pre-war shocks and find that the pre-war correlation of the two shock series is 0.98.

3.2.5 Another note on detrending

The taste shifts can also be derived by using the original, non-approximated version of the intratemporal first-order condition:

$$\Delta_t = c_t - \frac{1-\eta}{\eta} w_t (1 - l_t).$$

The correlation of this time series and the original sequence is 0.92. Moreover, the dynamics are well described by the autoregressive process

$$\begin{aligned}\Delta_t &= \underset{(11.08)}{1.33}\,\Delta_{t-1} - \underset{(3.06)}{0.37}\Delta_{t-2} + d_t \\ \overline{R}^2 &= 0.91, \quad SE = 99.12, \quad DW = 1.81.\end{aligned} \tag{11}$$

The 1921 to 1980 correlation of the shocks coming out of (10) and (11) is 0.93.

In the following Section, I will confront the identified preference innovations with the theoretical model. It is only then that one can make any reasonable judgements on the importance of these shocks to the depth and persistence of the Great Depression in the United States.

4 The model and the Great Depression

In this Section I use the calculated shocks and generate the model time series of relevant variables. This constitutes an important test for their relevance for the Great Depression era. The methodology is different to the standard real business cycle approach. There, the model is simulated given random draws from a distribution that represent innovations of (technology) shocks. The realizations of selected second moments of the artificial time series are checked against moments of data. The test here addresses a different question: can preference shocks explain the timing and depth of the Great Depression? To this avail, period-by-period shock realizations are fed into the artificial economy and period-by-period model realizations are calculated. Then the predictions of the model are compared directly to the historical path of the U.S. economy. Early work on real business cycles has questioned the usefulness of direct comparisons to historical data (see for example Prescott, 1986, p. 16). To my knowledge, Hansen and Prescott (1993) was the first attempt using the methodology as it is used here. Recently, the comparisons-to-historical-data methodology has been applied by a number of authors particularly with respect to theoretical predictions concerning the Great Depression (see for example, Cole and Ohanian, 1999, or Bordo, Erceg and Evans, 2000, for the role of technology shocks or money shocks respectively).

4.1 The baseline model

The procedure for obtaining artificial output series is as follows. I use the autoregressive process (10) to compute a shock series $\{d_t/c\}_{1929}^{1939}$. The disturbances are then fed into the artificial economy. I assume that the model economy enters 1929 in a stationary state. Here I rely on Balke and Gordon's (1986) computation of trend output which reveals that right before the onset of the Great Depression the U.S. economy was near its long-run trend. Figure 2 shows the behavior of annual real U.S. GNP and that of the model with constant returns. Both the artificial series and the data series were set so that output in 1929 equals 100 and both series refer to detrended (per capita) figures. As for the U.S. series, GNP data was divided by adult population and detrended by the average growth rate of real output per adult (1.9 percent per year).

The key finding is that the model economy predicts a drastic slowdown in economic activity starting in 1929. Not only does the timing of the depression match U.S. data, but the duration of the downturn appears to match as well. In 1933 the model's output is about 23 percent below trend. This is not quite as deep as the U.S. recession: in 1933 GNP hovered 38 percent below trend, however, the model can account for about 59 percent of the decline in GNP.[9] The second finding is that the model predicts a relatively slow recovery. In particular, by 1939 output is still 25 percent below trend compared to the 27 percent divergence from trend in the data. Furthermore, the model predicts the 1937-1938 recession correctly in timing and depth. Hence, the model replicates the two dips that we observe in the 1930s data. There are some differences between the behavior of the model economy and the behavior of the U.S. economy during the episode, nevertheless. Most notably, the artificial cycle's trough does not coincide exactly with data. The model lags by about one year. In other words, the speed with which the economic collapse takes place is slower in the artificial economy. The phase shift reverses later on as the model leads the way into the 1937-38 recession.

4.2 The role of increasing returns

I will now turn to the role of increasing returns in production and inquire whether externalities can propagate the shocks in such a way as to help bring the model and data closer together. Bernanke and Parkinson (1993) conclude that the data suggest significant increasing returns in the 1920s and 1930s. Burns (1933) also points to evidence for increasing returns. Reflecting on recent estimates for the U.S. economy, I assume that scale economies are small. I set γ so that the depth of model output coincides with that in data: $\gamma = 0.115$ which is not empirically implausible and it coincides with the value that is promoted by Laitner and Stolyarov (2004).[10] When setting increasing returns at this value, the model's and data's maximum decline match (Figure 3). Moreover, by 1939, the artificial economy is slightly more

[9] The largest deviation of model output from steady state (28 percent) occurs in 1934.

[10] Burnside, Eichenbaum and Rebelo (1995) suggest that when variable utilization is considered, the evidence for increasing returns is weak. They report a point estimate of 0.98, however, the standard error of 0.34 is large and so any conventional confidence interval estimate would include 1.115.

depressed than the U.S.: the real business cycle puzzle of predicting a swift recovery does not arise here.

It appears that increasing returns have the effect of providing a stronger propagation mechanism of the shocks. Thus, I infer that when I combine the measured taste shocks with a modest increasing returns to scale economy, then the Great Depression decline in economic activity as well as its slow recovery are fully accounted for by the preference-driven model.

4.3 The role of variable capital utilization

I will now examine the effect of variable capital utilization. To accomplish this, I compute artificial output with constant returns to scale and fixed capital utilization. The volatility is reduced significantly (Figure 3). In 1933 the artificial economy can only explain about 39 percent of the decline in output thus it falls short of giving a full account of the Great Depression. As was shown in Section 4.1, with endogenous utilization rates, however, the shocks are propagated more strongly – the baseline model with variable utilization can account for about twice as much. I conclude that both endogenous capital utilization and increasing returns are important features of the taste shock theory of the Great Depression: unless they are present, preference shocks are not able to explain most of the economic volatility that was experienced during the 1930s.

Overall, Sections 4.2. and 4.3. show that any over-proportional impact of technology shocks during the Depression years must be questioned. Taking the very likely importance of variable factor utilization seriously and including (the occasionally disputed assumption of) mildly increasing returns, then atemporal shocks can account for essentially all of the Great Depression.

4.4 Other variables

How does the model behave when considering other dimensions of the data? To examine this, I will now look at the movements of GNP components and factor inputs.

Figures 4 to 6 report the behavior of artificial consumption, investment, and labor input *vis-a-vis* data equivalents. With regard to U.S. data, consumption is measured as expenditures on nondurables and services; investment is measured by business fixed investment. Labor input in the data series is measured by total hours worked. Once again, both the model and data series were set so that variables in 1929 equal 100 and all series refer to detrended per-capita versions.

First of all, each variable drops sharply coinciding with the pattern that we find for the U.S. economy. Specifically, investment and consumption move in the same direction (Figures 4 and 5). The procyclical pattern of

GNP aggregates is possible because of three factors: (i) persistent shocks, (ii) increasing returns and (iii) variable capital utilization.[11] Investment's stark tumble resembles that found in data. Consumption appears to be somewhat too smooth in the model. In the increasing returns case, consumption falls by 20 percent whereas the data displays a 28 percent drop.[12] The striking aspect of U.S. consumption is that after its initial drop in 1932, it remained depressed until 1939. Cole and Ohanian (1999) speculate that this behavior may reflect the convergence towards a new growth path. The current model can reproduce the U.S. consumption pattern while maintaining the single steady state assumption: artificial consumption hardly moves up from its 1932 level for the rest of the decade. Model hours track data closely; the same holds for investment (Figures 5 and 6). Model capital utilization hits bottom in 1934 at about 20 percent below the 1929 level (Figure 7). The magnitude of the decline broadly conforms to the findings in Bresnahan and Ruff (1991).

Next, I confront the model with the finding that detrended total factor productivity (TFP) fell by about 20 percent in the United States between 1929 and 1933. I calculate artificial TFP as the residual of a naive Solow decomposition:

$$z_t = \frac{y_t}{k_t^{1/3} l_t^{2/3}}.$$

Because of the presence of increasing returns and of variable capacity utilization in the model, taste shocks lead to a procyclical series on TFP. Figure 8 plots the Solow residuals for both the model and U.S. data. Granted the match is not perfect, still, between 60 and 82 percent of the measured technological decline can be explained by the presence of increasing returns and by capital utilization.[13] In fact, the fall in model TFP arises in large parts due to the presence of variable capacity utilization. At constant returns, model TFP still accounts for between 20 to 30 percent of the decline in data, while at $\gamma = 0.115$ and constant utilization rates, model TFP declines by only 3 percent (of course, at $\gamma = 0$ and constant capital utilization, model TFP stays constant). As the consequence of both increasing returns and variable capital utilization, artificial TFP remains depressed throughout the 1930s. This stands in contrast to Ohanian's (2001, p.37) claim that TFP figures suggests the presence of technology shocks since utilization should have rebounded swiftly. The current model predicts low utilization for the whole decade. There is one important difference between the behavior of

[11] For example, if preferences followed a first-order process with coefficient 0.85 and returns to scale were constant, then predicted investment is countercyclical (see the Appendix for a discussion).

[12] This suggests additional forces at work that the model does not capture. Changes in risk aversion or credit rationing are factors that come to mind.

[13] Thanks to Hal Cole for suggesting to compute TFP.

model TFP and U.S. TFP: model productivity does not take the deep dip in 1932 and 1933 and, consequently, it does not show the quick recovery. The differences between artificial and data TFP suggests that either the model is mis-specified (which could be corrected by either increasing the amount of externalities or, perhaps, by applying a different theory of capital utilization), that sectoral factors are important (which of course cannot be accounted for by a one-sector model) or that the model misses some other shocks.[14]

In the end, the preference-driven model's success is matched by a new puzzle. Despite its ability to predict the U.S. output pattern, its predictions with respect to consumption and TFP are less successful. This latter flips the Cole and Ohanian (1999) puzzle – the TFP-driven RBC model cannot account for the length and depth of the Great Depression – on its head. It remains to be seen if modifications of the model structure will be able to produce a better match.[15]

4.5 Atemporal shocks in perspective

Lastly, I will extend the simulation of the model to the 1921 to 1980 timespan. Preference shifts are represented by the second-order process (10) and the model starts enters the year 1921 in steady state.[16] Figure 9 reproduces model and data growth rates of output. First, the volatility of both series declines significantly after World-War-II. Second, model volatility is 97 percent of that of U.S. output growth's suggesting that much of the variation in output is accounted for by the shocks. If considering the 1950-1980 period only, that numbers falls to 0.57. Third, and most importantly, the correlation of these series is 0.74 for 1921 to 1939 and 0.32 for the 1950 to 1980 period. Thus, taste shocks constitute the source of a significant portion of the United States business cycle.[17] The disturbances had an unusually large impact during the interwar years and had a smaller impact after 1960. The lower cohesion in the post-1945 period may also reflect successful stabilization policies.

A natural question that arises is, assuming that the theory of the Great Depression is correct, how frequent are depressions? I begin with summarizing the empirical shocks.

[14] I plan to investigate the behavior in future research. Note that Francis and Ramey's (2003) SVAR-based computation of technology shocks is also not unambiguous regarding what these shocks looked like: depending on the specification of the regression there may have even been positive shocks during the early 1930s.

[15] RBC theories of the Great Depression (such as Cole and Ohanian, 1999) do not report model consumption *et cetera*, thus, it is not clear if the RBC model works any better along a more disaggregated level.

[16] See also the Appendix.

[17] In a related study, Gali and Rabanal (2004) report that preference shocks account for 57 percent of the variance in postwar U.S. output.

The Jarque-Bera statistic of equation (10) residuals is 4.579: the null hypothesis of a normal distribution cannot be rejected at the 11 percent significance level. The eight years with the strongest negative shocks are 1921, 1930-1932, 1934, 1937-1938 and 1942. The first date corresponds to the 1921 recession which at a four percent fall of output was relatively small compared to the Great Depression. The next six shocks all occur during the Great Depression era. They include 1937-1938 which was one of the largest recessions in U.S. history.

What makes the Great Depression sequence unique is the bunching of the three big shocks from 1930 through 1932. Moreover, all of these shocks are outside the residuals sequence's one-standard error band. Of course, the choice is inherently somewhat arbitrary, but let us consider this pattern as the benchmark for the occurrence of depressions. Given that the probability for shocks to fall short of the lower error band is 16 percent, and assuming that shocks are independent over time, this implies that the probability of such a three shock sequence is 0.4 percent. Phrased alternatively, taking three large negative shocks as the benchmark, depressions could be expected about every 250 years.

5 Concluding remarks

I can identify from the intratemporal optimality condition a number of unusually large negative taste shocks bunched in the 1930s. These shocks reflect a mix of a drop in consumption demand and a higher propensity to consume leisure. I apply the measured shocks to a dynamic equilibrium model. The model supports the hypothesis that preference shocks played a major role in both generating the economic downturn as well as prolonging the downturn. Noteworthy is the model's ability to account for the lion's share of the decline in economic activity. If one accepts the presence of modest increasing returns to scale and of variable capital utilization, then preference shocks can account for the depth of the depression in its entirety.[18] Furthermore, I find that the speeds of adjustment in the model parallel those in the Great Depression which were much slower than in other recessions. The model performs particularly well between 1934 and 1939. However, despite its ability along these dimensions, the model predictions with respect TFP (and consumption) are less successful. Thus, the preference-driven model flips the Cole and Ohanian (1999) puzzle on its head. It remains to be seen if modifications of the model structure will be able to produce a better match.

[18] In a sense, this somewhat deflates Modigliani's (1977) attack on neoclassical economics – without the market imperfections, the Depression would only have been about half as deep and shorter.

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6 Appendix: Notes on comovements and the 1920s

With the presence of variable capital utilization, the preference process implies that consumption, investment and labor all covary positively with output even under constant returns to scale. Highly persistent preference shocks imply that consumption demand will be high for a number of periods. This requires factor inputs to rise and investment to go up as well such that capital is accumulated more intensely. This contradicts Baxter and King's (1991) original contention. Empirical preference dynamics are very persistent: for the estimated Δ-process (10), the half-life is 8 years (the inverted AR-roots are 0.83 and 0.40). Figure 10 plots impulse response dynamics of the constant returns to scale economy following a one-time shock to Δ_t. Noteworthy are the positive comovements of all variables, the correct ordering of relative volatilities and the hump-shaped shock propagation.

Figure 11 displays the model realizations for the full pre-war period; the simulation starts in 1920 and all series have been normalized such that they take on the value 100 in 1929. Theory is able to account for the relative smooth upward trend that proceeded the Depression and the cyclic is significantly smaller in the 1920s – despite the relative strong disturbances that are calculated for the 1920s. The reason is the absence of the sort of negative shock bunching that arose from 1930 through 1932.

Table 1: Calibration

α	β	γ	δ	g	n	η
1/3	0.97	0	0.08	0.019	0.01	0.79

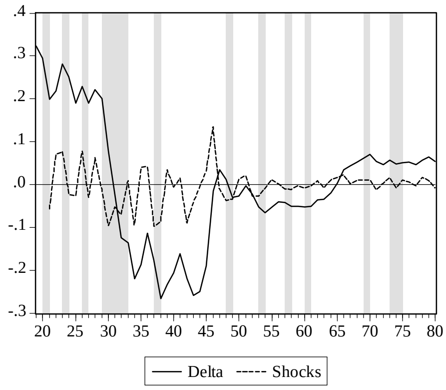

Figure 1: Preference shifter, preference shocks and NBER recesssions

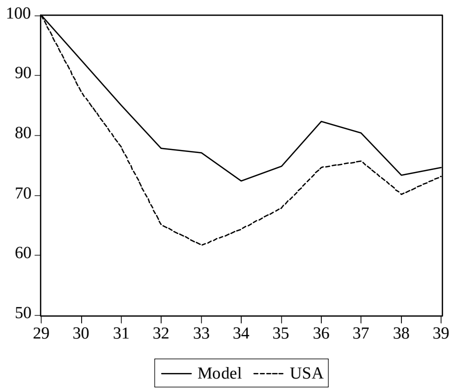

Figure 2: Constant returns to scale model

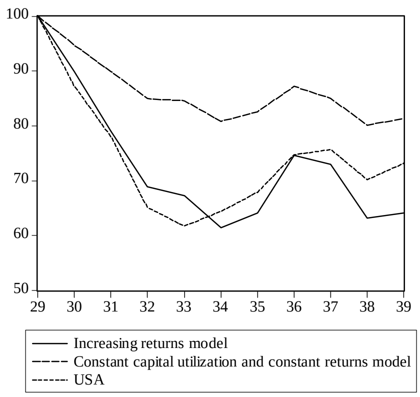

Figure 3: The effects of increasing returns and of capital utilization

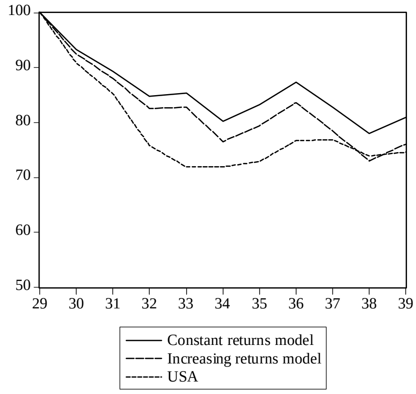

Figure 4: Consumption

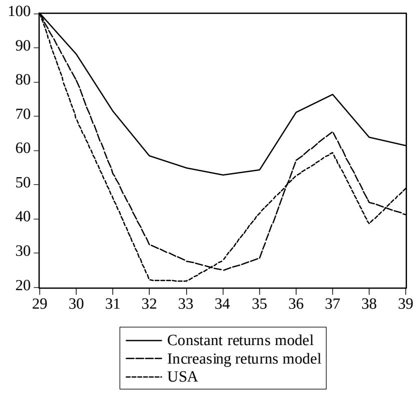

Figure 5: Investment

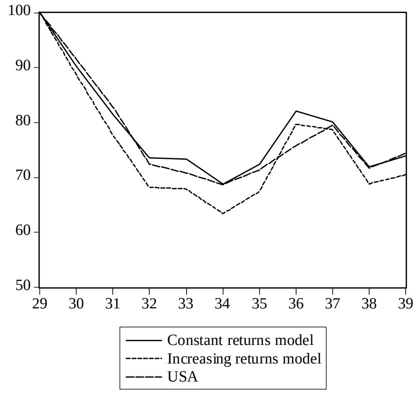

Figure 6: Employment

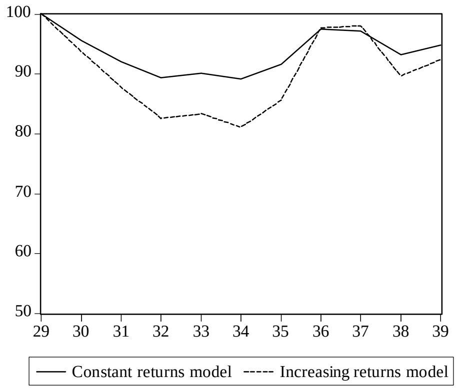

Figure 7: Capital utilization

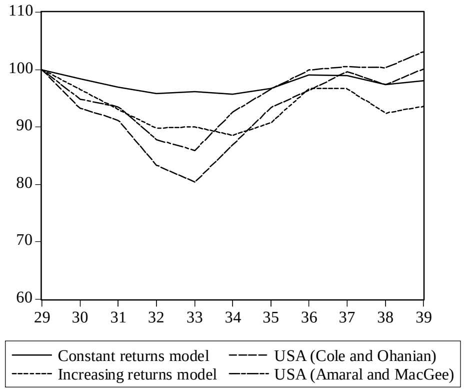

Figure 8: "Total factor productivity"

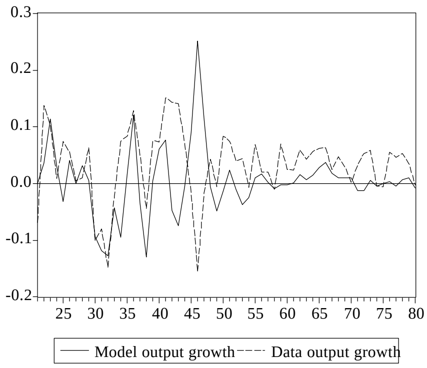

Figure 9: Output growth model vs. U.S. (1921-1980)

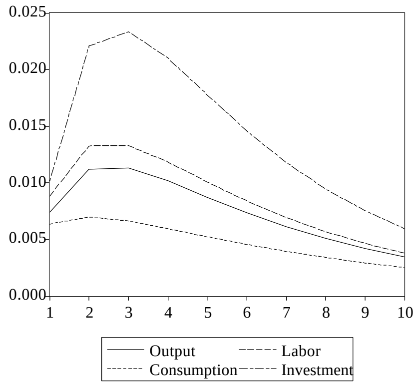

Figure 10: Impulse response dynamics (deviations from steady state)

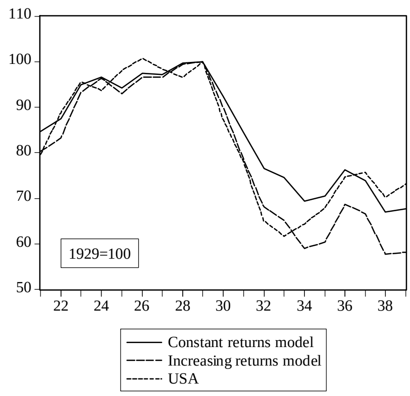

Figure 11: The 1920s

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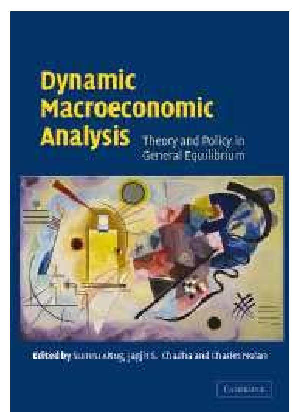

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