Credibility of the Interwar Gold Standard, Uncertainty, and the Great Depression

by

J. Peter Ferderer*

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*The Jerome Levy Economics Institute and Clark University

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Abstract

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This paper constructs a theoretical model to show how the credibility of a country's commitment to an international gold standard regime is driven by fundamental determinants such as: 1) shifts in domestic policy, 2) a breakdown in cooperation between central banks, and 3) unilateral devaluations by foreign central banks. Because the credibility of the gold standard regime is an important determinant of domestic interest rate uncertainty, the latter is endogenously linked to changes in the fundamental determinants.

Applying this analysis to the interwar period, the paper shows that GARCH measures of interest rate uncertainty rose dramatically in the U.S. during the early 1930s and that movements in this series can be explained by events which affected the credibility of the U.S. commitment to the gold standard. Also, interest rate uncertainty explains a great deal of the variation in aggregate output and its components during the interwar period. Thus there is evidence that the breakdown in the gold standard contributed to the Great Depression by injecting increased uncertainty into the U.S. economy.

I. Introduction

Economists have begun to re-examine the role that the international gold standard played in bringing about the Great Depression.[1] Much of this work points to a breakdown in international cooperation and reduced credibility of the gold standard regime as the principal source of world-wide economic contraction. For example, Temin (1989) has argued that the gold standard imparted a deflationary bias on the world economy because policy adjustments of gold standard countries were asymmetric; deflationary policies pursued by countries suffering from balance-of-payments deficits were not offset by expansionary policies in surplus countries. Moreover, Eichengreen (1992) contends that reduced credibility of the gold standard regime intensified deflationary forces by forcing policy authorities to pursue increasingly restrictive measures to defend exchange rate parities.

The breakdown in international cooperation and loss of credibility have been attributed to several factors. Some scholars contend that the absence of a hegemonic central bank — such as the Bank of England during the prewar gold standard — to coordinate world monetary policy was responsible for the breakdown in cooperation.[2] Others argue that the exchange rate parities set when the gold standard regime was reestablished in 1926 did not reflect the disparate inflation rates experienced by participant countries since World War I.[3] These fixed rates implied balance-of-payments disequilibria and lead to an environment of de-stabilizing speculation with investors anticipating realignment.[4] Finally, Eichengreen concludes that a shift in the post-WWI political landscape made it difficult for central banks to coordinate their actions and reduced the credibility of the interwar gold standard regime. With a disruption in the existing social contracts regarding the distribution of fiscal burdens and with labor gaining political power, it became less clear whether maintaining external balance would remain the focus of policy as it had in the prewar era. The credibility of the regime was further reduced by a breakdown in international cooperation which was driven by: a) objections of domestic interest groups who had gained political, b) disputes over war reparations, and c) disparate conceptual frameworks of policy-makers. The net impact of these political changes was that the fixed exchange rates were no longer perceived by the public to be equilibrium rates and de-stabilizing speculation resulted.[5]

While there is disagreement in the literature concerning the source of the breakdown in the gold standard, there is less discord about the nature of the transmission mechanism through which the breakdown affected the real economy. In particular, the literature has focused on the stance of monetary and fiscal policy called for by adherence to the gold standard's "rules of the game" as the primary determinant of economic activity. For example, Eichengreen argues that adherence to the gold standard caused contractionary monetary policies in the U.S and France in 1928 to be quickly exported to other countries. These countries were prevented from undertaking unilateral money supply expansions or increases in public spending because such policies would produce balance-of-payments deficits and threaten their ability to stay on the gold standard.[6] The loss of credibility magnified the problem because it meant that policy-makers had to pursue increasingly restrictive policies to defend the exchange rate parities.

This paper focuses on an additional transmission mechanism through which the collapse of the gold standard affected the U.S. economy during the interwar period: the uncertainty channel. It is argued that the breakdown in international cooperation and loss of credibility in the gold standard regime injected considerable interest rate uncertainty into the U.S. economy and that this uncertainty depressed aggregate spending. The loss of credibility forced policy authorities to initiate dramatic shifts in policy instruments to defend exchange rate parities and these adjustments not only affected the stance of monetary policy, but the volatility of policy as well.

At a theoretical level there is good reason to believe that uncertainty affected economic activity during the Great Depression. First, the literature on financial intermediation under asymmetric information shows that credit rationing increases and the risk premium charged by lenders rises when investment projects become riskier.[7] Second, recent work on irreversible investment decisions shows that investment spending is highly sensitive to uncertainty when investment expenditures are sunk costs.[8] In particular, Ingersoll and Ross (1992) demonstrate that interest rate uncertainty plays as important a role (if not more important) in the determination of investment spending as the level of interest rates.

While this transmission mechanism differs greatly from that which has been emphasized in the literature, it has been discussed by other scholars. For example, Hamilton (1988) speculates that:

> speculators anticipate changes in the terms of gold convertibility. This institutionalizes a system susceptible to large and sudden inflows and outflows of capital and to destabilizing monetary policy if monetary authorities must resort to great extremes to reestablish credibility. Such a system requires individuals to adapt their behavior to the contingencies of rapid and dramatic changes in interest rates, credit availability, and price levels. This characterizes the events of 1931 most accurately. Surely, it contributed to propagating the Great Depression.

Moreover, Ferderer and Zalewski (1993) provide evidence that interest rate uncertainty — measured by the risk premium embedded in the term structure of interest rates — rose in response to the breakdown of the gold standard and helps explain the decline in investment spending during the Great Depression.

The present paper extends this earlier work in several directions. First, we construct a theoretical model to show how credibility of the gold standard regime (i.e., the probability that existing parities will be maintained and devaluation will not occur) is linked to various economic fundamentals. These include: a) shifts in domestic monetary and fiscal policy, b) breakdowns in cooperation between central banks, and c) unilateral devaluations by foreign central banks. Second, we show that domestic interest rate uncertainty arises as an endogenous response to reduced credibility of the gold standard regime. Thus we formally demonstrate that changing political forces can affect the credibility of the gold standard and uncertainty about domestic interest rate.

The third contribution of the paper is empirical. Using a Generalized Autoregressive Conditional Heteroscedastic (GARCH) measure of interest rate uncertainty, we show that interest rate uncertainty rose to unprecedented levels in the U.S. during the early 1930s. Moreover, an examination of the historical record suggests that behavior of interest rate uncertainty during this time is consistent with the predictions of the theoretical model. For example, interest rate uncertainty rose in the U.S. following Britain's departure from the gold standard (and devaluation of the pound) in late 1932 and following attempts at monetary expansion in 1932 and 1933.

The final contribution of the paper is also empirical. It is shown that interest rate uncertainty does about as well as monetary variables in explaining fluctuations in aggregate output and its components (particularly equipment investment) during the interwar period.[9] Moreover, much of the variation in the money multiplier during the interwar period can be explained by movements in interest rate uncertainty. Taken together, these findings support the hypothesis that increased uncertainty depressed economic activity during the 1930s by inducing firms to delay investment expenditures and by restricting the level of financial intermediation.

The outline of the paper is as follows. The next section presents the theoretical model. Estimation of the interest rate uncertainty measure is discussed in section III. Section IV examines the historical record to determine if there is a link between interest rate uncertainty and events which the theoretical model predicts should affect uncertainty. Section V presents results from empirical models which compare the power of monetary and uncertainty variables for explaining output fluctuations during the interwar period. The final section concludes the paper and discusses the policy implications.

II. The Model

The first part of this section examines the factors which determine the credibility of a country's commitment to a fixed exchange rate regime. The speculative attack model of Blanco and Garber (1986) is utilized for this purpose. The second part of this section shows how the credibility of the commitment affects domestic interest rate uncertainty.

A. The Basic Structure

Under the international gold standard a country is required to fix the value of its currency in terms of gold and stand ready to buy and sell gold unconditionally at that price. When each participant country sets a fixed price for gold, exchange rates become fixed. For example, let $\bar{g}_{\$}$ = log($/oz.) be the log of the fixed (denoted by the bar) dollar price of an ounce of gold and $\bar{g}_{£}$ = log(£/oz.) the log of the fixed sterling price of gold. Then the log of the fixed exchange rate (the domestic price of foreign currency) is:

$$\bar{e}_t = \bar{g}_{\$,t} - \bar{g}_{£,t}$$

The exchange rate remains fixed as long as each country maintains a fixed price of gold. Also, the absence of arbitrage opportunities ensures that exchange rates prevailing in secondary markets converge to this official rate.

An important building block for this model is the domestic money market.

Equilibrium in the money market implies:

$$\mathbf{m}_t - \mathbf{p}_t = \beta + \Omega\mathbf{y}_t - \alpha\mathbf{i}_t + w_t \tag{2.1}$$

where $\mathbf{m}_t$, $\mathbf{p}_t$ and $\mathbf{y}_t$ are logarithms of the money stock, domestic price level, and aggregate output, respectively; $\mathbf{i}_t$ is the domestic interest rate; β, Ω, and α are parameters; and w_t is a stochastic money demand shock. Assuming covered interest rate parity,

$$\mathbf{i}_t = \mathbf{i}_t^* + E_t\bar{\mathbf{e}}_{t+1} - \bar{\mathbf{e}}_t \tag{2.2}$$

where $\mathbf{i}_t^*$ is the foreign interest rate and E_t is the market's expectation conditional on information available at time t. Finally, the domestic price level is given by

$$\mathbf{p}_t = \mathbf{p}_t^* + \bar{\mathbf{e}}_t \tag{2.3}$$

where $\mathbf{p}_t^*$ is the logarithm of the foreign price level.

We abstract from the banking system so that the money supply is equal to the monetary base. Moreover, we can express the consolidated balance sheet for the domestic economy's banking system as:

$$\mathbf{m}_t = \log[\mathbf{D}_t + \mathbf{G}_t \cdot \exp(\bar{\mathbf{g}}_\$)] \tag{2.4}$$

where $\mathbf{D}_t$ is the domestic credit component of the monetary base[10] and $\mathbf{G}_t$ is the stock of gold reserves expressed in ounces of gold. The gold stock is valued at the official fixed price of gold. To simplify the analysis, we abstract from central bank holdings of foreign currency as a reserve asset.

B. Policy Rules

In a small open economy operating under a fixed exchange rate regime, the domestic money stock and interest rate are driven by events occurring in the rest of the world. Given equation (2.4), this implies that changes in the domestic credit component of the money stock will have a direct impact on the stock of gold held by the central bank. Thus the behavior of domestic credit must be specified to pin down the behavior of the gold stock.

The policy rule for domestic credit creation is specified so that $\mathbf{D}_t$ is determined exclusively by the need to accommodate fiscal policy. We assume that $\mathbf{D}_t$ evolves according to the following deterministic process

$$\mathbf{D}_t = b\mathbf{D}_{t-1} \tag{2.5}$$

where b is a policy parameter. If the government's deficit is growing over time, then $b > 1$.

The policy rule for devaluation is determined by the behavior of the gold stock. As long as the central bank has a stock of gold in excess of some critical level, $\mathbf{G}$, the official price of gold can be maintained and the exchange rate remains fixed at $\bar{\mathbf{e}}$. When, in contrast, the gold stock falls to the critical level, the central bank must raise the official price of gold to $\hat{\mathbf{g}}_{\$}$ and set a new higher exchange rate $\hat{\mathbf{e}}$. Only when the stock of gold reaches $\mathbf{G}$ does the central bank repudiate $\bar{\mathbf{g}}_{\$}$ and $\bar{\mathbf{e}}$.

Rather than assume that the critical level of the gold stock is fixed, we specify that

$$\mathbf{G}_t = d\mathbf{G}_{t-1} \tag{2.6}$$

where d is influenced by the level of cooperation between central banks. For example, if central banks are increasingly reluctant to make gold reserve loans to the home country when it experiences balance-of-payments deficits, then d > 1.

C. The Probability and Magnitude of Devaluation

When the central bank is forced to devalue, the new official price of gold $\hat{\mathbf{g}}_\$$ and exchange rate $\hat{\mathbf{e}}$ must be viable. To be viable, these two prices must be set higher than those that would prevail in a floating exchange rate regime. If the new exchange rate is set below the floating rate, the central bank will continue to experience a fall in its gold stock. Thus the floating exchange rate places a lower bound on the value of the new fixed exchange rate.

To solve for the floating exchange rate, we fix the central bank's stock of gold at $\mathbf{G}_t$ and combine (2.1) through (2.4) to get

$$\mathbf{h}_t = -\alpha E_t \tilde{\mathbf{e}}_{t+1} + (1 + \alpha)\tilde{\mathbf{e}}_t \tag{2.7}$$

where $\mathbf{h}_t \equiv \log[\mathbf{D}_t + \mathbf{G}_t \cdot \exp(\bar{\mathbf{g}}_\$)] - \beta - \Omega \mathbf{y}_t + \alpha \mathbf{i}^*_t - \mathbf{p}^*_t - w_t$, and $\tilde{\mathbf{e}}_t$ is the hypothetical floating exchange rate. Note that we value the critical level of the gold stock at the official price of gold prevailing before movement to the floating rate regime occurs. This follows from the assumption that reserves are valued at book value.

To specify an autoregressive process for $\mathbf{h}_t$ we assume that the remaining exogenous variables in the model evolve according to:

$$\mathbf{y}_t = \mathbf{y}_{t-1} + \xi_t \qquad \xi_t \sim N(0, \sigma^2_\xi) \tag{2.8}$$

$$\mathbf{i}^*_t = \mathbf{i}^*_{t-1} + u_t \qquad u_t \sim N(0, \sigma^2_u) \tag{2.9}$$

$$\mathbf{p}^*_t = \mathbf{p}^*_{t-1} \tag{2.10}$$

Equation (2.8) specifies that output follows a random walk; (2.9) makes the foreign interest rate stochastic; and (2.10) specifies a constant foreign price level. Under these assumption we can write

$$\mathbf{h}_t = \theta_1 + \theta_2\mathbf{h}_{t-1} + \mathbf{v}_t \tag{2.11}$$

where: $\theta_1 > 0$, $\theta_2 \lesseqgtr 1$, and $\mathbf{v}_t = \alpha u_t - \Omega\xi_t - (w_t - w_{t-1})$. The distribution over $\mathbf{v}_t$ is given by the normal pdf f(v) with a zero mean and standard deviation σ_v. Notice that θ_2 is conditional on the policy parameters. For example, if $b < 1$ and $d = 1$, then $\theta_2 < 1$ and $\mathbf{h}_t$ is mean-reverting.

Solving the difference equations (2.7) and (2.11), we obtain the floating exchange rate $\tilde{\mathbf{e}}_t$

$$\tilde{\mathbf{e}}_t = \mu\alpha\theta_1 + \mu\mathbf{h}_t \tag{2.12}$$

where $\mu = 1/[(1 + \alpha) - \alpha\theta_2]$.[11] Because the behavior of the floating rate is determined by the path of $\mathbf{h}_t$, this latter variable determines the viability of the current parities.

The impact of different policies on the viability of the current fixed exchange rate can be discussed in the context of (2.12). For example, a shrinking deficit ($b < 1$) with a fixed critical level of gold reserves ($d = 1$) takes pressure off of the current fixed exchange rate because $\mathbf{h}_t$ and $\tilde{\mathbf{e}}_t$ fall over time. In contrast, continually expanding deficits ($b > 1$) with a fixed critical level of gold reserves ($d = 1$) causes $\mathbf{h}_t$ to be nonstationary and puts the current fixed exchange rate under ever increasing pressure. Finally, a fixed government deficit along with reduced cooperation between central banks which continually raises the home central bank's critical level of gold reserves ($d > 1$) makes $\mathbf{h}_t$ nonstationary and puts the current fixed exchange rate under increasing pressure.

The policy rule for devaluation implies that the new fixed rate, $\hat{\mathbf{e}}_t$, is a mark-up over the floating given by (2.12). That is, when the gold stock reaches $\mathbf{G}_t$ the central bank sets the new fixed rate as:

$$\hat{e}_t = \tilde{e}_t + \delta v_t \tag{2.13}$$

where δ is a nonnegative parameter. The devaluation rule specifies that the central bank will select a new fixed exchange rate equal to the minimum viable rate plus a mark-up dependent on the magnitude of the disturbance that forced devaluation. The logarithm of the new official price of gold implied by this exchange rate is $\hat{g}_{\$} = \hat{e} + \bar{g}_{£}$.

Given the model, we can describe the world as being in one of two states at any point in time. State one occurs at t+j ($s_{t+j} = 1$) when devaluation does not take place. State two occurs at t+j ($s_{t+j} = 2$) when devaluation takes place. The probability of being in state one, based on information available at time t, is $pr(s_{t+j} = 1)$, and the probability of being in state two is $pr(s_{t+j} = 2) = 1 - pr(s_{t+j} = 1)$.

The probability of devaluation a time t+1 based on information available at t is equal to the probability that the fixed rate at t+1 will exceed the fixed rate at t

$$\begin{aligned} pr(s_{t+1} = 2) &= pr(\hat{e}_{t+1} > \bar{e}_t) \\ &= pr(\mu\alpha\theta_1 + \mu\mathbf{h}_{t+1} + \delta\mathbf{v}_{t+1} > \bar{e}_t) \\ &= pr(\mathbf{v}_{t+1} > k_t) \end{aligned} \tag{2.14}$$

where $k_t = [\bar{e}_t - (1+\alpha)\mu\theta_1 - \mu\theta_2\mathbf{h}_t]/(\mu+\delta)$. Thus agents assign a probability to the event that devaluation will occur one period in the future given knowledge of the density function f(v) and k_t.

Our objective in the next subsection is to derive the variance of $\mathbf{i}_{t+1}$ conditional only on information available at time t. To do so, both $E_t\mathbf{e}_{t+2}$ and $E_t\mathbf{e}_{t+1}$ need to be derived. To simplify the analysis, we assume that agents know with certainty that devaluation will not occur at t+1, i.e.,

$pr(s_{t+1} = 1) = 1$, and focus on devaluation uncertainty for t+2.[12] Given a zero probability of devaluation at t+1, the probability of devaluation at t+2 based on time-t information is

$$pr(s_{t+2} = 2) = pr(\mathbf{v}_{t+2} > E_t k_{t+1}) \tag{2.15}$$

where $E_t k_{t+1} = [\bar{\mathbf{e}}_{t+1} - (1+\alpha)\mu\theta_1 - \mu\theta_2\theta_1 - \mu\theta_2^2\mathbf{h}_t]/(\mu+\delta)$.

We can also solve for the magnitude of devaluation. Focusing on the state of the world two periods into the future, we get

$$E_t(\mathbf{e}_{t+2} | s_{t+2} = 1) = \bar{\mathbf{e}}_{t+1} \tag{2.16}$$

and

$$\begin{aligned} E_t(\mathbf{e}_{t+2} | s_{t+2} = 2) &= E_t(\hat{\mathbf{e}}_{t+2} | s_{t+2} = 2) \\ &= \mu\theta_1(1+\alpha) + \mu\theta_2\theta_1 + \mu\theta_2^2\mathbf{h}_t + (\delta+\mu)E_t(\mathbf{v}_{t+2} | s_{t+2} = 2) \end{aligned} \tag{2.17}$$

where $E_t(\mathbf{v}_{t+2} | s_{t+2} = 2) = \int_{E_t k_{t+1}}^{\infty} \mathbf{v}f(\mathbf{v})d\mathbf{v}$

Thus the expected exchange rate in t+2 when devaluation is known to occur is a function of the models underlying parameters.

Finally, we can combine the expressions in (2.16) and (2.17) with the probability of devaluations to get the conditional (conditioned only on the information set and not on the state) expectation for the exchange rate two periods hence

$$E_t\mathbf{e}_{t+2} = pr(s_{t+2} = 1)\cdot\bar{\mathbf{e}}_{t+1} + pr(s_{t+2} = 2)\cdot E_t(\hat{\mathbf{e}}_{t+2} | s_{t+2} = 2) \tag{2.18}$$

This equation shows that the expected exchange rate is an increasing function of the probability of devaluation. This link between credibility and the expected exchange rate has important implications for the conduct of monetary policy because it implies that reduced credibility forces the central bank to initiate large increases in domestic interest rates to restore money market equilibrium.

D. Endogenous Interest Rate Uncertainty

Given the existence of devaluation uncertainty for t+2, it is easy to show that the conditional interest rate variance can be expressed as:[13]

$$\mathbf{Var}_t \mathbf{i}_{t+1} = \mathbf{E}_t\left[\mathbf{Var}_t(\mathbf{i}_{t+1} \mid s_{t+2})\right] + \mathbf{Var}_t\left[\mathbf{E}_t(\mathbf{i}_{t+1} \mid s_{t+2})\right] \tag{2.19}$$

where $\mathbf{E}_t$ and $\mathbf{Var}_t$ are the expectation and variance, respectively, conditional only on the time t information set, while $\mathbf{E}_t(\cdot \mid s_{t+2})$ and $\mathbf{Var}_t(\cdot \mid s_{t+2})$ are the expectation and variance, respectively, conditional on the time t information set and the state of the world at t+2.

As we demonstrate in the appendix, the conditional variance for the interest rate can be written as:

$$\mathbf{Var}_t \mathbf{i}_{t+1} = \sigma_u^2 + \left[E_t(\hat{\mathbf{e}}_{t+2} \mid s_{t+2} = 2) - \bar{\mathbf{e}}_{t+1}\right]^2 \cdot pr(s_{t+2} = 1) \cdot pr(s_{t+2} = 2) \tag{2.20}$$

Equation (2.20) illustrates that two main factors contribute to interest rate uncertainty. First, uncertainty increases when the variance of foreign interest rates shocks, σ_u^2, rises. Large shocks to foreign interest rates produce dramatic adjustments in the domestic money stock to restore equilibrium with fixed exchange rates and this raises uncertainty about interest rates.

Second, interest rate uncertainty arises as an endogenous response to reduced credibility of central bank's commitment to the exchange rate regime. When the current fixed exchange rate is completely credible, agents place zero probability on devaluation, $pr(s_{t+2} = 2) = 0$, and uncertainty is driven only by the variance of foreign interest rate shocks. As the current fixed rate becomes less credible, the probability of devaluation rises above zero, $pr(s_{t+2} = 2) > 0$, and uncertainty rises above the level which prevails under perfect credibility. Finally, as agents become certain that devaluation will occur, $pr(s_{t+2} = 2) \to 1$, uncertainty is once again driven solely by the variance of foreign interest rate shocks. Thus there is a nonlinear concave relation between conditional interest rate variance and the probability that a discrete devaluation will take place.

To illustrate the endogenous nature of interest rate uncertainty in this model, suppose that the policy authorities de-emphasis external balance and emphasize internal balance. That is, a path of rapid deficit growth is chosen in order to fight recession regardless of the impact that this has on the central bank's gold stock. This shift in policy causes b, θ_2 and μ to rise and $E_t k_{t+1}$ to fall. The net impact is that $pr(s_{t+2} = 2)$ rises. As long as the probability of devaluation does not rise beyond .5, interest rate uncertainty increases. Thus increased emphasis on internal balance raises interest rate uncertainty by undermining the credibility of the current exchange rate parities.

As a second example, consider the impact of reduced cooperation among central banks. When cooperation is reduced individual central banks cannot count on foreign central banks to lend them gold reserves during balance-of-payments crises. In the context of the model, this has the effect of raising the parameters d, θ_2 and μ which makes $\mathbf{h}_t$ nonstationary and raises the probability of devaluation. Thus a breakdown in international cooperation can also raise interest rate uncertainty by undermining the credibility of the current exchange rate parities.

Finally, an unexpected unilateral devaluation by a foreign central bank causes interest rate uncertainty to rise. When a foreign central bank raises the price at which it buys and sells gold (e.g., $\bar{\mathbf{g}}_{£}$ rises), $\bar{\mathbf{e}}_{t+1}$ falls which leads to a reduction in $E_t k_{t+1}$ and an increase in the probability that the home country will devalue. Thus by devaluing, foreign central banks can cause the credibility of the home country's commitment to the current parities to fall and interest rate uncertainty to rise.

III. Measuring Interest Rate Uncertainty

The objective of this section is to construct a measure for interest rate uncertainty. To measure interest rate uncertainty we use the autoregressive conditional heteroscedasticity (ARCH) model pioneered by Engle (1982). The basic idea is to specify a time-series model for the interest rate and to associate the conditional variance of the model's error term with the level of interest rate uncertainty experienced by economic agents. If the conditional variance clusters intertemporally, then the model's disturbances have autoregressive conditional heteroscedasticity.

As Bollerslev, Chou and Kroner (1992) point out, an observationally equivalent representation of the ARCH model is the time-varying parameter moving-average model. We follow Bera, Higgins and Lee (1992) and specify the following linear time-varying parameter model as:

$$\mathbf{i}_t = \alpha + \beta_1 \mathbf{i}_{t-1} + \ldots + \beta_n \mathbf{i}_{t-n} + \varepsilon_t \tag{3.1}$$

$$\varepsilon_t = \sum_{j=1}^{k} \phi_{jt} \varepsilon_{t-j} + u_t = \sum_{j=1}^{k} (\phi_j + \eta_{jt}) \varepsilon_{t-j} + u_t \tag{3.2}$$

$$\mathbf{h}_t = \mathbf{var}(\varepsilon_t | \Omega_{t-1}) = \sigma^2 + \sum_{j=1}^{q} \gamma_j \varepsilon_{t-j}^2 + \sum_{j=1}^{p} \lambda_j \mathbf{h}_{t-j} \tag{3.3}$$

where $\mathbf{i}_t$ is the tth observation of the interest rate, α is a constant, and the β_i are autoregressive coefficients. The disturbance ε_t follows a stochastic k-order autoregressive process with ϕ_j constant, η_{jt} stochastic for all j and $u_t \sim N(0, \sigma^2)$ a finite-variance homoscedastic error process. The two error processes are assumed to be independent. Furthermore, $E(\eta_t) = 0_{k \times 1}$ and $E(\eta_t \eta_t') = \Sigma$ where $\eta_t = (\eta_{1t}, \ldots, \eta_{kt})'$. To simplify, we assume that Σ is a diagonal matrix.

The conditional variance of the disturbance ε_t is given in (3.3).[14] The information set at t-1, Ω_{t-1}, includes all past disturbances $(\varepsilon_{t-1}, \ldots \varepsilon_{t-q})$ and variances $(\mathbf{h}_{t-1}, \ldots, \mathbf{h}_{t-p})$. The conditional variance is specified in a flexible manner so that both ARCH and generalized ARCH, or GARCH(p,q), models can be estimated. An ARCH error process exists when the variances of the stochastic component of the autoregressive parameters in (3.2), the η_{jt}, are nonzero. These variances make up the diagonal of Σ. Thus $\Sigma \neq 0$ and $\gamma_j \neq 0$ are equivalent.

As Bera et al. (1992) point out, it is important to consider the possibility that serial correlation and conditional heteroscedasticity exist in the model simultaneously. This is because conditional heteroscedasticity can be mistaken for autocorrelated disturbances. The model (3.1)-(3.3) allows us to simultaneously test for the presence of autocorrelated errors and time-varying conditional variances.

Testing for ARCH entails testing whether or not the autoregressive coefficients are time-varying. This is equivalent to testing the null hypothesis H_o: $\gamma_j = 0$. The Lagrange multiplier statistic for testing this hypothesis in the presence of autocorrelation is denoted $\mathbf{LM}_{\mathrm{ARCH}|\mathrm{AR}}$. This statistic is calculated as the number of observations (N) multiplied by the R-squared (R^2) from the regression of $\hat{u}_t^2$ on $(1, \hat{\varepsilon}_{t-1}^2, \ldots, \hat{\varepsilon}_{t-q}^2)$, with

$$\hat{\varepsilon}_t = \mathbf{i}_t - \hat{\alpha} - \sum_{j=1}^{n} \hat{\beta}_1 \mathbf{i}_{t-1} \qquad \text{and} \qquad \hat{u}_t = \hat{\varepsilon}_t - \sum_{j=1}^{k} \hat{\phi}_j \hat{\varepsilon}_{t-1}$$

where hats over parameters denote that they are maximum likelihood estimates. The $\mathbf{LM}_{\mathrm{ARCH}|\mathrm{AR}}$ statistic is distributed asymptotically as χ^2 with q degrees of freedom. Clearly, the validity of the test is conditional on proper specification of the AR process.

To test the null hypothesis of no autocorrelation (H_o: $\phi_j = 0$) under the assumption of a particular form of ARCH, we construct the Lagrange multiplier statistic denoted by $\mathbf{LM}_{AR\,|\,ARCH}$. Under the null hypothesis, the model reduces to one with only ARCH disturbances where

$$\hat{\varepsilon}_t = i_t - \hat{\alpha} - \sum_{j=1}^{n} \hat{\beta}_1 i_{t-1} \qquad \text{and} \qquad \hat{h}_t = \hat{\sigma}^2 + \sum_{j=1}^{q} \hat{\gamma}_j \hat{\varepsilon}^2_{t-j}$$

Then

$$\mathbf{LM}_{AR\,|\,ARCH} = \left(\sum_{t=1}^{N} \frac{1}{\hat{h}_t} \hat{\varepsilon}_t (\hat{\varepsilon}_{t-1},...,\hat{\varepsilon}_{t-k})\right)' \text{x}$$

$$\left(\sum_{t=1}^{N} \frac{1}{\hat{h}_t} (\hat{\varepsilon}_{t-1},...,\hat{\varepsilon}_{t-k})'(\hat{\varepsilon}_{t-1},...,\hat{\varepsilon}_{t-k})\right)^{-1} \text{x} \left(\sum_{t=1}^{N} \frac{1}{\hat{h}_t} \hat{\varepsilon}_t (\hat{\varepsilon}_{t-1},...,\hat{\varepsilon}_{t-k})\right)$$

which is distributed asymptotically as χ^2 with k degrees of freedom. The validity of this test is conditional on the proper specification of the ARCH.

To construct the ARCH models we use yields on three-month Treasury securities from the *Banking and Monetary Statistics*. We use the yield available in the third month of the quarter to obtain quarterly observations for this series. Figure 1 illustrates this yield (TBILL) over the interwar period along with the federal Reserve's discount rate (DISCOUNT).[15]

Table 1 shows results from specification tests for various ARCH(q) and GARCH(p,q) models. The specification of equation (3.1) employed is the simple univariate autoregressive model with n=1. For autoregressive errors of order zero, one and two we report $LM_{ARCH\,|\,AR}$ in Section A of Table 1. The results indicate that for all orders of the AR process considered and for q running from one to six we can reject the null hypothesis that H_o: $\gamma_1 = \gamma_2 = ... = \gamma_q = 0$. Therefore there is strong evidence of an ARCH process in the interest rate innovations. Also, the long lag structure in the conditional variance equation suggests that the parsimonious GARCH model is appropriate.

Section B of Table 1 reports results for tests of the null hypothesis of no autocorrelation, H_o: $\phi_1 = \phi_2 = ... = \phi_k = 0$ under different assumptions about the order of the ARCH and GARCH models. In all cases but one we cannot reject the null hypothesis of no autocorrelation in the disturbances. This finding suggest that the time-varying conditional variances are not generated by autocorrelated disturbances.

Table 2 reports estimates for the GARCH(1,1) model. This model is preferred over the ARCH model because of the efficient use it makes of the data series. Also, this model out performs the other GARCH models in that its individual coefficients are more highly significant. Interestingly, the likelihood ratio statistic at the bottom of Table 2 allows us to reject, at extremely high levels of significance, the null hypothesis that $\gamma_1 + \lambda_1 = 1$. In fact, the linear combination of these two parameters is much higher than one suggesting that conditional variances follow an IGARCH process (see Engle and Bollerslev (1993)). Thus shocks to the conditional variance are highly persistent and affect uncertainty over all future horizons.

IV. The Historical Record

Section II showed that domestic interest rate uncertainty is a function of the credibility of the exchange rate regime. Moreover, we discussed how the latter is influenced by shifts in domestic monetary and fiscal policy, breakdowns in cooperation between central banks, and unilateral devaluations by foreign central banks. This section examines the historical record to determine whether there is evidence that interest rate uncertainty was driven by these events. Our focus is on the dramatic rise and fall in uncertainty which occurred during the 1932 to 1934 period.[16]

A. Britain's Departure from the Gold Standard

The gold standard began to collapse during the international financial crisis of 1931. The crisis began in May of 1931 with the failure of Credit Anstalt, the largest private bank in Austria, and quickly spread to Germany by July of 1931. The crisis brought about a cessation of international lending and the German central bank responded by shifting to an expansionary policy so that constrained domestic borrowers could obtain credit. The result was a massive withdrawal of highly mobile foreign deposits which forced Germany to suspend convertibility into gold and impose foreign exchange restrictions.

The crises quickly spread to Britain and by the Fall of 1931 the country's balance-of-payments began a rapid deterioration as a result of debt defaults and deposits frozen in closed European banks. As devaluation rumors spread, capital began to flow out of Britain unchecked by the Bank of England. The Bank hesitated to raise the Bank rate due to the damage such a move would likely inflict on the already depressed economy. The unwillingness to raise interest rates resulted in Britain's quick decision to abandon the gold standard on September 20, 1931.[17] By the end of October, a total of 15 countries had left the gold standard.

Several scholars have argued that Britain's departure from the gold standard represented a major event which affected expectations about future U.S. policy toward gold. For example, Friedman and Schwartz (1963) conclude that there was widespread fear that the U.S. would follow Britain and abandon the gold standard and that foreign holders of U.S. assets began to convert their assets into gold.[18] Eichengreen (1992) provides a similar assessment. He argues that countries such as the U.S. which remained on gold in 1931 were threatened by gold reserve losses and convertibility crises because their commitment to the gold standard regime became less credible. Moreover, these countries could not expect assistance from foreign central banks (i.e., by loosening their credit conditions or by making short term loans to the country in crisis) because of the breakdown in international cooperation among central banks.

To maintain gold reserves and currency convertibility in the face of a run on the dollar, the Federal Reserve responed to the events of late 1931 by pursuing a restrictive monetary policy. On October 9, 1931 the Federal Reserve increased the discount rate from 1½ percent to 2½ percent, then to 3½ percent on October 16. According to Friedman and Schwartz, this was "the sharpest rise within so brief a period in the whole history of the System, before or since".[19]

The description of the expectational environment in late 1931 provided by Friedman and Schwartz and Eichengreen, along with the behavior the Federal Reserve, is consistent with the theoretical model presented in section 2. By raising the Sterling price of gold, the Bank of England forced an appreciation of the dollar. This action raised the probability that the U.S. would devalue (see equation 2.15) and reduced the credibility of the U.S. commitment to the gold standard. The reduced credibility raised the expected exchange rate (see equation 2.18) and forced the Federal Reserve to raise short-term interest rates to a much higher level — relative to the case where existing parities were credible — in order to restore money market equilibrium. Thus the loss of credibility generated by Britain's devaluation explains why the Federal Reserve was forced to initiate such a dramatic increase in the discount rate.

The loss of credibility also explains why domestic interest rate uncertainty rose so rapidly at the end of 1931. When the dollar strengthened in response to devaluation of the Sterling, reduced credibility was exported to the U.S. and this should have increased conditional interest rate variances of investors (see equation (2.20)).[20]

B. Expansionary Monetary Policy in 1932 and 1933

Another event which may have contributed to interest rate uncertainty following Britain's departure from gold was the aborted shift in U.S. monetary policy in 1932. According to Epstein and Ferguson (1984), the Federal Reserve, under pressure from Congress, backed off its emphasis on external balance and began conducting open-market purchases between February and June of 1932. Eichengreen (1992, pp. 315-316) discusses how this movement towards a reflationary policy was followed by a drain of gold reserves from the U.S. as investors began to fear devaluation. Once the open-market purchases were ceased in mid 1932, the fear of devaluation was reversed.

Figure 2 shows that interest rate uncertainty rose rapidly during the first part of 1932 when the open-market operations began and fell towards the middle of 1932 when the expansionary policy was aborted. The behavior of this series is consistent with the model discussed above; a shift towards internal balance (a rise in b and θ_2) should reduce the credibility of the existing parities and raise the level of interest rate uncertainty.[21] Once the policy was reversed, the credibility of the U.S. commitment to the gold standard should have risen and interest rate uncertainty should have declined.

Expansionary monetary policy in the U.S. may have also contributed to the increased interest rate uncertainty in early 1933 shown in Figure 2. Wigmore (1987) has argued that expansionary monetary policy in early 1933 fueled expectations of devaluation of the dollar. This expectation led to a capital flight from the U.S. and by March 4 the New York Federal Reserve bank's gold stock had fallen by 60 percent in less than one month. According to Wigmore, the March 1933 Banking Holiday was called by the Federal Reserve to implement a suspension of gold convertibility.

C. The U.S. Leaves the Gold Standard

Following the Bank Holiday the Roosevelt administration made it illegal for U.S. residents to hold gold. Several months later, at the end of January 1934, President Roosevelt, under the authority of the newly passed Gold Reserve Act, specified a fixed price of $35 per ounce of gold, a 59.06 percent rise in the official price.[22] While official devaluation took place in January of 1934, a number of scholars have argued that market participants anticipated this event many months in advance. For example, Temin and Wigmore (1990) conclude that devaluation of the dollar actually began in April of 1933 and was the "single biggest signal that the deflationary policies implied by adherence to the gold standard had been abandoned..." and that the policy change was "clearly articulated and understood" as the dollar fell against the pound by over 100 percent in the last eight months of 1933.[23]

At first glance, the dramatic decline in interest rate uncertainty during the second half of 1933 might appear to be inconsistent with the hypothesis that market participants anticipated devaluation at this time. However, as we saw in equation (2.20), a rise in the probability of devaluation increases interest rate uncertainty only up to a point. When the probability of devaluation rises above fifty percent, interest rate actually begins to decline. Thus the finding that interest rate uncertainty began to decline well before the official devaluation suggests that market participants were confident that the U.S. would leave the gold standard as early as mid 1933. Moreover, once it was made illegal for U.S. citizens to hold gold, the link between international developments and U.S. interest rates was greatly diminished. Thus the variability of shocks to foreign interest rates no longer should have influence uncertainty about domestic interest rates. Figure 2 suggests that interest rate uncertainty was, in fact, low for the remainder of the interwar period.

To summarize, the departure from the gold standard at the end of 1933 marked the end of a turbulent period of transition in U.S. monetary policy which began in 1931. We have argued that this transition was characterized by a high level of interest rate uncertainty as the U.S. commitment to the gold standard became less credible. With the transition complete and credibility of the new regime established by early 1934, interest rate uncertainty all but disappeared and the stage was set for expansion out of the Great Depression.[24]

V. Interest Rate Uncertainty and Economic Activity

A. Uncertainty-Augmented Monetary Models

To examine the degree to which interest rate uncertainty can explain the fluctuations in economic activity during the interwar period, the GARCH variable is introduced into two different monetary models for the U.S. economy. One advantage of this approach is that monetary variables provide a parsimonious control for the general state of the economy. Another advantage of this approach is that it allows us to compare the explanatory power of interest rate uncertainty with that of monetary conditions.

To explore the dynamic relationship between economic activity, monetary conditions and interest rate uncertainty, unrestricted vector autoregressions (VARs) are estimated. The equation for the economic activity variable, y_t, from the VARs takes the following form:

$$\Delta\log(y_t) = a + \sum_{i=1}^{4} b_i \Delta\log(y_{t-i}) + \sum_{i=1}^{4} c_i \Delta\log(x_{t-i}) + \sum_{i=1}^{4} d_i \Delta GARCH_{t-i} + u_t \qquad (5.1)$$

where x_{t-i} is a measure of monetary conditions (possibly a vector); $GARCH_{t-i}$ is the conditional interest rate variance; a, b_i, c_i and d_i are coefficients; and u_t is an error term. To avoid econometric problems associated with using nonstationary variables, each of the series is first-differenced. All data is quarterly.

Following King (1985) and Gordon and Veitch (1986), two approaches are used to measure monetary conditions. The first simply takes the M1 aggregate and divides it by the GNP deflator. The second approach separates the money supply into the real monetary base (BASE) and money multiplier (mm) components, where the latter is measured by taking the ratio of the money supply to the monetary base.[25] This decomposition of the money supply allows us to distinguish between the impact of inside and outside money. This is an important distinction to make for the interwar period given the emphasis economic historians have placed on different sources of disruptions to the money supply. For example, Friedman and Schwartz (1963) have focused on the banking crises of the early 1930s and the impact they had on the money multiplier (i.e., by raising the public's demand for currency and the banks' demand for reserves). In contrast, Temin (1989) and Eichengreen (1992) have focused on the impact that unsterilized international gold flows had on the monetary base. If the money multiplier helps explain economic activity, then support is provided for the Friedman-Schwartz view. If the Temin-Eichengreen channel is relevant, then movements in the monetary base should help explain fluctuations in economic activity.

The VARs include one of five different measures of real economic activity. These are: 1) gross national product (GNP), 2) producers' durable equipment expenditures (EQUIP), 3) nonresidential structures investment (NRS), 4) durable consumption expenditures (DURC), and 5) nondurable consumption and services expenditures (NDURC). For a complete discussion of the data series used in the VAR models, see Balke and Gordon (1986).

Results for the economic activity equations are reported in Table 3. The Table provides two statistics used to evaluate the forecasting power of the right-hand-side variables. Panel A shows F-statistics which tests the null hypothesis that the coefficients on lagged values of a particular right-hand-side variable are jointly equal to zero. Panel B shows the percentage of forecast error variance for the economic activity variable that is accounted for by impulses to the right-hand-side variables at the eight quarter horizon. The economic activity variable is placed first in the ordering, the monetary variable(s) second (and third), and the GARCH variable last. Therefore the uncertainty variable is handicapped relative to the other variables in the system.

The F-statistics in Panel A of Table 3 show that the money supply, as measured by M1, has a statistically significant (at the five percent level) impact on real GNP and each of the disaggregated measures of economic activity. When we decompose the money supply into its two components, the monetary base has a significant impact on each of the five categories of economic activity. In contrast, the money multiplier has a significant impact only on real GNP, nonresidential structures, and durable consumption. Taken together, these results provide some evidence that unsterilized gold flows and the banking crises affected the U.S. economy during the interwar period.

The last column of Panel A presents F-statistics for the GARCH variable. In both monetary models, the interest rate variance enters significantly into the GNP equation. Moving down the rows of Panel A we observe that the F-statistics are not uniformly high for the different categories of economic activity. The interest rate variance has a strong statistical effect on equipment investment and nondurable consumption spending, a somewhat weaker impact on durable consumption spending, and essentially no effect on nonresidential structures investment.

Panel B of Table 3 shows the percentage of forecast error variance for the economic activity variables that can be accounted for by impulses to monetary and uncertainty variables at the eight quarter horizon. The results generally support those in Panel A. That is, the GARCH variable explains about as much of the GNP forecast error variance as do the monetary base and money multiplier even though GARCH is placed last in the ordering. Moreover, the GARCH variable contributes a relatively large amount of explanatory power to equipment investment and nondurable consumption expenditures.

The finding that the interest rate variance has a stronger impact on nondurable consumption spending than on durable consumption is somewhat surprising. Recent theoretical work predicts that expenditures which are relatively more irreversible and can be delayed should be more sensitive to uncertainty.[26] Since these attributes seem to better describe nondurable good expenditures, theory suggests that they should be more highly sensitive to uncertainty. One possible explanation for the finding to the contrary is that the categories of expenditure we have considered are too broad and that each includes expenditures that are irreversible and can by delayed. For example, automobile purchases — a durable good expenditure — are relatively reversible since autos have an active secondary market, while clothing purchases — a nondurable good expenditure — are relatively irreversible since clothing cannot be easily resold. Therefore it is difficult to draw inferences about the irreversibility channel at this level of aggregation.

To summarize, the results in Table 3 indicate that the conditional interest rate variance had a strong influence on economic activity during the interwar period. Moreover, this variable contributes approximately the same amount of explanatory power as do the various measures of monetary conditions.

B. The System's Other Equations

An interesting issue to explore is whether there is any interaction between the monetary variables and interest rate uncertainty. If interest rate uncertainty adversely affects the economy by reducing the level of financial intermediation, then the GARCH variable should help to explain fluctuations in the money multiplier. This is due to the impact that uncertainty has on the willingness of banks to make loans which is reflected, to some extent, in their demand for excess reserves and the money multiplier. In contrast, there does not appear to a strong reason to believe that an exogenous change in the money multiplier affects interest rate uncertainty. Concerning the interaction between interest rate uncertainty and the monetary base, the theoretical model presented in section II suggests that increases in the domestic credit component of the monetary base should lead to an increased probability of devaluation and greater interest rate uncertainty. However, the increased probability of devaluation should also lead to a flow of gold out of the U.S. which reduces the monetary base. Thus the net effect is that fluctuations in interest rate uncertainty are not necessarily associated with movements in the monetary base.

Table 4 shows F-statistics and variance decompositions from the monetary variable and interest rate equations. An interesting finding to emerge from Table 4 is that the GARCH variable has a very significant impact on the money multiplier, while strength of the feedback effect from the money multiplier to the GARCH variable is much weaker. This finding suggests that part of the monetary contraction in the U.S. during the Great Depression may have been due to an increased demand for liquidity by the banking system in the face of increased uncertainty.

Table 4 also shows that the GARCH variable has a significant impact on the monetary base, while there is little evidence of feedback from the monetary base to the GARCH variable. The absence of a feedback effect is consistent with the discussion from above. In contrast, the strong effect running from lagged values of the GARCH measure to the monetary base is more difficult to explain. One possible explanation is that exogenous shocks to interest rate uncertainty affect the U.S. gold stock and monetary base by influencing the desire by investors to hold U.S. financial assets. The model in Section II could be easily altered to incorporate this type of effect.

B. Alternative Models for GNP Components

To evaluate the robustness of our findings to alternative specifications, we estimated VAR models that included: 1) the growth rate of one real GNP component, 2) real GNP growth, 3) the first-difference of the three-month Treasury bill yield, and 4) the first-difference of the GARCH variable. These models are motivated by two considerations. First, a considerable amount of empirical research has shown that accelerator models, which focus on the role of lagged changes in output or sales, do a good job of explaining aggregate investment spending.[27] Similar types of results have been documented for consumption spending. Second, it is possible that the GARCH variable does a good job of explaining economic activity only because it is picking up movements in the level of interest rates. By including both the interest rate and the GARCH measure we can determine the extent to which this is the case.

Table 4 reports results for the economic activity equations from these models. Panel A of Table 4 shows that none of the variables appear to explain nonresidential structures investment, while only GNP has a significant impact on durable consumption spending.[28] In contrast, the GARCH variable is highly significant in both the equipment and nondurable consumption equations with F-statistics well above the one-percent critical values. The variance decompositions in Panel B show the same result. The GARCH variable explains over 20 percent of the forecast error variance for both equipment expenditures and nondurable consumption spending. Finally, the results do not support an empirical link between lagged movements in the interest rate and variations in the GNP components.

The findings in Table 4 provide additional evidence that there is a strong link between interest rate uncertainty and economic activity during the interwar period. The finding that the GARCH variable continues to provide a high level of explanatory power even when short-term interest rate is included in the models suggests that the former is not important simply because it is a proxy for the level of interest rates. While the finding that lagged GNP does not contribute a great deal to explaining variation in equipment investment appears to clash with previous empirical work, this result might be due to the fact that the accelerator effect is being picked up by lagged values equipment expenditures. Overall, the finding that the GARCH variable continues to have a strong impact on equipment expenditures even though lagged equipment expenditures and GNP are included in the models provides strong evidence of the contractionary impact of uncertainty on investment spending during the interwar period.

VI. Conclusion and Policy Implications

One of the benefits associated with fixed exchange rate regimes is that they reduce uncertainty facing export-producing firms. However, if this reduction in exchange rate uncertainty increases uncertainty somewhere else in the system, then it is not clear that the benefits of fixed exchange rates outweigh the costs.

This paper argued that the system of fixed exchange rates erected under the interwar gold standard introduced significant interest rate uncertainty into the U.S. economy during the 1930s. Moreover, this uncertainty rose in response to a breakdown in credibility of the regime and had a significant impact on aggregate income. Thus the experience from the Great Depression suggests that the costs of maintaining a fixed exchange rate regime can be very large indeed, especially when the regime's credibility diminishes.

This paper has important policy implications because it suggests that the utility of a particular policy is strongly influenced by its credibility. Moreover, policy-makers can, to a limited extent, control the credibility of a policy. For example, economic theory and experience suggest that unilateral pursuit of expansionary monetary and fiscal policies lead the public to anticipate devaluation which undermines the credibility of the fixed exchange rate regime. In other words, there is a fundamental incompatibility between maintenance of fixed exchange rates and expansionary policies undertaken independent of the policies of other countries. Thus it is vital that fixed exchange rate regimes be accompanied by international cooperation and that expansionary policies be pursued on a multilateral basis. If cooperation is not forthcoming, the positive effects of expansionary policies will be offset by a loss of credibility and increased uncertainty.

The findings of this paper also offer some perspective on the recent debate over the need for a quasi-fixed exchange rate regime in Europe. The convergence of macroeconomic policies mandated by the European Monetary Union (EMU) has forced many central banks to pursue tight monetary policy and peg their exchange rates within narrow bands. This monetary straight jacket has had an unexpectedly severe impact on the European economy with unemployment reaching very high levels. This outcome, along with the exchange rate crises of late 1992, has caused an increasing number of academic economists to question the necessity of a pegged exchange rate system.[29]

The debate over the exchange rate regime in Europe has largely ignored the credibility question. The perspective provided by this paper suggests that breakdown in the credibility of the exchange rate mechanism (ERM) may, through its impact on uncertainty, be an important factor contributing to the economic contraction in European . If this is the case, then the true costs of the ERM exceed those brought about by the contractionary stance of monetary policy called for by adherence to the ERM. Without a full accounting of these costs, a proper evaluation of the optimal policy regime cannot be made.

Appendix

Given the two-state nature of the devaluation uncertainty, equation (2.19) can be written as

$$\mathbf{Var}_t \mathbf{i}_{t+1} = \sum_{z=1}^{2} \mathrm{Var}_t(\mathbf{i}_{t+1} | s_{t+2} = z)\mathrm{pr}(s_{t+2} = z) +$$

$$+ \left[E_t(\mathbf{i}_{t+1} | s_{t+2} = 2) - E_t(\mathbf{i}_{t+1} | s_{t+2} = 1)\right]^2 \cdot \mathrm{pr}(s_{t+2} = 1) \cdot \mathrm{pr}(s_{t+2} = 2) \qquad \text{(A.1)}$$

The first term on the right-hand side of (A.1) is the expectation, over the two states, of the interest rate variances conditioned on knowledge of whether or not devaluation occurs at t+2. The second term is the variance, over the two states, of the expected interest rate conditioned on knowledge of whether or not devaluation occurs at t+2.

Given (2.2), (2.17) and (2.18), we can solve for the components of (A.1):

$$E_t(\mathbf{i}_{t+1} | s_{t+2} = 1) = \mathbf{i}^*_t$$

$$E_t(\mathbf{i}_{t+1} | s_{t+2} = 2) = \mathbf{i}^*_t + E_t(\hat{\mathbf{e}}_{t+2} | s_{t+2} = 2) - \bar{\mathbf{e}}_{t+1}$$

and

$$\mathrm{Var}_t(\mathbf{i}_{t+1} | s_{t+2} = 1) = E_t\left\{\left[\mathbf{i}_{t+1} - E_t(\mathbf{i}_{t+1} | s_{t+2} = 1)\right]^2 | s_{t+2} = 1\right\} = \sigma^2_u$$

$$\mathrm{Var}_t(\mathbf{i}_{t+1} | s_{t+2} = 2) = E_t\left\{\left[\mathbf{i}_{t+1} - E_t(\mathbf{i}_{t+1} | s_{t+2} = 2)\right]^2 | s_{t+2} = 2\right\} = \sigma^2_u$$

Inserting these expressions into (A.1) gives us equation (2.20).

References

Balke, Nathan S. and Gordon, Robert J., "Appendix B: Historical Data," in *The American Business* Cycle: *Continuity and Change*, Robert J. Gordon (ed.), (Chicago, 1986), 781-850.

Bera, Anil K., Matthew L. Higgins and Sangkyu Lee, "Interaction Between Autocorrelation and Conditional Heteroscedasticity: A Random Coefficient Approach," *Journal of Business and Economic Statistics*, (April 1992), 133-142.

Bernanke, Ben S., "Nonmonetary Effects of the Financial Crisis in the Propagation of the Great Depression," *The American Economic Review*, 98 (June, 1983a), 257-76.

Blanco, Herminio, and Peter M. Garber, "Recurrent Devaluations and Speculative Attacks on the Mexican Peso," *Journal of Political Economy*, 94(1), 1986, 148-166.

Board of Governors of the Federal Reserve System, *Banking and Monetary Statistics, 1914-1941,* (Washington, DC, 1943).

Bollerslev, Tim, and Ray Y. Chou and Kenneth F. Kroner, "ARCH Modeling in Finance: A Review of the Theory and Empirical Evidence," *Journal of Econometrics*, (52), (1992), 5-59.

Bollerslev, Tim and Robert F. Engle, "Common Persistence in Conditional Variances," *Econometrica*, 61(1), (January 1993), 167-186.

Cecchetti, Stephen C., "The Case of the Negative Nominal Interest Rates: New Estimates of the Term Structure of Interest Rates during the Great Depression," *Journal of Political Economy*, 96(6) (1988), 1111-1141.

Chandler, Lester V., *American Monetary Policy: 1928-1941*, (New York 1971).

Clark, Peter K., "Investment in the 1970s: Theory, Performance, and Prediction," *Brookings Papers on Economic Activity*, (1979:1), 73-124.

Dernburg, Thomas, F. *Global Macroeconomics*, New York: Harper & Row, 1989.

Dixit, Avinash, "Investment and Hysteresis," *Journal of Economic Perspectives,* 6 (Winter 1992), 107-132.

Eichengreen, Barry, *Golden Fetters: The Gold Standard and the Great Depression*, 1919-1939, (New York 1992).

————— ,"Relaxing the External Constraint: Europe in the 1930s," NBER Working Paper # 3410 (August 1990).

Eichengreen, Barry and Charles Wyplosz, "The Unstable EMS," *Brookings Papers on Economic Activity*, (1:1993), 51-143.

Engle, Robert. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica*, 50 (1982), 987-1007.

Epstein, Gerald and Thomas Ferguson, "Monetary Policy, Loan Liquidation and Industrial Conflict: The Federal Reserve and the Open Market Operations of 1932," *Journal of Economic History*, XVIV, (1984), 957-984.

Evans, Martin and Paul Wachtel, "Inflation Regimes and the Sources of Inflation Uncertainty," *Journal of Money, Credit and Banking,* 25(3), (August 1993), 475-511.

Ferderer, J. Peter and David A. Zalewski, "Uncertainty as a Propagating Force in the Great Depression, manuscript, Clark University, 1993.

Flacco, Paul R. and Randall E. Parker, "Income Uncertainty and the Onset of the Great Depression," *Economic Inquiry*, 30 (January 1992), 154-171.

Friedman, Milton and Anna Jacobson Schwartz, *A Monetary History of the United States, 1867-1960*, (Princeton N.J. 1963).

Gordon, Robert J. and Veitch John M., "Fixed Investment in the American Business Cycle, 1919-83," in *The American Business* Cycle: *Continuity and Change*, Robert J. Gordon (ed.), (Chicago, 1986), 267-357.

Hamilton, James D., "Role of the International Gold Standard in Propagating the Great Depression," *Contemporary Policy Issues,* VI (April 1988), 67-89.

Ingersoll, Jonathan, E. and Stephen A. Ross. "Waiting to Invest: Investment and Uncertainty," *Journal of Business* 65(1) (January 1992), 1-29.

Kindleberger, Charles P. *The World in Depression: 1929-1939*, Berkeley: University of California Press, 1973.

King, Stephen. "Monetary Transmission: Through Bank Loans or Bank Liabilities?" *Journal of Money, Credit and Banking*, 18(3), (August 1986), 290-301.

Minsky, Hyman P., *John Maynard Keynes*, (New York 1975).

Pindyck, Robert S., "Irreversibility, Uncertainty, and Investment," *Journal of Economic Literature,* 29 (September 1991), 1110-1148.

Romer, Christina, "The Great Crash and the Onset of the Great Depression," *Quarterly Journal of Economics*, (August 1990), 597-624.

———, "What Ended the Great Depression?" *Journal of Economic History*, (December 1992), 756-784.

Stiglitz, Joseph and Andrew Weiss, "Credit Rationing in Markets with Imperfect Information," *American Economic Review*, 71 (June 1981), 393-410.

Sumner, Scott, "The Role of the International Gold Standard in Commodity Price Deflation: Evidence From the 1929 Stock Market Crash," *Explorations in Economic History*, 29 (1992), 290-317.

Temin, Peter, *Did Monetary Forces Cause the Great Depression*? (New York 1976).

———, *Lessons From the Great Depression*, (Cambridge 1990).

Temin, Peter and Barrie A. Wigmore, "The End of One Big Deflation," *Explorations in Economic History*, 27 (1990), 483-502.

Wigmore, Barrie, A., *The Crash and Its Aftermath: A History of Security Markets in the United States: 1929-33*. (Westport CT. 1985).

———, "Was the Bank Holiday of 1933 Caused by a Run on the Dollar?" *Journal of Economic History*, XLVII, 739-756.

Williamson, Stephen D., "Costly Monitoring, Loan Contracts, and Equilibrium Credit Rationing," *Quarterly Journal of Economics*, (1987), 135-145.

FIGURE 1

Interest Rates

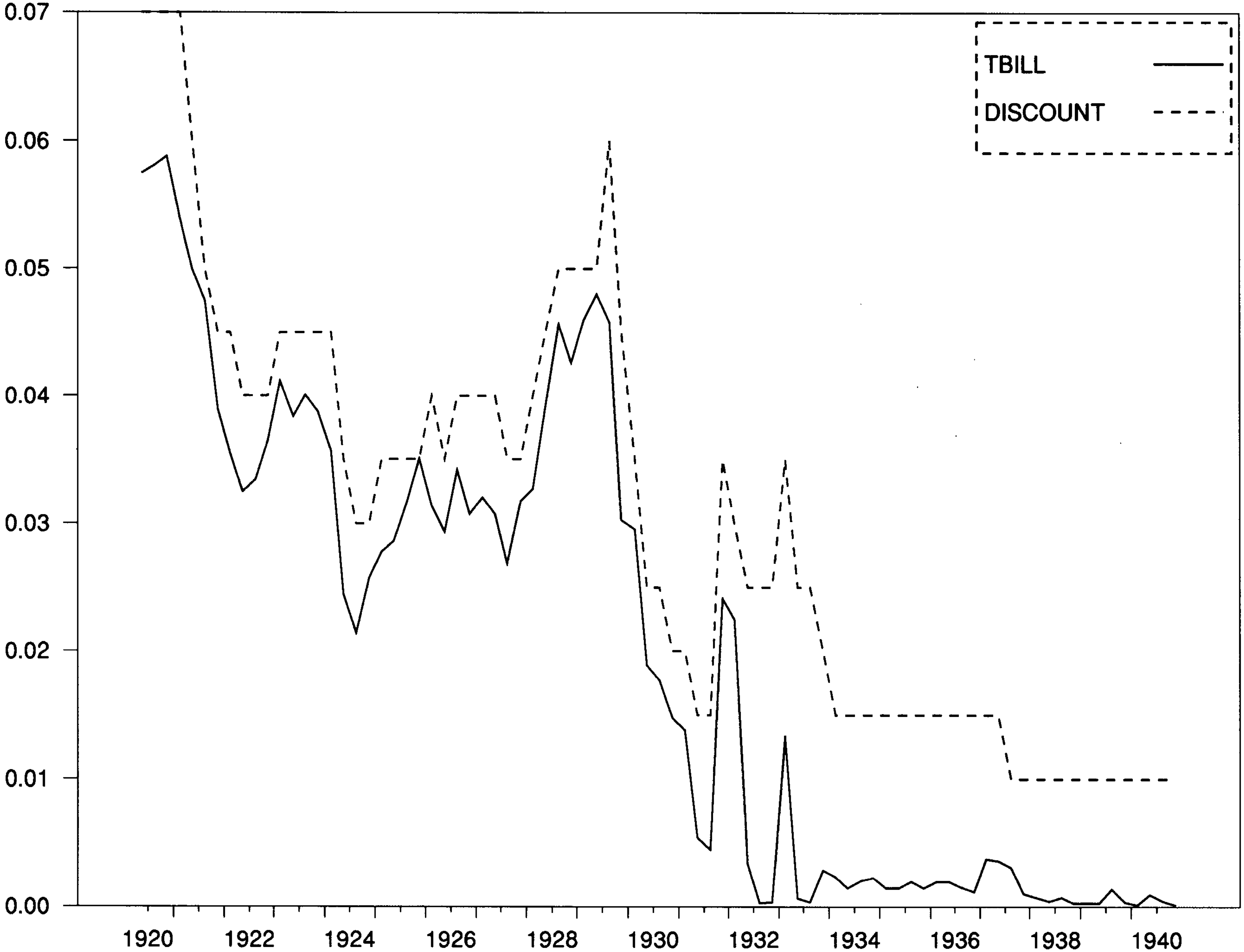

FIGURE 2

Conditional Variance of T-Bill Rate, GARCH(1,1)

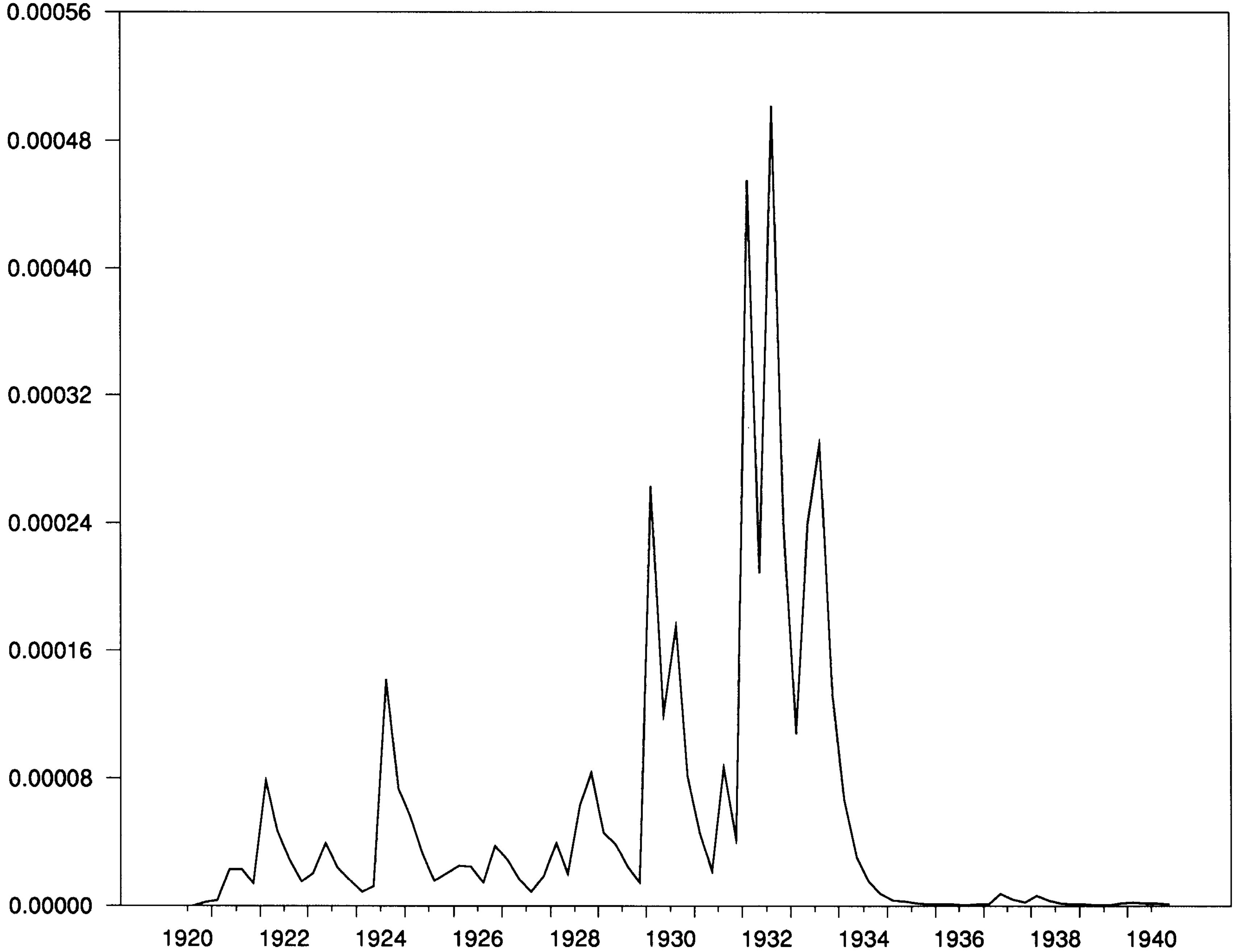

Table 1 — Specification Tests

Panel A: Testing for ARCH

$\mathbf{LM}_{ARCH|AR}$

(1922:2 - 1940:4)

	ARCH(1)	ARCH(2)	ARCH(3)	ARCH(4)	ARCH(5)	ARCH(6)
AR(0)	10.26***	20.92***	21.09***	21.26***	21.13***	23.11***
AR(1)	10.14***	22.01***	28.58***	18.80***	18.58***	23.45***
AR(2)	12.97***	25.25***	24.69***	27.01***	29.44***	24.77***

Panel B: Testing for Autocorrelated Errors

$\mathbf{LM}_{AR|ARCH}$

(1922:2 - 1940:4)

	AR(1)	AR(2)
ARCH(1)	.60	3.09
ARCH(2)	.67	1.66
ARCH(3)	.01	.66
ARCH(4)	3.07*	3.08
ARCH(5)	.25	.28
ARCH(6)	1.65	1.66

$\mathbf{LM}_{AR|GARCH}$

(1922:2 - 1940:4)

	AR(1)	AR(2)
GARCH(1,1)	2.44	2.51
GARCH(2,1)	2.43	2.62
GARCH(1,2)	1.21	1.26
GARCH(1,1)	1.45	1.52

NOTE: $\mathbf{LM}_{ARCH|AR}$ is distributed asymptotically as χ^2 with m degrees of freedom where m is the order of the ARCH process. Likewise, $\mathbf{LM}_{AR|ARCH}$ and $\mathbf{LM}_{AR|GARCH}$ are distributed as χ^2 with k degrees of freedom where k is the order of the AR process. Statistical significance at the 1%, 5% and 10% level are given by ***, **, and * respectively.

Table 2 — GARCH Model Estimates

Results for GARCH(1,1)

(1920:3 - 1940:4)

Parameter *x* Variable	Parameter Estimate	Asymptotic Standard Error	Asymptotic t Ratio
α constant	0.0001	0.00023	0.45
$\beta_1 \mathbf{i}_{t-1}$	0.986	0.005	196.00***
γ_o constant	0.00000045	0.00000024	1.82
$\gamma_1 \varepsilon^2_{t-1}$	1.140	0.323	3.53***
$\lambda_1 \mathbf{h}_{t-1}$	0.453	0.075	6.00***
log Likelihood value:		412.6	
likelihood-ratio statistic for IGARCH($\chi^2(1)$): $[H_o: \gamma + \gamma_{m+1} = 1;\ H_o: \gamma_1 + \gamma_{m+1} > 1]$		63,435***	

Statistical significance at the 1%, 5% and 10% level are given by ***, **, and * respectively.

Table 4 - Results for Monetary and Interest Rate Uncertainty Equations

Sample: 1921:3 - 1940:4

Panel A: F-Statistics

Endogenous Variable	Right-hand-Side Variables: Δlog(GNP)	Δlog(mm)	Δlog(BASE)	ΔGARCH
Δlog(mm)	.86	.96	.37	7.08***
Δlog(BASE)	.39	1.79	4.25***	3.56**
ΔGARCH	.48	2.47*	1.37	8.92***

Panel B: Decomposition of Variances (8 quarter Horizon)

Endogenous Variable	Δlog(GNP)	Δlog(mm)	Δlog(BASE)	ΔGARCH
Δlog(mm)	16.3	57.4	4.0	22.4
Δlog(BASE)	11.1	32.1	44.4	12.4
ΔGARCH	5.9	13.6	10.3	70.1

Notes: Estimated Regressions use four lags of each variable. All variables are in 1972 dollars except for the money multiplier and GARCH estimates of interest rate variances. Statistical significance at 1%, 5% and 10% level are given by ***, **, and * respectively.

Table 5 - Uncertainty-Augmented Output-Interest Rate Models for Real GNP Components

Sample: 1921:3 - 1940:4

Panel A: F-Statistics

Endogenous Variable	Right-hand-Side Variables: Δlog(GNP)	ΔSTR	ΔGARCH
Δlog(EQUIP)	1.51	.51	4.30***
Δlog(NRS)	1.08	.31	.56
ΔLog(DURC)	4.80***	.44	1.76
ΔLog(NDURC)	1.43	.65	5.27***

Panel B: Decomposition of Variances (8 quarter Horizon)

Δlog(EQUIP)	9.8	0.1	20.5
Δlog(NRS)	7.1	2.6	4.9
ΔLog(DURC)	14.6	4.2	5.7
ΔLog(NDURC)	9.2	3.7	23.5

Notes: Estimated Regressions use four lags of each variable. All variables are in 1972 dollars except for the interest rate and the GARCH estimates of interest rate variances. Statistical significance at 1%, 5% and 10% level are given by ***, **, and * respectively.

Table 5 - Uncertainty-Augmented Output-Interest Rate Models for Real GNP Components

Sample: 1921:3 - 1940:4

Panel A: F-Statistics

Endogenous Variable	Right-hand-Side Variables		
	Δlog(GNP)	ΔSTR	ΔGARCH
Δlog(EQUIP)	1.51	.51	4.30***
Δlog(NRS)	1.08	.31	.56
ΔLog(DURC)	4.80***	.44	1.76
ΔLog(NDURC)	1.43	.65	5.27***

Panel B: Decomposition of Variances (8 quarter Horizon)

	Δlog(GNP)	ΔSTR	ΔGARCH
Δlog(EQUIP)	9.8	0.1	20.5
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ΔLog(NDURC)	9.2	3.7	23.5

Notes: Estimated Regressions use four lags of each variable. All variables are in 1972 dollars except for the interest rate and the GARCH estimates of interest rate variances. Statistical significance at 1%, 5% and 10% level are given by ***, **, and * respectively.

Footnotes

[1]This literature stands in stark contrast to the large literature which focuses on domestic forces. For example, the well known argument of Friedman and Schwartz (1963) is that the banking crises of 1930 and 1931 lowered the money multiplier by raising the public's demand for currency and banks' demand for reserves. The resulting fall in the stock of money combined with a stable money demand function then led to the unprecedented fall in income. Along somewhat different lines, Bernanke (1983) emphasizes the impact of the banking crises on the level of financial intermediation.

[2]See Kindleberger (1973) for a discussion of this view.

[3]Prices rose by about one hundred percent during the war in the U.S., but increased by approximately 150 percent in Britain and 200 percent in France.

[4]See Dernburg (1989, p. 386) for a summary of this view.

[5]In contrast, Eichengreen argues that the prewar gold standard was credible because the public was confident that policy would be conducted to maintain balance-of-payments equilibrium at the existing exchange rate parities. This confidence was driven by the distribution of political power that favored groups which preferred external balance (i.e., bankers) over groups which preferred internal balance (i.e., labor). Thus the prewar gold standard was insulated from domestic political pressure and this increased its credibility. Also, the existence of good international relations meant that foreign central banks were willing to lend gold to countries whose reserves came under attack and coordinate multilateral monetary expansions. This cooperation reinforced the regime's credibility since it meant that "commitment was international, not merely national." Eichengreen (1992, p. 8).

[6]Not only did the contractionary domestic monetary policy depress domestic demand directly, but an indirect effect as well because the shifting of contractionary policy abroad caused exports to decline. Nevertheless, the initial driving force was the change in the policy stance.

[7]See Stiglitz and Weiss (1981) and Williamson (1987).

[8]See Robert Pindyck (1991) and Dixit (1992).

[9]Other studies have also explored the role that uncertainty played in driving economic activity during the Great Depression. However, these studies focus exclusively on the stock market crash of October 1929 as a source of income uncertainty. See Romer (1990), and Flaco and Parker (1992).

[10]This includes public debt held by the central bank and private debt held by the banking system.

[11]It is assumed that $\alpha\theta_2/(1 + \alpha) < 1$ to rule out the possibility of speculative bubbles.

[12]By making this assumption we reduce the number of states in the model from four to two without altering the basic findings.

[13]See Evans and Wachtel (1993).

[14]Note that $\mathbf{h}_t$ is being used to represent a different variable in this section.

[15]While the adjusted interest rate series contained in Cecchetti (1988) provide a more precise measure of Treasury bill yields (i.e., they have been purged of "exchange privilege" value), this data limits our analysis to the 1929 to 1940 sample. Because the *Banking and Monetary Statistics* and Cecchetti series are highly correlated, use of the former should not adversely affect the analysis.

[16] For the sake of brevity, we do not discuss the behavior of interest rate uncertainty during other periods. However, there is evidence that reduced international cooperation may have contributed to the uncertainty in other periods. For example, the rise in interest rate uncertainty during 1930 occurred at a time when there was a great deal of international conflict about trade issues. In fact, Sumner (1992) has argued that the large decline in stock prices during June of 1930 resulted from "a major tariff fight [the Smoot-Hawley tariff] in the U.S. Congress" and "stories reporting threats of reprisals from various nations." It is also possible that domestic developments may have contributed to interest rate uncertainty. For example, Eichengreen (1992) has argued that political conflict and changing leadership in the Federal Reserve is partially responsible for the financial market turmoil of the late 1920s.

[17] For a more detailed chronology of these events, see Temin (1989), pp. 65-73.

[18] Friedman and Schwartz, (1963) p. 316.

[19] Faced with the potential of large capital outflows, members of the Federal Reserve Board unanimously concluded on November 30, 1931 that the outlook was too uncertain to permit long-term policy formulation and that they should only discuss policies applying to the end of the year. See Chandler, *American Monetary Policy*, p. 178.

[20] Eichengreen (1990) shows that the volatility of exchange rates, inflation rates and real interest rates rose substantially following Britain's departure from the gold standard in September of 1931.

[21] Eichengreen (1992, p. 315) and Temin and Wigmore (1990) argue that economic activity continued to decline during 1932 in the face of monetary expansion because industrialists expected that there would be a reversion to deflationary policies once the Congress adjourned in July and pressure was removed from the Federal Reserve. An alternative explanation is that the increased uncertainty generated by the policy shift offset the stimulative effect of the open-market purchases.

[22] See Friedman and Schwartz (1963, p. 469).

[23] Others have argued that there was a great deal of uncertainty about whether or not official devaluation would take place. See Eichengreen (1992, p. 344) and Ferderer and Zalewski (1993).

[24] It is interesting to note that Romer (1992) attributes the expansion out of the Great Depression to monetary stimulus provided by gold inflows into the U.S. The behavior of interest rate uncertainty during the second half of the 1930s suggests that reduced uncertainty may have also played a role.

[25] Because we are estimating the models in first-differences of logs, the growth rate in the real monetary base, $\Delta\log(BASE)$, and the growth rate of the money multiplier, $\Delta\log(mm)$, are introduced separately into the models. This is the approach use by King (1985).

[26] See Pindyck (1991) for a discussion of this issue.

[27] See Clark (1979).

[28] Gordon and Veitch have also shown that spending on nonresidential structures is largely exogenous.

[29] See the General Discussion (p. 136) in Eichengreen and Wyplosz (1993).